COLOMBIA ON THE PATH TO A KNOWLEDGE-BASED SOCIETY

Reflections and proposals

Volumen 1

El futuro es de todos

Gobierno de Colombia

MISIÓN DE SABIOS

COLOMBIA - 2019

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Volume 1

First edition, 2020

Printed ISBN: 978-958-5135-22-2
Digital ISBN: 978-958-5135-23-9

Printed ISBN (Spanish version): 978-958-5135-12-3
Digital ISBN (Spanish version): 978-958-5135-13-0

Collection
Misión Internacional de Sabios 2019

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Bogotá, D. C., Colombia, 2020

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Reflections and general proposals

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Manifesto: Towards a knowledge-based society for the next generation

A country in which all children can study; in which we can drink water from rivers, where people are happy and live in peace, a country free of violence and where people can leave their homes unafraid, where we live together and take care of our animals, where there is no hunger and we welcome immigrants, a country of all colors. These are some of the things that this generation of children and teenagers want for our country over the next twenty years. They also dream of technology that is used for everyone's benefit, where science leads us to discover fantastic things, where all waste is recycled or turned into fertilizer, where the indigenous and Afro-Colombians are respected, and where peasants and low-income families can enjoy the same opportunities as the rest. They demand the same rights for everyone and for schools to be able to receive disabled children without any difficulty. They want education not to feel like an obligation and for everyone to learn all they need to get where they want to be in life, where the poor and immigrants have a place to sleep, where everyone respects each other and believes in the ideas of children and adults alike.

These dreams are shared by Isabela, Carlos, and Andrés in Mocoa, Putumayo; Angie in Pereira and Valeria in Puerto Concordia, in Meta; Tomás in Rionegro and Valentina in Manizales; Samantha, Samuel, Santiago and Diego from Buinaima, in Bogotá, and several hundred other children and adults who live in our country's cities and countryside, and who—in essays and poems, and in drawings of flags, trees, green mountains, yellow metro trains, and blue rivers—told us about the country they want and about what they expect from science.

These desires coincide with those of researchers and scientists from Colombia and other countries that are involved in the International Mission of Experts 2019 for Science, Technology, Innovation and Education). Our children are able to imagine a brighter future for Colombia while researchers—who work in laboratories or move around the country, trying to understand people, communities, natural resources or the nation's seas—strive to preserve the curiosity and capacity to dream of the future that we once had as children.

Each and every Colombian is called upon to think about, design, and build this possible future country. From the scientist who traveled our country's coasts for a month to think about the Mission, to the Nobel Prize winner who supported us in our initiative: this group of researchers defined a route via which we can reach that country we all dream of. Basing our work on the plans that governments develop for their four-year periods, we tried to see what Colombia would look like for the next generation, over the next twenty or thirty years. We wanted to anticipate the achievements and the problems they will experience, and to think about how to prepare ourselves and how to ensure that the upcoming generations reap the fruits of this reflection.

Pursuing this line of thought, we have found that scientific knowledge, curiosity-driven research, technological developments, innovation and creation, supported by high-quality education to which everyone has access, and which both builds on people's knowledge and forms their character, opens the doors of that longed-for country. A country in which children can dream, put their imagination to work, create, experience, and discover new things, while adults and older people have ample opportunities to learn throughout their lives.

Accordingly, the Mission proposes that our first great task as a society—comprised of the State, families, large and small businesses, our teachers and ourselves, the researchers among us—is to ensure that all children, from the moment of conception until the age of 5, have access to an education that is specially designed for them, with adequate nutrition, access to healthcare, affection, respect, and attention. This is how we can bridge the necessary gaps to allow every child to aspire to an education in the school, college, and university or institute they want to study in, including, of course, going on to work in research laboratories, workshops, studios and businesses, with effective equal opportunities and the necessary skills to take advantage of them.

Building the country of our dreams for that new generation necessarily implies the implementation of comprehensive education for zero to five-year-old children as the highest priority, as that is where it all begins. Over 90% of the neuronal connections of the human brain are established in that short period of time: empathy and coexistence, ethics, acceptance of diversity, creativity, and the ability to be happy. The State and society have taken steps to advance in this direction and have made progress in recent decades, but we need to go further and with more speed.

And let us not forget about our teenagers. We want to see them study, develop, unlock life prospects, and gain their freedom built on a diverse high school education that exploits the potential of the local economy and their communities' culture and traditions. We want them to continue to dream of having the freedom to choose a future that a quality education can offer them. We want everyone to have the necessary scientific and cultural foundation, along with an understanding of their local and global contexts, to tackle the life changes that await them as a result of scientific and technological advances, whatever path they may choose. Opening up this range of options and providing them with the possibility to choose who they want to be cannot only be contained to our dreams; it is an urgent duty in a country that aspires to defeat violence, insecurity, and frustration.

Our young people are demanding that universities, research centers, entrepreneurs, workers, teachers, researchers, State institutions, and social innovators take on new roles. If we are to move forward, we need a joint effort and resources, beginning with those of the State. Indeed, this government has committed itself to this improved future, for which, among other things, it has to earn the trust of the private sector.

The Mission of Experts, convened in February 2019 by the President of the Republic and whose guidance was entrusted to the Vice-President, calls on the national government, the regions and Colombian society to make efforts that go beyond what has been planned so far to strengthen the basic natural, social, and human sciences, and artistic creation. Without sciences or art, no country has been able to develop technology or continuous processes of innovation and design, and therefore the sustained consolidation of its productivity and competitiveness. When Colombia has developed these sciences to a sufficient level, it will be easier to stimulate companies' demand for the knowledge that will ensure their survival.

The efforts required will involve obtaining loans, redirecting budgets, and proposing legislative acts to reform the Constitution, so that the regions can allocate 25% of royalties to early childhood education, create regional innovation centers, promote research and fund networks of community innovation centers.

To make the best use of these resources, the Mission of Experts unfolds into five missions, which combine basic research and knowledge creation with innovative processes and actions to transform production processes and life in cities and rural communities.

1. Today, Colombia has the opportunity to develop the knowledge needed to harness our valuable water resources and to prepare for global climate change. The goals established as part of this quest for knowledge propose that by 2030, all Colombians should have access to drinking water, the quality of bodies of water must be maintained, and society will be protected from extreme climate events.
2. We should understand, enhance, and take advantage of the resources deriving from our country's biological and cultural diversity to build a bioeconomy and a creative economy that will lead the transition to a new productive model. This knowledge will allow us to transform the food, pharmaceutical, textile, cosmetic, and energy sectors as well as sectors concerned with the creative industries. It will make it possible to preserve diversity, strengthen cultural identities, and create a much-needed sense of belonging for the country.

3. Colombia can adopt a new productive, sustainable and competitive model which harnesses the burgeoning industrial revolution, integrated production, the convergence of technologies and scientific disciplines, and the transition to cleaner energy. In that event, we can establish green industries, use intelligent and sustainable materials, take advantage of the immense possibilities presented by renewable energies, reap the rewards of our connections with each other and bridge the gaps between rural and urban life.
4. These paths must converge on the task of making Colombia a more equal society. Many countries in the world today face risks of social fragmentation due to the historical exclusion of large layers of their populations. This is why we believe that economic growth is only sustainable if it is accompanied by equity and inclusion, with social policies that incorporate interdisciplinary knowledge to transcend short-term assistance. The role of science and social innovation in designing solutions for each context is essential to achieving the goal of a Colombia with opportunities for all.
5. Colombia needs to grow and become more equitable. As has been seen in countries that have managed this, these are not incompatible goals, and can be achieved when broad layers of the population have access to education. For this to happen, there is much to do before a larger section of the population can enjoy quality education, and all members of the Mission have reflected on this and made proposals to reach this goal. Access to education will contribute to closing the gaps and leading Colombia forward by tapping into the knowledge and work of its people.

When nations set themselves ambitious but possible goals for significant transformations, they define missions. In these missions, ministries, institutions, organizations, and companies make decisions and devote efforts alongside the contributions and desires of citizens. Today, the members of the Mission of Experts are requesting that the national government, on behalf of the entire nation, take definitive steps towards a Colombia at the forefront of knowledge, so that this may be the legacy that we leave to the next generation.

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The Mission's scope: Agreement for a Colombia at the forefront of knowledge

The Mission of Experts 2019 (*Misión Internacional de Sabios 2019 para el avance de la ciencia, la tecnología, la innovación y la educación*) integrates the contributions of 46 Colombian and foreign researchers, grouped into eight thematic pillars. The Mission warns about the urgency of undertaking actions and initiatives that address a complex global economic environment and assume the challenges of diversifying and modernizing the economy in-line with the Sustainable Development Goals (SDG).

The world is moving forward in the midst of a large-scale technological convergence of great speed, intensity, and capacity for social, cultural, and economic transformation. The fourth industrial revolution will reconfigure productive chains, and provide new service and business models that can improve productivity and wellbeing, but it must also consider the growing demands for energy, protection of natural resources, and higher levels of education coverage.

The convergence of science and technology in previously separate domains—nanotechnology, biology, and cognitive disciplines—will have impacts that range from improving health with the help of superior medical diagnostic and disease treatment tools, to changing occupations—the jobs we have in 2020 will not be the same by 2050—, and modifying organizations and social relations.

To take advantage of the advances and to manage the inevitable uncertainty that such convergence generates, we must develop our skills as a nation. First of all, Colombians must receive training that can bring about and react to change. Secondly, coordinated strategies must be designed on several fronts, including the governance of the National System of Science, Technology and Innovation and effective and flexible management structures, as proposed in this document.

By taking advantage of its soil and water resources, biodiversity, solar radiation and location; its cultural diversity; the expertise of its universities and graduates; its ancestral knowledge, and the links it has with a diaspora of talents linked to top-level research entities, Colombia has the opportunity to become an international technological leader in certain areas of biotechnology, the creative industries and Industry 4.0.

A country cannot depend on other countries for the basic knowledge required to drive accelerated economic development or to defend a significant position in the global economy. Wealth generation is increasingly associated with scientific productivity and requires the creation of new industries and development of our own technologies based on our people's capabilities and our natural resources, while at the same time serving the long-term wellbeing of our nation. Knowledge generation and economic growth will be energized if there is an explicit agreement between the State, the private sector, society and academia to all move in the same direction.

Colombia Today: Progress on vulnerable foundations

Colombia has made progress on several fronts over the past two decades. For example, the gross domestic product (GDP) per capita doubled between 2000 and 2017 (USD 6,651 in 2017) and the middle class is now larger than the poor. However, major structural weaknesses persist in an international context of rapid technological change and much uncertainty. The economy is poorly diversified and of low complexity. Although the Gini coefficient improved from 0.56 in 2010 to 0.51 in 2018, it is one of the highest in Latin America. Eighty percent of exports come from mining. Manufacturing was reduced to half the percentage of GDP it covered in the 1980s. The most worrisome deficiency of the Colombian economy is that total factor productivity (TFP) made zero contribution to economic growth between 2000 and 2016, a phenomenon directly associated with low investment in research and development (R&D).

A theory of change based on STI investment

The idea of investing in science, technology and innovation (STI) is to increase economic productivity by improving products and services, based on a mix of public and private investments in four types of programs: research excellence, collaboration between industry and researchers and technology transfer (missions + centers), innovation by business R&D, and adoption of innovative non-R&D based startups. Productivity goals should address Colombia's major social and environmental challenges by implementing public policies and regulations that stimulate local contributions to solving global-level problems.

The relationship between R&D and economic growth is long-term and requires patience to consolidate. Under certain plausible assumptions, a 20% increase in R&D investment would increase GDP by 1.12%, a result that would be observed with a 5-year lag.

Cross-cutting proposals

Given the above considerations, the Mission considers it essential, for the future of the STI and the country's progress, that four cross-cutting proposals be implemented:

Increasing and managing funding

Funding for the STI in Colombia has been chronically low and is the main bottleneck for its development. The public sector should finance/co-finance STI that does not have high private profitability, but that has high expected social benefits, especially high-risk STI with public entrepreneurial orientation. The public sector should not finance STIs with low private profitability and whose social returns, including all their externalities, are lower than the cost of public funds. Finally, the private sector should finance STIs with large private profitability.

To go from 0.25 to 1.50 % of GDP in STI ($16 billion per year, equivalent to the sum needed to build a metro system for Bogotá every year) requires (i) substantial increases in public funding and (ii) financial engineering capacity in the design of *combined financing* instruments, which includes co-financing incentives, stimuli for private R&D, boosting early financing ecosystems, credit enhancement mechanisms, and issuance of debt instruments, among others. These two tasks are of great magnitude and complexity. They require a strong and sophisticated team that understands the constraints of sources and characteristics of uses, which cannot be satisfied with a zero-cost fiscal policy.

Using a simple model of the evolution of the public and private financing effort, the R&D investment path would follow two phases: Phase 1 ('public patient capital') is characterized by a high level of effort from the public sector and Phase 2 ('private R&D take-off') by an upturn in private investment. At the end of Phase 1 in 2023 it could reach 0.8% of total investment in R&D as a percentage of GDP, and at the end of Phase 2 it could reach 1.2% of total investment in R&D as a percentage of GDP.

Effective governance of the SNCTI and functions of the STI Ministry

The National System of Science, Technology and Innovation (SNCTI) should be different from the National Competitiveness System and should not be included in or dependent on it. The SNCTI should be based on open participation. The essential elements of SNCTI governance are (i) The STI Ministry; (ii) a National STI Policy Council, composed of experts who advise the President on the country's STI developments; (iii) a National Scientific Council (a consultative body on scientific and ethical issues in research); (iv) an executing agency for STI programs, with important financial engineering capabilities; and (v) mechanisms for the relationship and coordination of the STI Ministry with the rest of the national and regional authorities, industry, and civil society, among which the Regional Innovation Systems stand out.

The new Ministry, as leader, will head the structuring of projects with attractive initiatives at an international level through an efficient and agile system of cooperation and knowledge management, which promotes the links between university-business-civil society and the environment, integrating the possibilities of each territory and through cooperation networks of an interdisciplinary and intersectoral nature.

As the head of SNCTI, the STI Ministry must organize itself based on three principles: (i) separation between policy formulation and execution; (ii) functional structure; and (iii) development of enabling factors. The first principle requires the creation of an executing agency with extensive financial structuring capabilities, which the Francisco José de Caldas Fund does not have. The second principle implies the recognition of differentiated functions of basic knowledge creation, technology development and transfer, promotion of private R&D, and adoption of frontier technologies to sort out programs, incentives and funding models. The third principle requires the inclusion of activities necessary for citizens to take advantage of STI, such as training, organizing networks, and the appropriation of knowledge.

These principles are flexible enough to accommodate region- or sector-specific priorities and research initiatives + creation. Accordingly, the Ministry must have (i) a Vice-Ministry of Knowledge Creation and Technology Development, and (ii) a Vice-Ministry of Talent and Social Appropriation of Knowledge. The Ministry will also be in charge of simplifying administrative processes and regulating scientific and technological activity, which as they are, constitute a serious impediment to its progress.

Support for missions and centers

Two powerful instruments to prevent the current atomization and dispersed use of funds are missions and centers. The missions guide research around the solution of specific cross-cutting challenges or the development of creative initiatives, which are attractive internationally. The centers produce economies of scale, scope, and agglomeration for technology transfer, with advantages over bilateral initiatives between individual researchers and industries.

They must be a neutral vehicle (independent of universities and industrialists), governed by private law, with high facilitation skills and marketing capacity. They are ideal for the management of cumulative innovation.

In addition to improving the effectiveness of fund allocation, missions and centers can (i) resolve the false dichotomy between basic and applied knowledge production, (ii) facilitate the relationship between industry and academia, and (iii) help implement a simultaneous policy of adoption and transfer to move more quickly towards the technological frontier.

Support for education

Education has always been a critical factor for human development and the effective transformation of societies, and it will become even more crucial in the context of accelerated technological change and environmental transformation. We must understand and identify the characteristics for a transformative education, which demands new pedagogies. These include

(i) to make rapid progress in the internationalization of access to and quality of education, the development of curiosity, creativity, sensitivity and aesthetic thinking, nutrition, health, affection and other components of comprehensive care for all children in the 0-5 age range, and (ii) in the diversification and internationalization of secondary education.

These two transformations demand the training of many more teachers, the creation of continuing education programs, and the sharing of lessons learned with trainers currently in the educational system. To this end, the Mission has proposed the creation of the Higher Institute for Research in Education and Advanced Teacher Training, and the design of an intensive plan to offer scholarships and incentives for the study of basic sciences in order to draw research and teaching closer together.

Likewise, the Mission makes a series of suggestions for structural and pedagogical changes to the educational system, to support permanent and lifelong learning and refresher training based on the generation of a great learning ecosystem. It also proposes to transform the country's secondary education and to innovate methods, tools and educational management based on the great possibilities offered by the development of convergent technologies and Industry 4.0.

An agreement to develop and leverage STI

For Colombia to consolidate itself as a reference in STI in biodiversity (and activities based on it, such as biotechnology, agriculture or tourism), creative industries, convergent technologies and Industry 4.0, an agreement must be reached in which (i) large companies understand that technological change is inevitable and that technology will not aid them, but will in fact put them out of business unless they invest in R&D; (ii) universities gain the trust of companies and regional governments with solutions to their problems; when results are recognized, increasingly sophisticated problems can be investigated. Prizes awarded to researchers should reflect their contribution to designing solutions; and (iii) the Government has the opportunity to lead the STI agenda by increasing public funding in basic science and co-financing pre-competitive research and development, this because there is no alternative for growth and so the State must assume an entrepreneurial attitude.

The relationship between basic science and its applications is mutually reinforcing. Research will combine curiosity with mission guidance. In Colombia's state of the economy and science, a parallel path should be embarked upon: the development of domestic capacities in basic science and technology and the acceleration of the adoption of frontier technologies.

With the aligned efforts of all actors and the implementation of the proposals mentioned above, in a decade, basic research in Colombia will be more consolidated and vigorous, relevant to an innovative business dynamic and to its population's increased wellbeing. Consequently, Colombia will be consolidated as a leading country in STI in biodiversity, creative economy, certain areas of converging technologies, and Industry 4.0. In particular, the time has come for Colombia to become a scientific power that puts to use its biodiversity and cultural diversity whilst at the same time conserving it. There is no other country with the comparative advantages and talent to assume that leadership.

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Context and emphasis

The context of the Mission

The Mission of Experts convened by the President of Colombia in 2019 is the third science, technology, innovation, education, and development mission in three decades. In 1987, on the occasion of the Science and Technology Forum that brought together government representatives, businesspeople and researchers, it was proposed that the nation reflect on the role that science and technology had played up to that point and the role they should play in the future. The following year, the Science and Technology Mission was convened, which delivered its first report in January 1991. The Year of Science and Technology was decreed and work began on the formulation of what would later become the Law of January 29, 1990. Part of the Mission's recommendations were reflected in a set of decrees derived from that law, among them a proposal to integrate a National System of Science and Technology, and the call to form networks focusing on knowledge creation and transfer. Among the recommendations that were not incorporated was that of articulating the budgetary management of all the ministries through a formal process of harmonization, and that of starting science education at preschool.

In 1993, the National Government convened the Science, Education and Development Mission, whose report entitled "Colombia: On the Edge of Opportunity" (*Colombia al Filo de la Oportunidad*) (1994), offered recommendations on the three objects which were part of its assignment, in addition to proposing technology policies and a model of private and public organizations focused on learning. It reiterated the importance of dedicating 2% of the value of GDP to research and development; it proposed the training of 30,000 scientists at PhD level in 10 years, as a way to make up for the delay in training human resources for research; suggested mechanisms to integrate science and technology; proposed the creation of secondary and technical education institutes closely linked to local production possibilities; proposed changes to educational models at all levels, as well as changes to the relationship between Colombia´s population and knowledge; and recommended the training of young researchers as soon as they enter university, among many others. Some of these recommendations were accepted, but others were never implemented.

The Mission of Experts 2019 convened by the President of the Republic has brought together 46 Colombian and foreign researchers, grouped into eight thematic areas. The national government entrusted the Mission with drawing up “a roadmap that will allow for the formulation, coordination and execution of a State policy for the development of STIs that, based on knowledge, will promote the productivity and competitiveness of the Colombian productive apparatus and our society’s development”.

The invitation was made at the beginning of the presidential term, together with the creation of the Science, Technology and Innovation Ministry and simultaneously with the discussion and approval of the National Development Plan. To respond to this call, the Mission has been reflecting on and making proposals concerning education, health, bio-economy, energy, oceans, cultural and creative industries, science, convergent technologies, innovation and, in general, on the role of knowledge in the Colombian economy, society, and culture.

The central document presented below synthesizes the Mission’s reflections, proposals, and invitations made to the government and to society.

The national context and the role of knowledge in the country's development

There is an urgent need to reflect on the role that knowledge should play in our society's development. This goes beyond the need to create institutional and political conditions to guarantee sustainable development in the country in the short, medium and long term. Various analysts have warned that the most pressing problems that threaten humanity, as well as the most promising opportunities, are no longer limited to national territories, but are now present on a global scale.

Incessant technological transformation and a multiplicity of variables make it virtually impossible to make reliable predictions of the planet's future, both on a social and political level and in relation to the environment, and this has created a scenario of uncertainty and a feeling of crisis. The issues are varied: on the one hand, the local and global impacts of technology (negative and positive), the transformation of how we work, and our resource exploitation practices (which have led to a deterioration of the environment). On the other hand, we have the ethical challenges deriving from the development of robotics, genetics and artificial intelligence, the consequences of the digital revolution, the humanitarian crisis resulting from the new needs of human migration throughout the planet and an education that does not have the humanistic and scientific comprehensiveness to which we should aspire. These and other questions require that each country, in a conscientious and responsible examination, establish an agenda to alleviate such problems and, based on a new vision of the present and future, project a viable model of progress and wellbeing.

In this context, it is clear that knowledge—scientific knowledge, in particular—can help us to distance ourselves from negative trends in society and the economy that increase social inequity, and instead support a policy of care for human dignity and the struggle for ecological sustainability. Knowledge and education are pillars that support democracy. Today, based within many different disciplines and the work of social movements, we try to respond to the greatest challenge: to maximize the preservation of the fabric of life.

Colombia is no stranger to these concerns. As one of the countries in the world that stands out for its extensive biological and cultural diversity, with two oceans that represent 44% of its territory, with more than 3500 km of coastline, and whose territory includes part of the Amazon region—one of the fundamental natural systems for global preservation and sustainability—Colombia is obliged to respond to this challenge creatively and aware of its responsibility towards future generations and humanity.

The Mission believes that the key to building a different future is the promotion of knowledge and education. Indeed, knowledge, which includes science, the humanities, the arts and ancestral knowledge, is fundamental to the development of new and creative alternatives to this crisis. Education, for its part, will be the means by which this knowledge can be created, shared, and disseminated based on humanistic and democratic principles.

One only has to look at the history of scientific activity in our part of the world to realize how closely science has been committed to the solution of the country's problems and to what extent it is involved in processes of general social and economic development and in terms of transformations in its inhabitants' mentalities (Melo, 1987).

In fact, historically, the nation has made great efforts to create the conditions for the establishment of scientific institutions, the formation of working groups, the consolidation of laboratories, the circulation of knowledge, the construction of scenarios for debate and criticism, and to be part of platforms that allow reciprocal contact with international knowledge.

The pioneering study on astronomy and chronology carried out in the 17th century by the priest Antonio Sánchez Cozar (Portilla and Moreno, 2019), and later the works of José Celestino Mutis and his collaborators at the head of the Botanical Expedition, are perhaps the first milestones in the history of science in Colombia. At the time of the Independence, establishing scientific rationality came at a high cost, taking the lives of scientists and science enthusiasts such as the astronomer Francisco José de Caldas, the botanists Miguel Pombo and José Joaquín Camacho, the zoologist Jorge Tadeo Lozano, and mineralogist Enrique Umaña, among others (Wasserman, 2018). In the first years of the Republic, science was promoted through its institutionalization and by expanding educational offerings. Projects like the Museum of Natural Sciences, the School of Mines and the Museum of Natural History provided exposure to incipient or previously unknown disciplines, such as chemistry, mineralogy, physiology, comparative anatomy, ichthyology, and entomology among others.

According to Wasserman (2018), in the middle of the 19th century, after decades of frustration, a new enthusiasm for science and knowledge arises. During the government of José Hilario López, the Chorographic Commission was set up, operating between 1850 and 1859, and intended to survey the country and draw up "a description and inventory of its physical and human wealth and a cartography that would support its development." Although Agustín Codazzi and Manuel Ancizar, leaders of the process, soon realized -and complained- about the indifference and incomprehension in the milieu for scientific matters, the outputs of the Commission turned it into a reference point in the history of science in the country. The *Liceo Granadino* was founded in 1856, offering training in human, social and natural sciences; in 1857 the *Academia Nacional* was established, focusing on the study of history and language, and some scientific and technical disciplines; 1859 marked the creation of the short-lived *Sociedad de Naturalistas*, and 1867, the institution that would become a key actor in the consolidation of knowledge production in the country to this day: *Universidad Nacional de Colombia*.

From the beginning of the 20th century until the 1960s, research institutes were opened and scientific communities were consolidated with the creation of the *Academia Colombiana de Ciencias Exactas, Físicas y Naturales*—still in force today and an example of the stable institutionalization of science in Colombia—and the *Instituto de Investigaciones Geológico Mineras* (Ingeominas), born of the merger between *Servicio Geológico Nacional* and the *Laboratorio Químico Nacional*.

The creation of the *Instituto de Agricultura y Veterinaria*, later called the *Instituto Nacional de Agricultura;* the *Consejo Nacional de Agricultura* and the *Oficina de Investigaciones Especiales*, which gave birth to the *Instituto*

Colombiano Agropecuario (ICA); the *Centro Interamericano de Agricultura Tropical* (CIAT) and the *Instituto Zooprofiláctico*—in charge of producing vaccines and biological material for veterinary use—have been instrumental in agricultural science research.

With respect to the health sciences, the most important milestone is the work of the *Instituto Nacional de la Salud* (INS). Independent initiatives such as the *Parque de Vacunación, Instituto de Estudios Especiales Carlos Finlay, Laboratorio BCG, Laboratorio de Higiene Industrial,* and *Laboratorio de Control de Productos Farmacéuticos* have been fundamental in terms of vaccine research. Of great importance for the social sciences was the foundation of *Instituto Etnológico Nacional* with Paul Rivet and the creation of ICANH) given by the merger between *Instituto Colombiano de Antropología* and *Instituto de Cultura Hispánica* in 1999, *Instituto Caro y Cuervo* in 1942, and *Instituto Geográfico Agustín Codazzi* in 1935.

For its part, the partnership between science and producers has been fruitful. Examples of this have been *Cenicafé*, for research on coffee; *Cenicaña*, for research on African sugarcane; and *Cenipalma*, among others.

The creation of *Colciencias* in 1968, as an organization for the promotion and funding of science, with a specific budget and a prospective vision, contributed to creating the conditions for the establishment of the National System of Science, Technology and Innovation (SNCTI) in the nineties.

The State of Science in Colombia (2018) report showed a significant increase in the creation of research groups in the country, a growth in the number of scholarships for doctorates and masters, and an increase in research centers. In the 2014 call to register research groups (Figure 1), 3840 research groups had been formed in all study areas; in 2017 this number had grown to 5207.

Although the articulated network of institutions, policies, and mechanisms for the promotion of science is quite recent and the funding of science, technology and innovation is still low in proportion to need, the scientific community has worked to establish itself and leave a mark on the country's development.

Ranking
Recognized 130

A1	A	B	C	D
293	386	869	1543	749

General Area of Knowledge	
Social Sciences	**1.221** (30.8 %)
Natural Sciences	**855** (21.6 %)
Engineering and Technology	**704** (17.7 %)
Medical and Health Sciences	**685** (17.3 %)
Humanities	**291** (7.3 %)
Agricultural Sciences	**214** (5.4 %)

Scientific Production and Technology (467,040 products)	
New Knowledge	18.1 %
Technological development and innovation	3.8 %
Social Appropriation of Knowledge	38.3 %
Training of Human Resources PATA CTEI	39.8 %

Figure 1. Research groups (Call 693/2014)
Source: Colciencias (2018).

The second decade of the 21st century we still find ourselves in search of a comprehensive policy, with the need for a consistent and long-term funding scheme, and with a pressing need to link this with the national productive system in an organic way. We must create the right conditions in the country for scientific practice, no matter the field of study—including the social sciences and humanities— to advance. This, because the development of alternative economies, the protection of the oceans and different ecosystems, the creation of new technologies that promote development and thinking on balanced models of coexistence, among many other fields of intervention, all require a solid institutional and financial platform. Thanks to scientific knowledge and its advances and developments throughout history, most indicators of human wellbeing around the world show increasingly favorable—and in some cases even spectacular—results (Pinker, 2018).

Although the projection for investment outlined in the Development Plan 2018-2022 seeks to increase investment in science, technology and innovation activities (ACTI) to 1.4% of GDP by 2022, we must concentrate investment efforts on the research and development (R&D) component because it is where the appropriation of knowledge is best manifested. Furthermore, it is essential that this task is not left solely in the hands of public policy makers, but is also entrusted to the general public. Strong social support is essential for the consolidation of knowledge as a primary factor in development. If we want to achieve equitable sustainable development by 2030, in accordance with the Sustainable Development Goals (SDG) set forth by more than 130 nations, a clear political decision is needed, alongside high investment levels by governments and the construction of national and international policies that are backed up by solid evidence (that is, supported by science).

Science will play a fundamental role in achieving all these goals. Basic science will help strengthen the scientific basis for sustainable management, improve our understanding of scientific issues, and help to build ample capacity and potential for responding to problems, some of which are unpredictable. The social sciences will be central in reaching goals like gender equality, reducing inequalities, sustainable cities and communities, peace, justice and strong institutions. Health sciences will support the goal of good health and wellbeing. Other, more production-oriented, disciplinary sciences will play a central role in ending poverty, zero hunger, affordable and clean energy, industrial innovation and infrastructure. The sciences related to the environment, the oceans and the bio-economy will be decisive in meeting goals such as climate action, life below water, life on land and again, zero hunger.

Other fields of knowledge that will be fundamental for the development of a healthy society and a harmonious coexistence with other living things, both human and non-human, are the arts and humanities. Parallel to the elaboration of this document, anthropological researchers Martin von Hildebrand and Wade Davis, together with Macuna indigenous leaders, in the Colombian film entitled *El sendero de la anaconda*, directed by Alessandro Angulo, have put forth proposals to preserve a single biological corridor from the Andes to the Atlantic, based on the knowledge of the region's indigenous peoples. This work highlights the power that cultural content can have for mobilizing ideas for change and coexistence, and shows that one of the strengths that can make Colombia a powerful interlocutor in the global context of knowledge is its native peoples' centuries of experience with the natural world and track record in environmental conservation, who can contribute innovative and relevant approaches for sustainability.

The country must seriously consider promoting the coexisting different forms of knowledge—from the scientific to the ancestral, and including the arts and other sensorial mediums—, and fostering a constant, fluid and horizontal dialogue between them. The need for this type of articulation is being perceived in various contexts and in recent years there have been proposals to move from an emphasis on STEM areas to STEAMD areas (with the addition of art and design).

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The current state of culture, science, technology, innovation and education in Colombia: Modern strategies to improve their impact

Reviewing the role of universities and their interrelationship with the country's problems

Advancing the development of STI and ensuring its contribution to the improvement of the country's productivity and growth, and consequently people's wellbeing, requires the cooperation of many actors moving together in the same direction, and their adoption of credible and firm commitments as a message to the rest of the actors.

In particular, Colombia's universities can contribute to institutional change and economic growth with an approach that integrates the solution of the country's critical problems with the production of knowledge. To this end, they must strive to change their relationships with society, the State, and industry. Research must be strategically complemented by economic and social activities.

Both at home and abroad, entrepreneurial universities, companies and the government rely on good intellectual capital. They are supported by a culture that allows them to take risks in the search for patents in cutting-edge sectors and in the construction of an institutional framework that defends intellectual property rights. All of this is compounded by the investment of abundant resources for research and development (R&D). For example, Stanford was supported for decades by extensive funding from the Department of Defense and from the beginning, encouraged students and professors to found technology companies; the Massachusetts Institute of Technology (MIT) emerged from the explicit and continued support of the State of Massachusetts, with a pragmatic approach to industry relations and selective initial recruitment, in which having a PhD or being smart was not enough. For example, physicists had to be application-oriented.

A less cited experience, but one of relevance to Colombia, is that of the United States' land-grant universities. These universities were created in the second half of the 19th century with an endowment of public lands in exchange for solving practical problems in agriculture, mechanics, and mining for the states' inhabitants, as well as educating the children of peasants. These universities have evolved as anchors in their societies and their needs, with the dense social fabric of their alumni and regional industry; many of them now form a group of world-class research universities.

However, solutions resulting from other economic, political, and cultural contexts cannot be easily transplanted. Colombia is facing a process of deindustrialization caused by the Dutch disease. Thus, the Colombian version of a research university must earn society's trust with solutions to critical problems, no matter how simple they may seem. If results are made visible, research in general will be strengthened and it will be possible to investigate increasingly sophisticated problems.

Integration of new knowledge production and new technology production

Mode 1 of scientific production was advocated by Vannevar Bush, who proposed a hierarchical and linear trickle-down relationship from basic disciplinary research to applications (in the sense that applications do not provide feedback to theory), and in which research and innovation are executed by different people. In Mode 2, knowledge and technology are developed in an application context. This mode is transdisciplinary and occurs in networks of heterogeneous actors.

Brian Arthur (2009) argues that, in reality, technology normally arises from expertise (*deep craft*), but non-trivial expertise requires the guidance of the basic sciences, and the protocols for the development of advanced technology and science are the same. In other words, the two modes cannot exist in isolation and actually feed off each other.

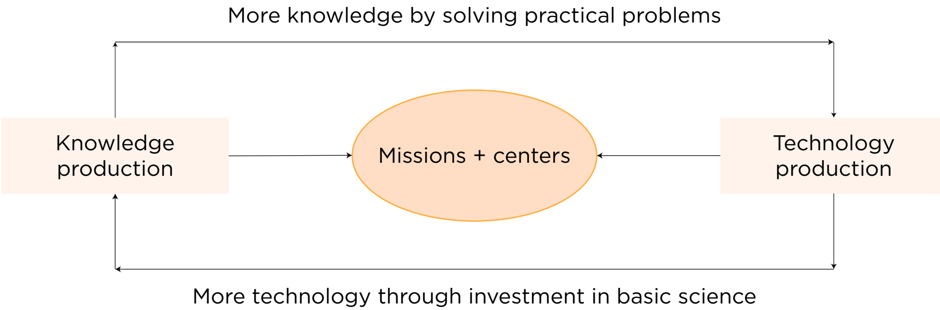


Figure 2. Platform for integrating knowledge creation and technological development
Source: Authors.

Choosing between creating new knowledge and developing new technology is a false dilemma. Mode 1 arose to justify the autonomy of scientific activity when its social and political value was not recognized. Mode 2 arose from the urgency of solving emerging practical problems and tackling major goals (Gibbons *et al.*, 1994); origins that can create misunderstandings.

In Colombia, the interaction between the creation of new knowledge and the development of new technology can be organized through missions and centers that will serve as a platform for direct interaction, as illustrated in Figure 2 (green lines); in this structure positive reinforcements appear between the two sides of the platform (blue lines). The centers and missions create economies of scale and scope, foster dialogue and trust between knowledge and technology, save scarce resources and legitimize science in the eyes of society by making results visible.

Whenever one creates such a platform, it is necessary to define the initial stimulus in order to ensure a self-sustained dynamic. When there are scarce public resources and science does not have an earned space in public policy, for a project to bring about change it must:

- Begin with the solution of the country's critical problems.
- Focus on economic sectors that are on the rise and subject to competitive pressures.
- Work in networks, promoting the production of open knowledge.

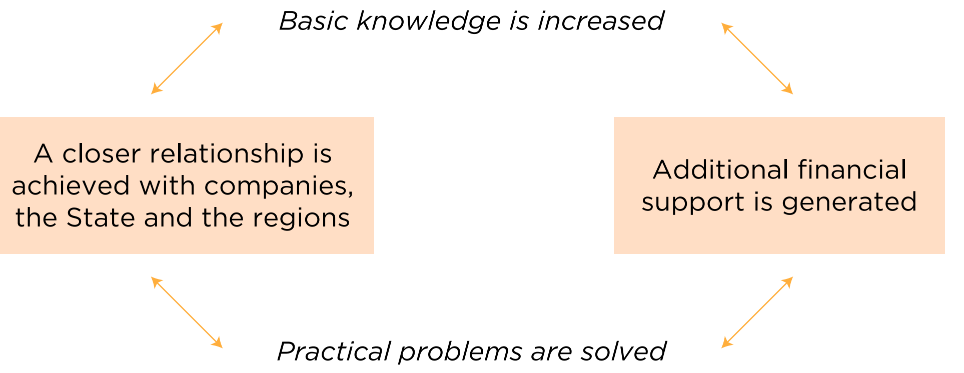


Figure 3. Dynamics of problem solving and knowledge creation
Source: Authors.

The dynamics of social and economic interaction of the two sides of the platform with the actors is presented in Figure 3.

The considerations detailed above have equivalent interpretations and dynamics in the context of research + creation (R+C). Art that does not consider the demands of an audience is equivalent to Mode 1 of knowledge production, while art that is more responsive to those demands requires the same type of feedback as the production of knowledge and technology, as shown in Figure 2[1].

Improving productivity and quality of life in Colombia requires profound cultural and educational transformation. We must start by recognizing cultural and biological diversity as the fundamental heritage on which the country's wealth is based. Although Colombia is a pioneer in the recognizing of cultural rights and in the definition of legal frameworks for their exercise, there is little appropriation of the possibilities that these frameworks offer for local cultures.

1 As part of the Creative and Cultural Industries pillar, discussions have been held on the parallel between basic research and experimental creation, which is not audience-oriented. The production of knowledge for these industries requires the construction of communication channels and feedback between this type of creation and the creation of content intended for audiences and users.

This is aggravated by the inequity in educational provision for scientific research, the arts, cultural management, and knowledge management in general. The State has a historical debt to guarantee the knowledge, conservation, and development of its natural and cultural heritage, and to support the communities and sectors that own these legacies, especially the indigenous and Afro-Colombian. There are shortcomings in the training of teachers in science, arts, culture and creativity in basic and secondary education. There is a lack of a better trained body of cultural and science journalists, and a lack of mechanisms for the appropriation of science and dissemination and circulation of cultural and artistic offerings between different regions.

These factors affect the population's appreciation of knowledge and make it difficult to understand the scope of the role of the sciences, the arts and culture as an engine of human, social and economic development.

The role of knowledge in Colombia's future

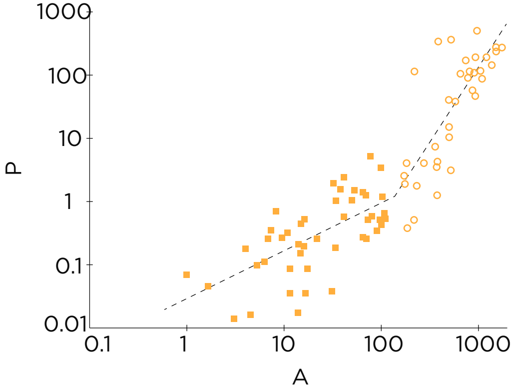
As explained in the previous sections, the Colombian economy must be based on knowledge. Sustainable development is based on the knowledge, conservation, and use of a nation's cultural and natural resources, in which research plays a fundamental role. Productive research must recognize two complementary approaches: curiosity-driven research and mission-driven research, as in Mode 2 of how to produce knowledge described above. The SNCTI must rely on universities with a vocation for research; on autonomous centers that are solidly financed by the State; and on the sector of productive enterprises, academia, the State, institutes, communities and other organizations that contribute to knowledge production.

Colombia needs to reach sustainable development goals on many fronts, by both growing its economy and creating a more equal society. In the United States, Korea, and Finland, for example, these are not conflicting goals and these examples show the close relationship between wide access to education and prolonged periods of high economic growth rates. For this to happen, it is essential to shift our mindset from a model of economic growth, based predominantly on income from the exploitation of natural resources, land ownership and monopolies, to one based on human capital and knowledge.

Knowledge is based on an inexhaustible resource: human creativity. Knowledge generates income of which a part must be reinvested in more knowledge, in increasing human capital and in improving the way we work. If industry, agriculture and (non-predatory) extractive activities are developed by adding value derived from knowledge, economic growth and equity can be achieved simultaneously and be mutually reinforcing.

A country that depends on others for basic knowledge will not be able to enjoy accelerated development nor be able to compete on the global stage. A study by Jaffe *et al.,* (2013) shows that there is a strong correlation between scientific productivity and the present and future wealth of middle-income countries like Colombia. The study indicates that countries that achieve greater productivity in basic sciences such as physics and chemistry (as measured in terms of publications), have greater economic growth in the next five years, compared to countries whose productivity is higher in applied sciences.

To create wealth and wellbeing, a country must be able to develop technology—rather than buying it from other countries—and create new industries. This is why the country must have inventors who exploit the discoveries made by basic science. Figure 4 shows the results of research by Bernardes and Albuquerque (2003) that supports the above. The flattest part of the curve indicates that countries that do not reach a critical mass in the development of science, (measured in scientific publications) have a low probability of becoming innovators. Only when they reach a critical mass of scientific development does the ratio of patents to scientific publications increase substantially. Colombia is still far from reaching that critical mass. Calculations for Colombia predict that the critical mass of scientific publications should be over 32,000, and it is currently less than half that number (15,400 in 2017, according to the S&T Observatory). This indicates that the State's efforts to support science must increase considerably if the goal is to increase patenting and make innovation a clear source of wealth for the country.



Log-log plot of articles per million of inhabitants versus patents per million inhabitants for the year 1998. Bernardes & Alburqueque 2003.

Figure 4. The relationship between knowledge production in the form of research articles and innovation measured by the creation of patents
KEY: Log-log plot of articles per million inhabitants versus patents per million inhabitants for the year 1998. Bernardes & Albuquerque 2003.

On the other hand, Hidalgo and his collaborators (Hidalgo *et al.*, 2007; Hidalgo and Hausmann, 2009; Hausmann *et al.*, 2011) proposed an economic complexity index (ECI) to explain the relationship between knowledge and wealth. According to these authors, modern societies are wiser because their knowledge bases are much more diverse and because they combine this knowledge to obtain better products; products that result in wellbeing and equity. For example, they point out that federal investment in genomic research between 1988 and 2010 created a positive economic impact of 7.76 billion dollars, while the US government's investment between 1990 and 2003 in the human genome project was only 3.8 billion dollars[2].

Revenues will also increase substantially over coming decades as there are important developments planned in terms of technology and projects such as the Earth Biogenome Project that intends to sequence the genomes of all eukaryotic life on earth (plants, animals and single-cell organisms) over a period of ten years.

Recent history shows that the countries that have been successful in overcoming underdevelopment are those that have made large investments in scientific research. China, South Korea and other Southeast Asian countries were as poor as Colombia half a century ago but by investing heavily in research and development, basic sciences in particular to start with, led them, in a relatively short time, to multiply the per capita income of their citizens several times over. These countries understood the close relationship between doing, inventing, and discovering.

Korea currently dedicates more than 4% of its GDP to scientific research (R&D), while Colombia only invests slightly less than 0.3% (less than Brazil, Argentina, and Mexico). The search for solutions to the country's most urgent problems needs to benefit from the dialogue between scientific knowledge and other types of knowledge and know-how. Like science, cultural and artistic practices produce knowledge that is embodied in works that can be protected by intellectual property mechanisms. These types of

2 See https://www.genome.gov/27544383/calculating-the-economic-impact-of-the-human-genome-project).

intangible assets are key to generating added value through innovation, which is why a culture that values and facilitates the exploitation of both industrial property and copyright must be promoted and consolidated, ensuring a balance between incentives for invention and the social benefits of using new products and processes.

But beyond intellectual property, the arts and culture create shared identities and visions of future worlds, without which it would be impossible to guide innovation and growth which is sustainable and equitable. We therefore need to emphasize the importance of transformation towards innovation processes that articulate different forms of knowledge, especially the sciences, arts, and traditional knowledge. The great cultural transformation that the country is calling for must focus on knowledge and education. A Science, Technology and Innovation System and a policy to promote knowledge must be anchored in the capacity to communicate different forms of this knowledge, including scientific knowledge produced at the behest of universities and research centers, working groups, and businesses, on the one hand, and knowledge built by social groups, artists, indigenous communities, and communities of African descent, on the other.

It is a matter of putting them all to work in solving the great social problems with the creation of a healthier and more promising relational ecosystem. High-quality education and the appropriation of science, culture and art, can lead to the shaping of more conscientious, critical, autonomous and sensitive citizens. A nation that dreams of a better future built in a land of tolerance, hope, construction and opportunity must be committed to transmitting a genuine passion for science, curiosity, discovery, experimentation, learning, and research.

We must therefore foster processes of knowledge appropriation and social learning in order to advance in terms of the country's economic and equitable growth in the medium term. We must also identify critical factors for government and societal decision-making, and develop mission-based research that focuses on conserving our cultural and natural capital. For example, it would be strategic to found a cultural and natural history museum that preserves our heritage for the future, and that encourages scientific vocations and entrepreneurship; promotes scientific research;

catalyzes a creative, innovative and sustainable economy, and helps to educate and inspire future generations.

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Justification for the selection of the eight pillars. The relationship between the pillars and the disciplines and techniques

Before choosing them, the Mission of Experts 2019 carefully studied the eight pillars considering how they can support a medium-developed country like Colombia by improving its conditions, positioning, and international relations. *Colciencias* and the Vice-Presidency of the Republic of Colombia, in a joint effort and supported by the *Academia Colombiana de Ciencias Exactas, Físicas y Naturales* (ACCEFYN) chose the areas based on international studies on this subject. Their selection considered the areas defined by the Organization for Economic Cooperation and Development (OECD), and includes disciplines and subdisciplines in which national capacities in science, technology and innovation (STI) have been measured.

Colciencias provided the Vice-Presidency of the Republic with relevant information about the Research Groups and about researchers with high levels of production in STI. This information is summarized in the table below, which illustrates the relationship between national STI capacities and the themes of the eight Mission of Experts 2019 pillars, as well as the OECD thematic areas.

We must emphasize the importance and transversality of the Basic Sciences (called Natural Sciences in OECD) in all of the Mission's pillars: mathematics, computing and information sciences, physical sciences, chemical sciences, earth and environmental sciences, biological sciences and others.

Another major OECD area is Engineering and Technology, which also stands out for its cross-cutting nature and relevance to all pillars, within it are subdisciplines such as civil engineering, electrical engineering, electronics and computer science, mechanical engineering, chemical

Table 1.

Primary National STI Program	Percentage of Research Groups in the Program	International Mission of Experts 2019 Pillars	OECD Areas
Human and Social Sciences and Education	37 %	Social Sciences and Human Development with Equity Creative and Cultural Industries	Social Sciences
Health	17 %	Life and Health Sciences	Health and Medical Sciences
Basic Sciences	12 %	Basic and Space Sciences	Natural Sciences
Engineering	8 %	Convergent Technologies and Industry 4.0 Creative and Cultural Industries	Engineering and Technology
Environment, Biodiversity and Habitat	6 %	Biotechnology, Bioeconomy and Environment	Natural Sciences Agricultural Sciences Engineering and Technology
Technologies for Information and Communication	6 %	Convergent Technologies and Industry 4.0, Creative and Cultural Industries	Natural Sciences Engineering and Technology
Agricultural Sciences	6 %	Oceans and Water Resources	Natural Sciences Agricultural Sciences
Biotechnology	3 %	Biotechnology, Bioeconomy and Environment Convergent Technologies and Industry 4.0	Natural Sciences Agricultural Sciences Engineering and Technology
Energy and Mining	2 %	Sustainable Energy	Natural Sciences Engineering and Technology
Marine sciences and Water resources	1 %	Oceans and Water Resources	Natural Sciences Agricultural Sciences
Geosciences	1 %	Basic and Space Sciences	Natural Sciences
Security and Defense	1 %		
		Creative and Cultural Industries	Humanities

Source: Colciencias, 2019.

engineering, materials engineering, medical engineering, environmental engineering, environmental biotechnology, industrial biotechnology, and nanotechnology, among other fields of engineering and technology.

By creating the Creative and Cultural Industries pillar, the promoters of the Mission recommend that SNCTI be articulated with the cultural sector, in an understanding that art and creativity must play an essential role in the transition to a knowledge-based society, especially at a time when these industries are emerging as a field in which the country can be competitive globally and in the short term. Similar considerations are made with the humanities, which as an OECD area also includes: art, history of art, architecture, music, cinema, radio, and television.

The systemic approach of the proposed interventions

Today, science, technology, innovation and education are intertwined in complex webs and can therefore be considered aspects of a complex system. The system has strong links and mutual influences with production, the economy, human development and with society at large. Science, for example, has the potential to engender innovation and to influence the education of young people, but a science education also has the potential to promote better informed decisions and to help citizens develop the ability to appraise arguments, discard prejudices, and thus promote respect for diversity and reject the exclusion of human beings on the basis of natural differences.

Scientific research also stimulates technological applications and innovations in all fields, but these in turn induce new research and (technologies and innovations) produce new useful knowledge and new theoretical questions by themselves. Greater knowledge of biological diversity, of the geological structure of the country or of atmospheric parameters does not necessarily lead to innovation. However, it can lead to conservation plans, better road design and natural disaster prevention mechanisms, as well as knowledge of social practices of specific communities, local languages and cultural expressions. These can be the basis of new scientific knowledge and even go as far as increasing our recognition of others, which in turn will have important effects on human wellbeing.

In a system like this, relationships are often non-linear and change over time, the relationship between education and less unemployment, for example, varies over time, and interactions and feedback between science and industry are multiple. Causations are difficult to establish. The results of the implementation of an education or innovation policy are sensitive to the baseline conditions and are subject to the point of departure. The relationship between science and innovation depends on whether or not a certain critical mass has been reached. New forces, realities, and conditions emerge, such as when a new production sector appears based on a scientific discovery, a new vaccine that makes certain treatments of a disease obsolete, or a new form of innovation. Self-organization and emergency phenomena may enhance or moderate the effects of the interventions (Holand, 1992; Kitson *et al*., 2018), for example, when a new community of innovative entrepreneurs appears and certain general incentives previously offered are no longer necessary. Intervening in such a system involves much more than acting on a variable to produce an outcome on a certain objective. When we act through policies and changes in the behavior of actors, we are actually changing the entire system and we want what is put in motion to move in the right direction.

The Colombian knowledge system involves multiple actors, some are individuals and some organizations: researchers and research groups, and the universities, centers and institutes where they work; companies, inventors, entrepreneurs and funders; think tanks and consulting offices; State officials and entities at different regional levels, promoters, funders and regulators; formally or informally organized social organizations and communities, of different levels and sizes; teachers, school administrators, schools and colleges where children and youth are educated; and organizations that act as interfaces such as non-disciplinary research centers or industrial groups and trade centers where different actors—currently scarce but indispensable for the system's operation and development—converge.

The Mission proposes interventions, mostly guided by the State, leading to changes that converge on a great purpose: to make knowledge the basis of the environmentally sustainable economic growth and social development of the Colombian nation.

Interventions (laws and other legal instruments, institutional changes, public policy measures or projects) implemented in any of the fields that are the object of the Mission, are of limited scope in the face of the magnitude of this complex system. Nevertheless, these proposals can lead to changes in the role that knowledge plays in industry, agriculture, health, economic activities in general and the environment; in the distribution of wealth and income; in the relations that occur between citizens and between communities; and in the population's culture and behavior.

The effects of the set of interventions proposed by the Mission are difficult to foresee in terms of their magnitude and timing. Virtuous and dynamic cycles can be formed leading to desired scenarios in which knowledge takes on a major role in the development of all activities, and actors from different categories become directly involved in knowledge production and transfer. Other interventions will demand continuous and permanent flows of effort and investment from the State to maintain those effects. Others still, will require large investments and continuous supervision by the State in a first phase, until critical masses are achieved from which other actors assume an important part of the effort. In some cases, the proposed interventions may become difficult to implement, due to insufficient resources or an actor's opposition to change, despite its importance for the country's future.

Some of the Mission's proposals are similar to those made by the Science, Education and Development Mission in 1994; others are similar to points contained in the Development Plan 2018-2022 or to specific programs of certain ministries, which perhaps share ground with many others or are not being developed on the scale we propose and are therefore losing exposure. However, in the new context that the Mission envisions, these proposals will be re-elaborated and articulated, and their interaction with others will be fundamental for all of them to succeed; we will resume work on them, insert them into a coherent whole, and draw awareness to how they contribute to converting knowledge into the basis of economic growth and the wellbeing of Colombian society and its diverse communities.

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Reflections and general proposals

Science, technology and innovation in knowledge production: The central and irreplaceable role of science

The terms science, technology and innovation are often associated as if they represent a single activity, related to the acquisition of knowledge and its use to promote economic and social development. Despite this association established by usage, each of the terms has been given a precise meaning that shows its specific characteristics and how it can be related to the other two.

UNESCO (1984) defined scientific research as a combination of systematic and creative activities aimed at increasing and applying the wealth of scientific knowledge. This definition is not limited to the natural sciences, it also applies to engineering and social and human sciences. Due to its nature as an organization that promotes good practice, in 1963 the OECD began to regulate the measurement of research and experimental development efforts and introduced, with its Frascati manual, the research indicator (R&D), which has since been used to compare nations' investment in science (OECD, 2002).

The R&D indicator measures not only effort in the production of pure scientific knowledge, but also its application in the development of derivative technologies. Later, in 1992, the OECD produced the Oslo Manual (2016), which defined innovation from a technological and new product development perspective, but in its subsequent editions significantly expanded the concept to cover social innovations, organizational innovations in marketing and services, and low intensity innovations in R&D. These international definitions have been adopted in Colombia.

Thus, for example, in 2015, *Colciencias* issued a guide to science, technology and innovation programs[3] that includes these definitions and it classified Research + Creation (R+C) as a new knowledge production activity. Although R&C has not been conceptualized in manuals such as the Frascati or Oslo manuals, the discussions around this term (and other similar terms such as practice-based research or artistic research) have taken place at least since the 1970s in areas related to art and design, and in Colombia they have enjoyed a prominent presence in universities over the last decade (Bonilla *et al.*, 2018).

There have been discussions which have prioritized one of these four aspects (science, technology, research and creation) in knowledge development, with arguments that are valid in all senses. There is no doubt that the scientific research activity that has unfolded since the 16th and 17th centuries has contributed decisively to the way in which we humans understand the world and life today. However, it must be recognized that there were civilizations and cultures with great technological advances and continuous processes of innovation that preceded science, with these events only being explained later. The construction technology used in the Egyptian pyramids was not based on the chemistry of clay, nor were the concave mirrors with which Archimedes set fire to the Romans' ships at the site of Syracuse designed with a deep knowledge of optics. The most notable example was probably the steam engine that preceded Carnot's development of thermodynamics by over a century.

This brief discussion shows that the three activities, science, technology and innovation, feed off each other and have been of immense importance in the economic, social and cultural development of human societies. There is now a clear correlation between investment in R&D and

3 Colciencias Resolution 740 of 2015 "By which the General Methodological Manual for the identification, preparation, programing and evaluation of projects is adopted."

nations' potential to develop dynamic economies and more prosperous societies. However, examples showing that this has been achieved based on just one of the three activities are not plentiful. Today, all three need to be involved and it is increasingly difficult to use definitions to separate them and to claim that one of them is a single and decisive factor for progress and wellbeing.

The societies that have managed to grow thanks to knowledge have done so by reconciling the three elements: more and better knowledge, harnessing the understanding that knowledge offers for the development of technologies, and innovative activity that brings these technologies to practically all aspects of modern human life. It is also clear today that innovation requires new technologies, that technologies constantly generate new questions for science, and that innovative technologies emerge from science. There are countries that have "curiosity-based" research programs that are extraordinarily successful. There are others that define strong national priorities, but always leave open a window of fundamental research, which is essential in the rapidly expanding frontiers of knowledge. When people in these countries talk about the scientific system, they are increasingly referring to all of this complex and intertwined activity, and not just to one of the aspects that comprise it.

In Colombia, we have traditionally been concerned with competitiveness, but this depends on many factors, most of which are not necessarily associated with science. Rather, productivity in the modern world depends directly on the ability of workers, innovative technologies and good ideas. In other words, it is substantially based on knowledge, science and technology, and a culture that leads to doing things well, with an inventiveness that depends on the quality of basic training in childhood and in higher education.

It is important therefore that we understand that what we call science is not limited to what takes place in laboratories. Knowledge grows from multiple sources, it is basic, applied and operational. It emerges in heterodox environments, non-disciplinary centers, communities, think tanks, companies and consulting offices, as well as in the most traditional institutes, universities, centers and schools.

Science understood in this way, in all its breadth, plays an increasingly important role in national development. The approach of this Mission, with eight pillars covering a good part of human activity dependent on knowledge, is intended to promote this comprehensive vision and to accentuate the central and irreplaceable role of science. Various sections of this document and its annexes include several proposals and calls for proposals, whose execution will undoubtedly depend on the Colombian government's and society's commitment to science.

Giving some examples will allow us to appreciate the importance of the challenges that await us and the role played by science and knowledge in the success of our responses. Colombia's biodiversity surely represents one of the greatest opportunities for development for the country and its people. Scientific studies will make it possible to know more about it, because despite what is known, there is much more that is unknown. Science will allow its conservation, but also its intelligent use. New developments should derive from these studies, that cover anything from the production of new molecules with pharmacological and industrial application and new nutrition resources, to ecotourism industries and regional and global integration companies. This can lead to the construction of a true bioeconomy. Conservation is not a minor goal. Our wealth of species makes us a reservoir of biological variety for the planet, with all the responsibility that entails.

The same is true of the country's cultural and social diversity, evident in multiple worldviews and ways of being, expressing oneself, and relating to the world. Although the Political Constitution and the General Law of Culture, 397 of 1997, establish the State's and citizens' duty to know and protect Colombian cultural heritage, research on these topics has occupied a secondary place on the science, technology and innovation agenda. The transformation that the country needs will not be possible without detailed knowledge of its human groups, their ways of being, their knowledge and their culture, even less so if the creative economy is to be promoted as one of the engines for the country's sustainable development.

Another important aspect is that we cannot ignore the basic sciences. We are approaching a second quantum revolution that will possibly change the world even more radically than science did in the twentieth century. If the country is to prevent inequality gaps from widening further, it cannot afford to exclude itself from the global effort. For years now, we have been in the midst of an active scientific revolution in biology and genetics that is having an impact on health, on the agricultural sciences, and on the planet's sustainability overall. Space sciences are increasingly important in the world, not only to understand the universe in which we live, but also to observe the earth from space and to manage the territory based on sound knowledge, addressing problems ranging from deforestation and security to pest control and agricultural productivity.

The social sciences must be at the center of the country's scientific development. Like 190 other countries around the world, we have committed ourselves to sustainable development goals that cannot be achieved without a foundation. One of the great national problems is social inequality, which can only be resolved with innovative policies of transformation, properly articulating the supply and demand for knowledge. Education is the main driving force to improving equity, and we must address it with theories and new educational techniques, but also with a knowledge base of neurocognitive development and with the construction of innovative educational institutions.

Health itself is one of people's greatest concerns. We live in mixed contexts where infectious diseases are still a problem, while chronic and old age diseases, typical of the developed world, take on the greatest importance. As a result, we are constantly forced to tackle new challenges that can only be solved with knowledge and education.

Energy transition to renewable and non-polluting sources is an ongoing process throughout the world and in the country. The survival of the world's economy may depend on how quickly and effectively this takes place. Colombia has a great comparative advantage in terms of access to alternative sources such as sun, wind and biomass, but these sources are of little use without a massive investment in knowledge acquisition.

We are also facing a new industrial revolution. Today's so-called convergent technologies will soon be (or are already) dominant in the world. Artificial intelligence, direct information to the brain, regenerative medicine, green intelligent nanomaterials, among many other developments, will be central not only to collective economic development, but also to personal development. This revolution is absolutely knowledge-dependent and will require high-level scientific studies.

The statement that almost half of Colombia's area corresponds to seas and rivers is an indisputable truth. If anything has prevented us from taking advantage of the immense wealth of our water sources and the vast biodiversity that inhabits them, it is, to a great extent, deficiencies in terms of knowledge and the absence of decisive policies to promote it.

Supporting the country's creative and cultural industries requires an activation of its creative potential based on its cultural diversity and in close articulation with science. Proposals made by the Mission such as building creative incubators with the participation of the State, educational institutions, businesses and the productive sector, not only ratify the vision of this broad science that includes culture and that is created in multiple spheres, but also promotes, once again, the use of local knowledge for better economic and social development.

In all fields, innovation is the result of greater knowledge, but at the same time it is also what drives production of knowledge and requires knowledge. We must harmonize the social organizations that promote innovation and articulate it with scientific research and creation. The relationship between innovative and knowledge-rich industries and citizens' wellbeing is increasingly evident. The Colombian context still does not encourage many of its industries to innovate, but increasing global competition will undoubtedly push them to do so and this will not be possible without more knowledge.

It may seem like a truism in today's world, but for this Mission it is very important to repeat it aloud. Successful nations are those that make knowledge the basis for the solution of their problems, the growth of their economies, and the consolidation of their societies. The science that produces that knowledge is an inseparable part of culture. Its role is indeed irreplaceable, but it cannot be conceived today as the solitary task of isolated higher education institutions, but as a collective social effort. The responsibility of those who now lead the country's fate is immense in terms of pushing our society into an era in which knowledge is our main asset. Many nations, especially the smaller ones, have developed, or have been forced to develop, strengths in certain fields of knowledge in which they can maintain or create advantages, for no one nation can compete in all areas.

This document contains many proposals intended to strengthen the role of science in economic development and in improving productivity. In this chapter we want to highlight those that concern how science ought to function so that it becomes increasingly significant in the country's development:

The creation of centers or institutes that serve as an interface between science and society

In the first link of the knowledge value chain, there is a gap in the county's institutional framework for implementing the initial stages of knowledge generation and transfer, which are necessary for product and process innovation. In order to bridge this gap, the State is encouraged to create technical and technological research centers or institutes on demand.

These centers or institutes will have technicians, professionals and scientists dedicated to thinking over and providing prompt solutions to the problems encountered by the companies in their sector. Each institute will conduct a characterization of the industries in its sector to identify technological gaps. Initially, they should be financed primarily by the State, but over time the private sector that benefits from the results will be interested in keeping them functioning at an optimal level, although the State should also support them in times of recession to ensure their continuity. The centers or institutes will necessarily have the capacity to act transdisciplinarily, they will have to have first-rate scientists and frontier infrastructure and equipment. Examples of this proposal could be *Agrosabia* in Colombia and *Embrapa* in Brazil.

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Education, development and social transformation

Nearly three decades ago, human development was defined as the widening of people's choices to maximize their capabilities and thus lead productive and creative lives in accordance with their needs and interests, which implies enhancing the range of choices for each person to live the life he or she chooses. Development is then much more than economic growth, which is only a means—albeit a very important one—for all of us to have access to greater opportunities[4]. Human development means the possibility of opting for a long and healthy life, of educating oneself and accessing knowledge, and of having a dignified standard of living. "Human development is all about human freedoms: freedom to realize the full potential of every human life, not just of a few, nor of most, but of all lives in every corner of the world—now and in the future" (UNDP, 2018).

Education continues to be understood as one of the decisive factors for human development and social transformation, even though we still have not been able to fulfill the targets of universal coverage and equal access, inclusion and quality as laid out in SDG No. 4. In this historical moment for our country in which we are pursuing peace, achieving this goal promises greater social wellbeing, equity, and economic prosperity for the most affected regions.

In Colombia, limited access to education for broad sectors of the population (formal education, development of citizens' skills, creation, science, innovation and preparation for work), and the difficulties in sustaining such processes at a high level of quality once they have been implemented, affect human development and are related, on the one hand, to the poor growth dynamics of the economy, productivity and innovation, and on the other, to the precariousness of social, political and cultural dynamics.

4 See https://desarrollohumano.org.gt/desarrollo-humano/concepto/

These limitations and difficulties are rooted in the vast inequalities that exist in our country. Despite the fact that income distribution has improved significantly over the last decade, Colombia continues to be one of the most unequal countries in the world. The Gini coefficient for 2018 was 0.51, a situation that negatively affects rural contexts and the most vulnerable populations (rural populations, indigenous people, women). Access to education improved significantly at primary level, but continues to be very low at the 0-5-year-old stage and at secondary and middle school levels. This is illustrated in the figure below, which shows net and gross coverage rates at various education levels (the percentage of students enrolled in the education system both counting and not counting those above the age corresponding to their grade).

An analysis of the experiences of other countries shows that broad and equal access to education has been an important factor in their economic development; for example, the United States between 1890 and 1970 (Goldin and Katz, 2007); Korea in the second half of the 20th century (Lee *et al.*, 2014); and Finland (Sahlberg, 2012). For all of these countries, this focus on education, always backed by strong State support, ushered in periods of accelerated production and increases in productivity and innovation. Wide access to education has also been a determining factor in improving the distribution of income, wealth and power (Atkinson, 2015; OECD, 2018).

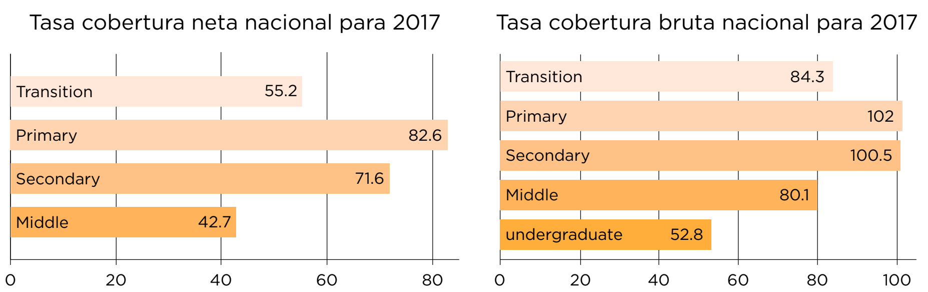


Figure 5. Net and gross national coverage rate 2017
Source: Colombian Ministry of Education - SIMAT (2019) and SNIES (2018)

The connection is not difficult to explain. When access to education is equitable, it broadens the base of people able to innovate, tackle the problems that surround them, strengthen the social fabric, increase the resilience of families and communities, and use their creativity for science or art. This contributes to an increase in productivity, improves income and wealth distribution, and enhances access to other social goods. In turn, the economic and political systems operate more effectively when there is a lower concentration of wealth and power resulting from high quality education. A formal education system with the explicit objective of elevating disadvantaged pupils can contribute to closing the social gaps.

Added to our country's historical challenges are the difficulties that arise from the great megatrends that shape the lifestyles, qualifications and jobs of the future. Recent literature concurs that globalization, the transformations in communication stemming from the virtual realities that permeate all areas of daily life, the Internet, demographic changes, climate change, the urgency of sustainability, automation – based on artificial intelligence – , robotization, biotechnology, and nanotechnology are transforming all areas of human life, demanding changes in the content and form of educational processes and creating possibilities to overcome hitherto insurmountable obstacles.

Considering all this, it is clear that the goals of national education policies cannot be limited to improving coverage or even quality, if this is understood simply as the pursuit of competencies linked to the demands of subject areas (or their practical applications), but rather as the need to reinvent the entire education system to make it relevant to changing demands and personal fulfillment. In a world of accelerated change, where the prospect of reaching 100 years of age will be a reality for a growing sector of the population, people will be able to redirect their personal and professional paths many times over throughout their lives, for better or worse.

A crucial task for the entire education system will be the development of general basic skills, in particular the different learning abilities and human skills - often called soft, socio-emotional or 21st century skills, which are lasting in the sense that they endure technological change. Now more than ever, developing autonomy and self-direction, critical thinking, creativity, collaboration, adaptability, relationships with other humans and with machines, and the capacity for lifelong learning are becoming decisive as goals that guide pedagogical practices, the design of curricula from open and flexible perspectives, and didactic teaching for learning inside and outside the classroom.

At the same time, competencies such as data and digital literacy; computational thinking and skills in science, technology, engineering, arts, mathematics and design (STEAMD); effective communication in a second language; self-recognition and improvement and a clear vision of our aspirations in the social, cultural and political spheres, must all become core competencies that effectively contribute to our country's development. The magnitude of the challenge requires effective, intelligent and scalable approaches, different from those we have adopted so far. The education system has to prepare at all levels for a world in which it is anticipated that, by 2030, a very high percentage of our occupations have not yet been invented (IFTF, 2018). This calls for the advent of "instant learning" and the development of people's skills to access such learning.

When thinking about an education fit for the future, the system that we imagine should educate for the needs of a productive system, but it should also include the challenges of environmental and social sustainability that our societies face. It is necessary to look to the future with an open mind, transcending a merely diagnostic perspective, and so remind ourselves of the urgency of closing those gaps and achieving more equitable learning outcomes across territories, populations and income levels, which are so disparate in our country today.

Research on the cognitive and brain mechanisms involved in learning has yielded important outcomes over the past twenty years. We have begun to understand the functioning of neuroplasticity, the effects of nutrition, sleep and emotional regulation, as well as the importance of attention span, prediction ability and error correction; indispensable ingredients for learning from early childhood and throughout life.

This reality demands new pedagogies that recognize that, when children enter school, they arrive with great differences; currently the educational system does not close these gaps. Such pedagogies must begin by recognizing the economic, social and cultural context of students in the educational process, understanding that this affects not only the input young people receive during their training, but also their knowledge and their image of themselves and their communities. They should also ensure that the student plays an active role in the learning process through evaluation, feedback, and hypothesis creation among other elements. A quality education necessarily implies the closing of the gaps in skills.

We must attain an educational model that proposes new, different pedagogies, that removes the emphasis on the progressive development of individuals' learning abilities, and instead makes it possible for them to learn for a specific task and move through the different phases of their lives. The model must also ensure that educators are aware of the changes in the brain's abilities caused by learning, and we must do away with punishment-based evaluation and correction methods and implement others that are emotionally neutral and that allow students to correct their own mistakes. We also need to think about education from an ecosystemic approach that articulates multiple actors, contexts and territories to support continuous, lifelong learning, in formal, non-formal and informal learning contexts.

The considerations detailed above lead the Mission of Experts to focus a large number of the proposals on education, of which the main ones are outlined below:

Universal access to education and comprehensive early childhood care

This proposal aims to ensure that all children living in Colombia have access to quality education complemented by nutrition, health, care, and affection. Ninety percent of our neuronal connections are established between the ages of zero and five years (Fraser Mustard, 2002; 2003), meaning that the physical, emotional and cognitive development of the child in these five years is critical. The Mission believes that the Colombian State should guarantee comprehensive attention and offer access for all those who are unable to provide this through their own means. It also stipulates that families should assume co-responsibility for this process.

Although Colombia has made important progress in this area (Presidency of the Republic of Colombia, 2018), especially with the From Naught to Forever program (*De Cero a Siempre*), there are still many challenges needing to be overcome (UNICEF, 2017; Save the Children, 2017; CSOs, 2018; DNP, 2019). Some 11.7% of under 5s live in absolute poverty and there are great disparities between the rural and urban population (DANE, 2018). “Nearly 50% of 3-year-olds and 36% of 4-year-olds do not attend any institution” (UNICEF, 2017; CSOs, 2018; DNP, 2019) and there is concern that “the majority of school offerings at this level (72.3 percent) only offer assistance services, leaving the pedagogical and preparation components for higher levels” (UNICEF, 2017; CSOs, 2018; DNP, 2019). One out of every four children do not receive basic medical care. Many are victims of violence and abuse (Save the Children, 2017). Teenage pregnancy is increasing and currently applies to 19.5% of women aged 15 to 19. Thirty-seven percent of women report being victimized by their partners (UNFPA, UNDP and UN Women, 2017).

The magnitude of the challenge of internationalization must include, in addition to existing provision, a strategy of decentralized comprehensive care for preschoolers, with a focus on family and community. The Regional Centers for Research and Development in Children, Youth and Family must guarantee the proper development of the comprehensive care route currently offered by the From Naught to Forever (*De Cero a Siempre*) program, throughout the national territory. The latter would constitute one of the Regional Centers’ organizational tasks, alongside others in which local and regional instances assume greater responsibility and comprehensive attention is more extensive. The Centers will also actively participate in the processes of training preschool teachers and in the organization of subregional networks of education innovation centers, which implement permanent teacher training.

Universal access to secondary and middle education and its diversification

The Mission's next central recommendation in terms of education is to provide universal access to secondary education (grades 6-9) and middle education (grades 10-11), and to ensure curriculum diversity to enable these education levels to connect with community activities and local economies. In these grade levels, as indicated in Figure 5, 41% of girls and boys of secondary school age and 53% of those of middle school age are not attending school. The context in which many adolescents live, especially in the countryside and in the urban centers of the vast majority of small towns, causes those out of school to be subject to high unemployment rates and multiple risks. Needless to say, it also closes off life options for them due to lack of education. The problem is both of coverage and of expanding the artistic, scientific and social work options of this group of children and adolescents. Thus, in addition to the State guaranteeing access to this education, it is a matter of directly connecting the training they receive with the economic, artistic, cultural and social potential of their municipalities or sub-regions.

While one part of the curriculum of these secondary and middle school programs should revolve around national themes such as history, another important part should be defined locally based on that local potential, and focusing on aesthetic and cultural content, the political, social and economic history of each area, as well as knowledge of the surrounding biodiversity. In many cases, in order to make secondary and middle school education more attractive, double degrees are proposed, combining training for university education with technical education.

This offer, together with agreements with the private sector for young people's employment, could bring pupils closer to a productive activity that helps them stay in school, as they often abandon education because of the need to support their families financially. Thus, there needs to be transversal approaches that articulate learning content with specific problems. This means that skills such as aesthetic sensitivity, scientific curiosity and creative problem solving should not be limited to subjects such as arts education, biology or mathematics, but should cut across the entire curriculum, making it possible to develop critical and transdisciplinary thinking.

A recommendation was made in this regard in the 1994 Science, Education and Development Mission. *Innovar* institutes should combine the high school curriculum with vocational education, coupling these in an explicit push towards innovation and technology-based entrepreneurship. The idea was successfully tested and the Ministry of Education promoted a network of these high schools in a hundred municipalities. The lessons learned in this pilot stage—in which some of these centers were successful, while others failed—allows us to conclude that the time has come to universalize and widely diversify this project, so that education is integrated into local life, and initial training and individual skills are connected with the potential of the sub-regions, while opening wider channels for technical, technological, and university training. Complementing these high schools with community colleges that—in partnership with universities—provide the first two years of university education would offer opportunities to students in regions where access to higher education is more difficult.

The arts as a tool for personal development and consolidating diversity

Early childhood is when the main reference points for the development of aesthetic expression (music, dance, fine arts) and the emotional and sensitive dimension that this entails are acquired, to then be enriched and strengthened throughout life. These reference points are the axes that configure cultural citizenship, audience formation for the creative and cultural industries, and globally competitive talent. The Mission's proposal consists of the effective implementation of compulsory arts education from early childhood and throughout basic and secondary education, with local content drawn from the country's different cultural regions. The objective here is to develop the core competencies of sensitivity, aesthetic appreciation and communication (Cuellar and Effio, 2010), and to make every Colombian citizen aware of the cultural diversity enshrined in our Constitution.

The development of social-emotional skills as a central goal of the educational system

Scientific research has shown that socioeconomic skills, including citizenship, are crucial not only in themselves but also because they positively affect many desirable life goals, including individual wellbeing, cognitive development, and occupational success. Encouraging these skills is particularly relevant in countries that have been subject to armed conflict, where education in historical memory helps reduce aftermaths of violence. Colombia faces great challenges in forming committed citizens who cooperate with each other, comply with the law, and demand respect for democracy. Moreover, given the alarming increase in mental health problems among children and youth, as well as the impact of multiple forms of violence on the population, the country faces enormous challenges to individual wellbeing and social cohesion. The Mission proposes the creation of a platform to finance programs to train teachers in social-emotional skills, citizenship competencies and education in historical memory. We call on teacher training colleges and educational institutions with bachelor's degrees to train new educators and those who guide teacher qualification programs to incorporate this competence into their institutional educational projects.

Restructuring of the Teacher Training System: Higher Institute for Research in Education and Advanced Teacher Training and Sub-regional Networks of Centers of Innovation in Education.

The internationalization of comprehensive care from 0 to 5 years and quality secondary and middle education demands training for a considerable number of teachers for these levels and others that will benefit from these programs who will receive better qualified students. Coverage should not be expanded at the expense of quality, as has occurred with other levels in the past.

This objective requires the structuring of the national teacher training system around a set of initiatives that ensure that research and development of knowledge and teacher training are combined. Rebuilding teachers' confidence, dignifying their work, strengthening their position in terms of their status in society, and recovering the spirit of learning in their own careers will transform the country's schools and colleges into spaces for the development of knowledge and thinking.

Two strategies are articulated within the proposal. First, the Mission proposes the creation of a Higher Institute for Research in Education and Advanced Teacher Training (ISIE), as a public establishment or a mixed corporation, in any case financed using combined resources from the national budget and contributions from the private sector and cooperation. The ISIE will be responsible for developing research in high level education and training teacher-researchers that will, in turn, educate the new teachers of our children and teenagers. It will also guide the continuing education processes of teachers currently working via associations, micro-centers, sub-regional education innovation centers, Regional Centers for Research and Development in Children, Youth and Family[5], and the networks of these groups, which should be strengthened with access to new technologies available to all sub-regions.

The second strategy of the new teacher training system is intended to ensure the permanent training of teachers currently working, through sub-regional networks of Centers for Innovation in Education. These centers are meeting places where experiences and lessons learned are shared, and where educational research projects are conducted; they may be guided by the Higher Institute for Research in Education and Advanced Teacher Training, *Universidad Pedagógica Nacional*, the UPTC, other universities that offer teacher training programs, the Academies affiliated with the *Colegio Máximo* and its chapters, and coordinated by the regional universities that will be called upon to adopt the subregional networks.

5 In Colombia, Brazil and other countries, there have been successful experiences with teachers' associations and residences, linked through networks, which disseminate knowledge and articulate pedagogical efforts.

In order to break the cultures of isolation and connect teachers working in remote communities, the Centers for Innovation in Education will operate in spaces adjoined to cultural centers throughout the country and will carry out tasks that link teachers with the community. To this end, they will act as regional centers for research and development in children, youth and family. A number of successful cases, among them the(*Centro de Innovación del Maestro* – MOVA –) in Medellín, serve as models for these spaces of permanent learning, research, and for building relationships between teachers and their community and culture. The State, private companies and NGOs should compete, through a broad investment plan, allocating an item in the General System of Contributions of the Departments, Districts and Municipalities (SGP) and regional royalties that will allow the expansion of the number of qualified teachers available, especially for early childhood and universal secondary and middle education.

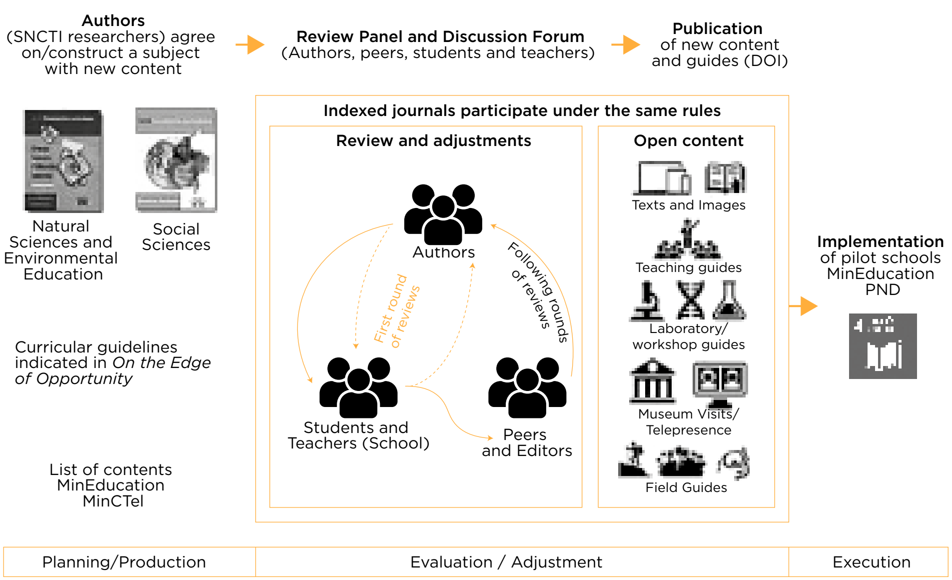
The Centers of Innovation in Education will operate as local systems of knowledge management that join together the research processes across the country; systematizing local practices; and serving as a space where teachers can work with families and their children, especially those aged 0 to 5. To this end, teachers will use strategies based on art and play so that pupils can strengthen and recognize their own cultures. It is important that all actors involved in comprehensive early childhood care be trained (women, caregivers, young people, teachers).

The two processes should be harmoniously developed in parallel, and should be supported by a National Research Program in Scientific Studies on Education that develops knowledge, advances research programs as part of large networks and allows teachers to share knowledge. Empowering teachers to systematically research and innovate, in the light of the most advanced scientific knowledge, is indispensable if we are to improve the quality of education, turning it into an instrument with which to close gaps in equality. The possibility of transmitting curiosity, the love for knowledge and the search for solutions to environmental problems to new generations, depends on teachers developing their own sensitivity and expressive skills, and their knowledge of the historical, social and cultural context in which they work through the arts, humanities and scientific disciplines.

The government and the educational institutions must rethink the role of teachers to convert them into a living example of what it means to be a learner in the 21st century. They must show flexibility, openness, and reassess their attitudes, knowledge and practices, without dispensing with the rigor inherent to scientific and educational activity. They must integrate new modes of learning and impart education using converging technologies to increase coverage and provide ample opportunities and enriching experiences for the Colombian population.

New educational texts and content

We want to correct the absence of educational texts and content that deal with regional contexts. The proposal is that researchers in the national system of science, technology and innovation contribute their knowledge—especially that which comes from their recent research—to create new educational content for schools. The idea is not to create a



Source: Authors, Oceans and Water Resources Pillar new subject area but to strengthen and openly innovate on the basic curriculum subjects (e.g., Natural Sciences, Biology, Physics, Chemistry, Mathematics, Calculus), with examples and case studies associated with our natural and cultural reality.

Complementary proposals

The Mission proposes a package of complementary measures (more extensively justified in annexed documents), connected to the previous proposals, to improve the quality of education which depends directly on teacher training.

a) All levels of education must consider that there will always be children with special needs, with dyslexia, dyscalculia, dyspraxia, and that we must adapt schools and assessment systems to this particular context for people with disabilities. There are several successful experiences in Colombia that can serve as models to advance this policy.

b) Participatory processes should feed into the design of the Regional Centers for Research and Development in Childhood, Youth and Family, of the Centers of Innovation in Education and the networks they form. The Ten-Year National Education Plan's survey and platform and the participatory process led by its management and academic commissions, involving nearly one million people throughout the country, should guide the adaptation of national proposals to local and regional plans (PNDE, 2017).

c) The inclusion in the territorial development plans of locally and regionally adapted proposals of each of the ten challenges outlined in the Ten-Year Education Plan, the National Development Plan, SDG, and the Mission of Experts, is indispensable to guarantee their implementation.

d) There is a great wealth of experience in educational innovation in Colombia. However, these innovations have not been systematically evaluated with a view to disseminating and generalizing the most successful ones. Open calls for innovation in education could support this selection and dissemination process.

e) All the accredited Universities in the country will be called upon, alongside those already offering high quality programs in education, to offer teacher training programs at undergraduate, master's and doctoral levels in pedagogy and didactics, especially in mathematics and basic sciences that have been identified as problem areas in the Pisa assessments. This must be compounded by an intensive scholarship program for the basic sciences that will bring research and teaching closer together and attract outstanding students who generally do not currently tend to choose teaching as a profession.

f) Formalize rural internships for undergraduate students as a final degree project option, guided by local teachers with training in education.

g) Create a scholarship program for students with high qualifications in the "saber-11" test who would like to train as educators.

h) Support national PhD programs and occasionally international doctoral training, especially in fields that are strategic for the country in all areas of knowledge. Ensure funding for graduate's continued research and establish streamlined regulations for the recognition of degrees. Given that the current offer for the creative and cultural industries is limited, special support is required for the creation of master's and doctoral training programs. This is also limited for fields and interdisciplinary areas that promote the linkage of value chains. For the social sciences, we must continue to support national PhD programs and autonomous research centers, and strengthen calls for research programs that address the serious problems that we as a country are facing, with research-intervention-creation strategies and in the framework of transformative social innovations.

i) Implement a strong incentive program to address regional disparities in education.

j) Promote and encourage graduate training in STI journalism for science graduates.

k) Implement remedial programs to prevent school abandonment and boost less advantaged students.
l) Promote research in learning sciences and its application in local educational contexts.
m) Involve current and future teachers in processes of digital transformation of the educational system, which today offers the opportunity to expand coverage and to boost access to and the quality of education in rural areas.
n) Training at all levels must be imbued with ethical values. The Mission calls on educators to ensure that, from early childhood education to doctoral training, there is a genuine concern for ethical behavior, moral dilemmas, and public perceptions of teachers and learners.
o) The Mission proposes a reform of the educational system to support lifelong and lifewide learning, enabling citizens to develop values and skills relevant to current and future life and work. The Science, Education and Development Mission's 1994 proposal for Cosmology, whose effectiveness has been tested on a small scale, is particularly relevant for this purpose.
p) Learning a second language, especially English, should be a component of education at all levels.

Extensive reflection on pedagogy in preschool, basic, and secondary education will be called for and will be needed to identify and cultivate personal talents, develop values and citizenship, and solid skills in the arts and basic sciences.

The different segments of the higher education ecosystem should be networked, recognizing the value of technical, technological, and university training for the country's development. The higher education ecosystem will be articulated with the productive and social systems, in order to interpret the needs and propose solutions that affect teacher training and public policies, and inspire new generations of Colombians. In this respect, we must assess and ultimately recognize the role played within the ecosystem by the set of emerging actors that are contributing to supplying educational services and that are outside the existing categories of educational institutions.

A number of surveys have detected a low management capacity in many companies to guide and direct innovation projects. Accordingly, the documents attached to this report include a proposal for a special training program for managers and entrepreneurs for managing innovation projects.

Finally, education for work should focus on those levels identified as critical by the obstacles to innovation analysis: the training of technicians and technologists with minimal scientific preparation that ensures their versatility and the possibility of changing careers over the course of their lives. The university offer of pre-university courses or undergraduate certificates that link secondary, technical, and technological education with higher education; the functional differentiation between technical, technological, and university education, which has been diluted; the periodic evaluation of all education for work institutions, as recommended by the OECD; the implementation of a system of equivalencies and homologations, and the expansion of the offer of technologies in high quality units, are indispensable instruments of the reform intended to modernize education for work as proposed by the Mission.

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Governance of science, technology and innovation

One of the purposes of STI governance is to attract increased funding and to leverage all available funds into coherent, high-impact social and economic programs. An automatic increase of investment in STI or transforming *Colciencias* into a government ministry, are not in themselves sufficient to reach a new normal of high investment in STI and higher levels of economic productivity. This new normal can only be sustained by competitive pressures on industry, by a change in incentives for and logic of universities and researchers (discussed in other sections), by a change in public policy in STI (see the section below) and by a functional organization of the new Ministry.

When a dynamic of change has been set in motion by all the actors involved, it is important to: (i) specify the role and scope of the National System of Science, Technology and Innovation; (ii) define an organizational structure of the Ministry for dialogue with society, geared towards implementation; and (iii) identify the main instruments and initiatives which will prevent the atomization and dispersion of resources, and to encourage the creation of networks. These issues are developed further below.

The National System of Science, Technology and Innovation (SNCTI)

The National System of Science, Technology and Innovation (SNCTI) should be different from the National Competitiveness System and should not be included in or dependent on it. The SNCTI (as defined by Laws 29 of 1990 and 1286 of 2009) must have open participation and, in practice, it will be the members who declare themselves part of the System. A non-exhaustive list includes public and private institutions of higher education, public and private technical and technological education institutions, training for work institutions, and academies constituted by law as advisors to the government, companies, business associations, trade associations, public institutes and centers that conduct scientific research, independent research centers, research centers belonging to production associations, non-profit organizations that conduct or promote research and citizens' associations that promote research.

The following elements are essential to the governance of the system:

- A National STI Policy Council, which should be the body responsible for discussing and advising the STI Minister regarding public policy on science, technology and innovation and for guiding the promotion of science, technology and innovation activities towards sustainable development, establishing links with other research systems and calling on them to become partners in STI activities.
- A National Scientific Council, which should be the consultative body in charge of delivering a scientific concept on STI-related issues to the government and of providing guidelines on scientific ethics to be taken into account in science, technology and innovation activities, projects and programs.
- Relationship and coordination mechanisms, which must be assessed by: (i) an inter-ministerial committee that saves on CONPES[6]-style paperwork; (ii) the figure of a high-level advisor to the Presidency of the Republic, used in institutionally strong countries where the independence and competence of the adviser is guaranteed; (iii) the scientific advisory commission of the Congress.
- The STI Ministry, which should be the head of the system and responsible for generating national policies that regulate and promote STI activity.
- An implementing agency that promotes STI programs and projects, including those funded by royalties and international cooperation resources. The agency will manage the existing funds with resources from the current national budget and royalties and will undertake

6 Conpes is the National Council of Economic and Social Policy. In recent years, STI Conpes documents have taken several years to be agreed upon and approved.

any necessary monitoring and evaluation. The executing agency will participate in coordinating the investment of other ministries and other national funds dedicated to STI activity.

Structure of the STI Ministry

Beyond the absence of shared expectations and spaces for structured dialogue, the main operational restrictions to STI development in Colombia are a lack of funds, the atomization of allocations, and unfocused spending (the absence of structured programs).

As discussed in the section on funding, there are four main uses/channels for organizing STI activities and funding. The channels that must have a solid organizational deployment in the new ministry are C1. Research excellence, C2. Collaboration between industry and researchers and technology transfer, C3. Innovation through business R&D, C4. Adoption and non-R&D based startups, C5. Research on regionalization and adaptation. These programs correspond to the use of resources.

These channels must also incorporate the (research + creation) line from the artistic and creative areas. This implies not only the recognition of their products, but their firm and constant promotion[7].

The Ministry of STI must have the following characteristics:

- A ministerial head in charge of policy and interaction with the rest of the cabinet, the leadership of the National STI Policy Council, with the capacity to align sectoral budgets.
- A Vice-Ministry in charge of designing the contents of the four types of programs mentioned above, whose classification is consistent with the nature of the problems to be solved and who can adapt the language of the international practice of CTI management. This Vice-Ministry must define the percentages of public co-financing,

7 There must be a dedicated administrative unit in the Science and Technology Ministry that interacts, at minimum, with the National Arts, Architecture and Design Board and the Association of Social Sciences and Humanities Faculties.

establish incentives and rules for aggregating sources, and interact with relevant actors in the definition of priorities. It is important to emphasize that this Vice-Ministry must incorporate dialogue with the traditional knowledge of indigenous people, Afro-descendants, *Raizal* communities and peasants.

- A Vice-Ministry with complementary functions (education, social appropriation of science, management of the diaspora and of international and regional networks, etc.)
- An independent agency in charge of financing and structuring projects using the logic of combined financing. This agency should seek to increase sources of payment, design the mechanisms of combined financing and credit improvements, strengthen the early financing ecosystem, and continuously interact with the actors of the combined financing ecosystem (public funds, donors and philanthropy, conventional private funds and alternative assets).

Missions and centers to design programs and focus spending

Two powerful instruments that will help avoid the current atomization of funds and their dispersed use are the missions and centers, whose role is outlined in other sections.

For the time being, we will highlight the following characteristics of each here:

- The missions locate different researchers around the solution of practical problems and thereby achieve both visible impacts and citizen support for the growing role of STI in the economy and society.
- The centers are part of an international trend of STI management for applied research with advantages in economies of scale, scope, and agglomeration. They should be neutral (independent from universities and industrialists), but at the same time, highly capable of fostering agreements between the parties and with a capacity for

commercialization. They are ideal for the management of cumulative innovation (they are key in biotechnology, for example), which requires building "quality ladders" between consecutive discoveries to ensure long term products.

Regional Innovation Systems (SRI)

STI governance should include the development and consolidation of Regional Innovation Systems (SRI), which are particularly relevant in a globalized world: the regional level can be scaled up to be applied to global opportunities and challenges more quickly. SRI would have advantages over national systems, as problems of policy identification and monitoring are better dealt with close to home.

The actors: State, private sector, third sector, educational institutions, communities

The search for solutions to the social and environmental challenges of our times exceeds the scope of State sectoral and territorial policies, and requires a commitment from national, regional, and local governments to promote dialogue, learning, and joint experimentation among diverse actors. The knowledge provided by national and international disciplines and expertise can be enhanced through these participatory processes.

An STI system brings together very different actors: State entities, education and research organizations, organizations that act as interfaces or intermediaries in knowledge development and transfer, productive and service sectors, funding agencies and civil society. The system works precisely because of the interaction among the actors. In the case of the Colombian STI system, there is limited interaction between the different actors. If we are to drive radical transformations in society, we must promote these interactions and mediations.

As a result of this isolation, some actors end up investing huge efforts in developing capacities to help achieve their core mission that other actors have already developed and could transfer or share. Funding shortages often exacerbate this trend and actors end up competing, and seeking to survive or stay in business. This dispersion by actors is a double-edged sword for the system and organizations. On the one hand, actors show versatility and creativity in adapting their talents to capture new funding opportunities; in doing so, they exhibit a great capacity to absorb new knowledge. On the other hand, changes in activity can slow down skills-building processes, since by migrating to other areas of knowledge, accumulated expertise is not used and the possibility of joining with other actors, making use of their complementary capacities or greater experience, is discarded. The Mission offers a proposal to overcome this fault in the system by establishing mission-oriented research that brings together actors with complementary capacities around strategic country issues.

In Colombia, it is common to hear complaints from actors about others in different sectors. This is the result of the shortcomings of the knowledge market, linked to the uncertainty inherent in research processes, which affect trust and limit collaboration. Academia challenges the State regarding its lack of investment and stable State policy, and industry for its unwillingness to risk take and for its small-scale perspective. In turn, the State demands a greater commitment from academia to generate "productive" knowledge and expects science, technology and innovation initiatives from industry. Industry demands immediate responses and greater efficiency from academia, while expecting the State to provide favorable conditions that will make research and development activities more predictable and profitable. Under these conditions, the STI system is presented as a set of isolated units that work together only by exception.

The question is, how can we change these relationships? The Mission's proposal established that the State should promote the establishment of autonomous organizations (centers, institutes, networks) that serve as mediators between actors, can be used as a space for dialogue and risk sharing, and as channels for knowledge to flow in different directions. The Mission calls upon different actors to open spaces where differences of approach can be thrashed out to overcome mistrust. Facing the social, environmental and economic challenges of the 21st century, and in particular, the pursuit of the Sustainable Development Goals, requires the cooperation of all the actors in the system.

In order for the State to lead this task of articulation, we must understand the conception of science, technology, innovation and culture it uses. The current science, technology and innovation Conpes, makes STI responsible for "generating economic and social development based on the knowledge" (Consejo Nacional de Política Económica y Social, 2009). However, the Colombian Constitution does not clearly define the role of science, technology, innovation and culture in terms of the country's development. Articles 70, 71, 360 and 361 of the 1991 Constitution show the lack of vision on these issues from the foundations of the State. Science, technology, innovation and culture are conceived as activities for learning (República de Colombia, 1991) which are fundamental to building a thinking, critical and deliberative society, but the Constitution falls short in defining what it intends to teach in terms of science, in providing incentives, and also in defining the role of STI in the country. The State must therefore design public policy that clearly defines the role of STI in Colombia in the pursuit of social equity, wellbeing, and sustainable development.

The State has taken on the role of promoting innovation by supporting skills building in the industry, as reflected in the STI Conpes. However, the DANE Surveys on Technological Development and Innovation highlight companies' low levels of innovation, with 96.4% of Colombian companies being micro, small or medium sized, only contributing 37% of the total

• National level • Departmental level • Municipal level	• Public and private research centers and institutes • Research groups • Public and private universities • Technical and technological institutions	• Goods and services companies • Production guilds and business associations • Chambers of Commerce • Associations
State	**Education and research entities**	**Industry**
• First level banking • Second level banking • BANCOLDEX • Venture capital funds • Fomipyme • International funds (IDB, USAID)	• Technology Development Centers (CDT) • Technology transfer agencies • Regional intermediaries • Technology-based business incubators • Technology Parks • Law and Intellectual Property Offices	• Non-governmental organizations (NGOs) • Non-Profit Organizations (NPOs) • Citizen associations • Professional associations • Think tanks
Financing	**Intermediaries**	**Civil society**

Figure 6. Actors in the national science, technology and innovation system
Source: Authors

added value. Only 0.2 % of the total number of manufacturing companies are innovative in a strict sense, 21.5 % are innovative in a broad sense, and 74 % are not innovative (DANE, 2017). In industry, services, and commerce the most frequent innovations are process or organizational. Innovations in products or services and in forms of marketing are rarer.

The public institutes are fundamental STI actors. They produce valuable knowledge for the country outside of market demands, providing essential knowledge for State operation, which is strategic for national sovereignty in health, geological resources, energy, water resources, biological resources, legal issues, and memory conservation among others. The government must take advantage of the capacities of its institutes to provide solutions to the country's problems. This document presents a proposal for the articulation, financing and regulatory definition of these institutes, due to their initiative in STI. It calls for the creation of joint lines of work and the establishment of challenges to be addressed, the definition of clear governance and an articulation within the State that allows horizontal cooperation among institutes and the leadership of each in their sector.

The basis of the science, technology and innovation system is a solid secondary education that ensures an adequate foundation in science and, at the same time, offers relevant training according to the potential labor or professional interests of young people. Universities are an essential component of this system, as they educate, research, innovate, and transform the country's territories. The higher education institutions located in the regions are fundamental to offering a contextualized and pertinent level of training outside of the capital. This training creates a critical mass of professionals who are the platform for knowledge transfer and appropriation. This, in turn, establishes a relationship between education and social and economic development. Higher education is fundamental to diminishing the inequity and regional gaps that affect our country.

The industry's poor performance in innovation is due to low levels of investment in innovative activities and limited knowledge absorption capacity. This is related to the reduced number of trained research personnel, insufficient ability to update their knowledge due to human resource limitations and scarcity of capital to invest, according to the above-mentioned survey. Other reasons for the low levels of knowledge use and low performance in innovation are companies' lack of information regarding public support instruments, the uncertainty associated with these processes, market convenience, and the need to solve short-term problems of liquidity, billing and planning.

A fundamental agent in any STI system is the intermediary or interface actors, among which the research and technology transfer organizations can be found. In knowledge-based societies, these organizations allow the effective articulation of the innovation system's actors around new technological solutions and focus on major lines or agendas of research and development for aspects of academic and administrative efficiency. Beyond the commercial purposes initially conferred on these actors, their work must transcend and seek the population's wellbeing, allowing parties to learn from each other, promoting collective cooperation and the creation of networks for the exchange of knowledge and skills.

In 2017, Colombia had 5207 recognized research groups, attached to educational entities, research centers or companies. These groups are an essential component of the science, technology, and innovation system because they both form and absorb highly specialized human capital. A large number of them conduct quality research at the forefront of knowledge and provide a collaborative response to a society's challenges, problems and needs. Most of them have relationships with companies or State entities, and some with communities, but they cannot satisfy the needs of a number of larger companies. Research groups are very sensitive to changes in policy direction and research priorities, as this induces them to develop new capacities to react appropriately to such changes. Their strengthening and participation in international knowledge networks are imperative for Colombia's development and the creation of relevant knowledge for the country.

Organized and unorganized civil society has much to contribute to STI systems. For example, projects such as family allowance funds, cooperatives, and user and consumer groups are examples of mission-oriented social innovation work. These organizations and associations lead participatory processes from the grassroots, in which local knowledge is valued and diverse capacities and actors are articulated to provide opportunities and meet the needs of the communities where they are present.

If citizens perceive knowledge as a factor of progress and sustainable development in their communities, skills-building in STI will find greater support from the State. Accordingly, the STI Ministry will advance policies for a more effective insertion of science education in the curriculum, to ensure a greater appropriation and appreciation of knowledge. Individually or collectively, citizens make decisions that affect their lives and the dynamics of their organizations, environments and communities, so the path towards a knowledge-based society must be founded on the comprehensive and contextualized training of the whole population.

The proposals made by this Mission focus on changing the inertia of the system in order to promote the emergence of new niches of knowledge, increase the skills and capacities of the actors involved, and rethink the structures of governance, so that society can adopt knowledge as an advantage for everyone. It is important to understand that science, technology, and innovation are social processes whose outcomes are determined by cultural, political, economic, and ethical values, as well as by the interests, activities, and commitment of all their stakeholders.

Proposals

In view of the reality of a new Ministry of Science, Technology and Innovation, the Mission considers it essential to implement ongoing international peer monitoring and evaluation of the work of the Ministry focusing mainly on its scientific strategy, its effectiveness in reaching goals, the progression of funding, territorial coverage, and the international impact of the research and innovation it funds.

Organized civil society should participate in the periodic definition and execution of the strategic missions adopted by the country. Another essential factor is the improvement of strategies that lead to joint research and development processes between universities and businesses, which in many cases, should be mediated by the intermediary centers and institutes. In order to instill greater trust among the system's actors, the Mission proposes complementary policies such as the creation of knowledge-based companies, the linking up of experienced researchers with the productive sector, the establishment of internships in companies as part of university curricula, and for undergraduate and graduate students to conduct research within companies. Social knowledge appropriation strategies will be focused on disseminating new scientific and technological developments, in order to promote the adoption of recent innovations and the active participation of different social groups in innovation processes.

An interconnected network of institutions needs to be consolidated in order to respond to the needs, demands and aspirations of students, their families, the State, and the productive sector. University-business-State programs that co-finance roadmaps with collaborative participation of universities, research centers and companies to promote mission-oriented innovation and research in different parts of the country will serve as an incentive to processes taking place in the territories.

Finally, communication channels will be created between policy makers, investors in new businesses and different social actors in order to consolidate initiatives and identify potential innovations that can be quickly disseminated to the rest of society.

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Universities in the National System of Science, Technology and Innovation

Universities around the world and in Colombia have played a fundamental role in the development of STI, and the Mission of Experts maintains that Colombian universities will continue to play this dominant role in the future. In the past, their leading role has been due to a relative weakness of other areas of knowledge generation in our system, but in the future they will undoubtedly have to engage in active conversation with research centers and institutes, think tanks, study groups, and diverse and heterogeneous organizations that will participate in the system. The university is one of the great legacies of the Middle Ages. It was born as a social institution in which those who want to learn and those who are willing to share their knowledge gather to impart, receive, research, and create new knowledge. Over the last two centuries, this role as a producer of knowledge and as an agent that directly supports the solution of the population's problems has acquired great relevance, giving rise to the research university, in which teaching is integrated with research, opening new horizons for the student. The university went from being an institution for a few intellectual elites to a democratic, open institution that serves the majority and promotes equity and social mobility.

Today, universities have an important influence on social life, since they promote knowledge building, autonomous discourse, democracy, and freedom. Universities take on many roles: the humanist, the manager, the protagonist, and they participate in education, social and economic development, and scientific, cultural and human progress in society.

In Colombia, the evolution of the university has trodden a similar path. It is a non-profit institution by law, regardless of whether it is public or private. Higher education is a public service according to the Constitution, and in Colombia, public and private systems are similar in size and, to a great extent, face similar challenges and problems. In the future, and with a view to achieving 80% coverage by 2030—the goal for the current Ten-Year

Education Plan—efforts must be coordinated and additive. Likewise, there is no doubt that in the accelerated development of science and technology they will play an increasingly important role in the educational process, while at the same time they will not be able to abstain from their role as producers of knowledge through research and creation.

The following figures reveal the current importance of universities in the country:

According to the National Information System in Higher Education (SNIES), in 2018, the population of graduates at all levels of higher education grew by 340% between 2001 and 2018 (from 138,658 graduates to 482,122); while, according to DANE, the country's population did not grow beyond 120%. This is a fact of great relevance not only because of the growth of the critical mass capable of producing knowledge and using it in favor of development, but also because it is one of the most significant strategies for the population's socioeconomic advancement.

Academic databases show that universities produce more than 95% of scientific publications and an even higher proportion of approved patents. They host more than 90% of people with doctorates trained in and outside of the country and 87% of the country's research groups, two concentration indicators that should diminish in the future.

Data from the indicators of the *Red Iberoamericana de Ciencia y Tecnología* show that nearly 20% of the total investment in research and development in Colombia comes from higher education institution resources, making it the second most important source in the country.

Universities in Colombia mainly contribute to research in the fields of social sciences, humanities, and artistic and cultural creation; for example, to history, anthropology, economics, psychology, pedagogy, literature, music and art. Thus, their support for research and artistic and cultural creation is broad and significant, and is not limited exclusively to the "hard sciences" and technology.

The university is a great center of knowledge production and transmission and is the epicenter from which knowledge spreads throughout society. The Mission has placed great emphasis on the future development of joint business and university endeavors that contribute to society through the transfer and use of knowledge, and we must emphasize that the country's internationalization of knowledge production has linked it to diverse and important scientific networks.

Universities are therefore called upon to continue to promote the development of science, to pose the questions that society needs answered, and to work on finding the answers to them. STI systems are inconceivable without university platforms, regardless of their original purposes. Therefore, universities must contribute to the improvement of autonomous centers in order to consolidate a general system of science and technology that transfers knowledge to society, and ensure the training of the talent needed by the country's research ecosystem.

Based on the recognition of universities' missions, their role cuts across science, technology and innovation processes. The interaction of universities with the STI system occurs at different stages of science and technology: from basic science, through applied research and technological development, to the development of prototypes. At present, it is common for universities around the world to found companies with a high scientific and technological content, which end up in a virtuous circle, strengthening the university itself.

Indicators show that the basic and applied science stages depend largely on the knowledge produced in universities, by researchers and their research groups or the various different structures in which they are organized. In the stage where activities are focused on the reproducibility of results at experimental or laboratory level, the role of universities is key. Universities can act as part of a network in which the human resources and the most advanced instrumental and analytical techniques are made available, to apply the knowledge produced from the conceptualization of technologies or the solution of problems in context. In the final stages, characterized by processes of innovation and transfer, they are also, in many parts of the world, transforming the way they work. In this case, the multiple enterprises created by universities are spin-off and start-up companies, and can form a virtuous cycle of knowledge production, its application, the technologies created, and their application. At these levels of high capitalization, the injection of private resources is vital, for example, from private funds of medium or low risk capital, which essentially allow the scaling and massification of technologies.

To project the future role of the university, the Mission suggests that first and foremost, universities need to improve their role in knowledge production, and this necessarily implies the need to diversify the sources of financing in the STI system, including the private sector and banking.

We must also consider that the research carried out by universities does not only apply to the field of basic and applied sciences, but also to the human sciences and artistic and cultural creation, areas of knowledge that also require that their funding be reconfigured, as well as new and larger sources of funding. Given the changes that are occurring around the world, the primary role of universities in the creation of new and autonomous knowledge must prevail and be preserved and strengthened. The institution that will be able to humanize and maintain a critical and ethical view of the dizzying scientific and technological advances of the years to come is, without a doubt, the university.

The Mission also made the following recommendations:

Adopt the methodologies of both curiosity-oriented and mission-oriented research, working from a challenge-based approach, with the participation of multiple actors through interdisciplinary and intersectoral academic articulation.

A large proportion of the existing centers needs to be transformed and improved in order to ensure greater access to scientific and technological infrastructure and services for the various actors of the STI system.

Students must learn (the badly named) '*soft*' and *'hard'* skills – in order for them to avoid becoming obsolete in the face of technological change – and this will be a crucial task for the entire education system. At the same time, competencies such as digital and data literacy, computational thinking, science, technology, engineering, arts and design (STEAMD) skills and effective communication in a second language must become essential to effectively contribute to individuals' – and the country's – development.

Educating in classrooms and training on campus should be guided by the universities' cultural practice and artistic creation, enriching and making an indelible impression on its students. Failure to do so impoverishes the idea of university and could see the concepts of culture and university senselessly divided to its detriment.

Finally, the advocacy, impacts and advances of science in the country must be studied and analyzed on an ongoing basis. Despite this being the university's longstanding mission, this critical position must be reinforced in the face of the implications and impact that scientific development has on other areas of national life.

General open data policy

Part of the comprehensive economic development of nations is due, to a great extent, to the recognition of data as an important element in creating added social and economic value. *Open science, with an emphasis on open data,* would increase the SNCTI's and the State's ability to respond to emerging problems (e.g., climate change, disasters, diseases, or epidemics) and would provide added value to investments made with public resources. The purpose of this initiative is to establish conditions to guarantee the universality of knowledge with an emphasis on open raw data. Open data should be seen as a social and economic asset, especially when used to meet the needs of society and for scientific research. Research with public resources will be conducted using an open data approach. Commercial exploitation should only be permitted under the condition that data remain in the public domain. Likewise, in the case of data protected as intellectual property, or if such data are integrated to databases that are not free of charge, conditions of access to both such data and the products derived from them must be established in the public interest through mechanisms to promote their use under equitable conditions and to raise funds proportional to the benefit derived from access, which should be granted to the public. These funds will be used to develop storage and processing capacities, such as data repositories or data articles, or to enhance national research and development networks. An objective of this policy should also encompass ethics in data management. Storing primary research data for ten years is a practice developed in many countries and should be adopted.

The principles of the policy are as follows:

Digital identifiers. The Open Science/Open Data movement promotes as good practice the publication of raw data with an identifier of the researcher and technician, a repository and indexed data article, both with a digital identifier, or as a supplement in a full publication (which would leave out the data article, but does not exclude it if it is also produced; see Figure 7).

Inter-operational open repositories. Raw data—produced in all sectors by public entities or in the course of publicly funded projects—should be archived according to an international standard, and should be formatted properly and use the existing network of repositories interoperatively. The system would require an advanced network with connectivity to advanced Latin American, transoceanic networks, with sufficient storage and processing capacity with access to Eduroam. As well as being interoperable, the repositories need to be redundant, public, with no access restrictions, and be operated under the same nationwide standards and rules.

Promotion of data articles. A data article, as well as indicating the repository where the data are located, should be peer reviewed and published in an indexed journal as proof of the scientific rigor with

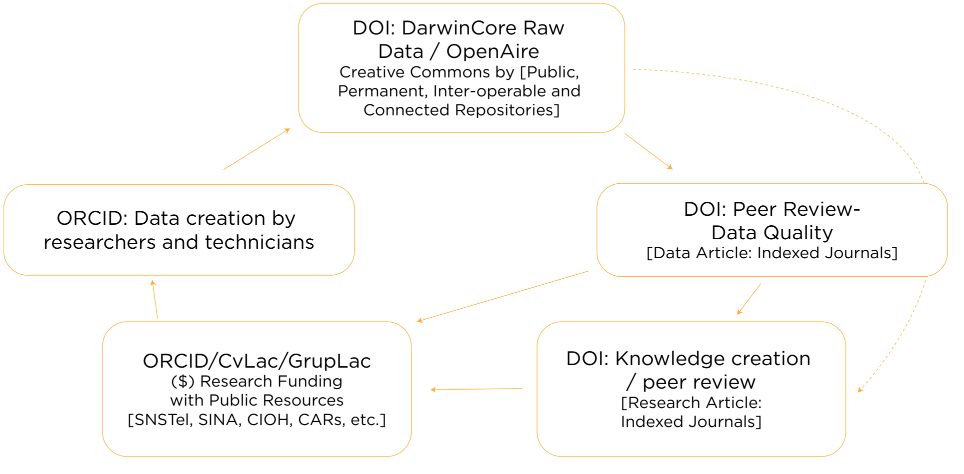

Figure 7. Diagram of the cycle for generating open data for open science, a product financed with public resources and its digital identifiers.
Research institutes, autonomous STI centers, and other interfaces

which the data was collected. The publication of these data in an article is the endorsement of the quality of the data contained, which is of great importance when they are collected by public entities or in the course of projects financed with public resources. This type of article does not require analysis or transformation of the data, but only that they be deposited in their raw format and duly labeled, including the methodological aspects of their collection within the standards of the working disciplines. That is, the data is deposited in a public repository and the data article is the metadata that includes a description and a statement of its possible use, the details of its collection, and should give credit and name authors.

Policy for research centers and institutes

The Mission of Experts 2019 has found that the policy for supporting research centers and institutes has been very weak in Colombia. Often, in many countries, leading universities create centers to support transdisciplinary activity and communication with companies and social organizations. Colombia has an important tradition in the development of centers and institutes, with positive experiences, but also with evidence of impediments to their smooth operation (e.g., in testimonies and file reviews). Many of these institutes are in a precarious financial situation, with some of the emblematic ones having disappeared (undoubtedly today they would be of high priority) and others have fallen short in the execution of their mission or this has been modified by circumstantial situations.

In this document, the Mission has decided to conduct a brief analysis of the international and national background in order to propose a policy for the different types of institutions that today are included in the definition of centers and institutes. It will also discuss the definitions adopted by *Colciencias* and the initiatives that have been implemented to promote and support them. The Mission proposes one main policy, but with diverse initiatives that fit the different institutions and strategies. Institutional heterogeneity is not a problem, on the contrary, it is a sign of agility and versatility in the response to challenges that require prompt action in a globalized and highly competitive world. Support must be adapted to fit the institutions and not—as is largely the case today—forced to meet previously assigned definitions and sometimes without sufficient demonstrations or experience.

International Background

A look at how various countries have developed their science and technology to achieve remarkable things reveals great heterogeneity in terms of strategies and in the type of centers and institutes established. In some countries, they have obeyed a centralized policy and have received significant national and local funding, while in others they have been left to develop spontaneously, depending on the demands of society (companies and various social organizations), but with support that is generally defined through competitive calls for proposals. Below we present some of the cases that constitute illustrative examples of this, although there are many more that could support these arguments.

The United States: National Laboratories

A result of an immense investment in scientific research initiated by the United States Government during World War II, the National Laboratories have served as central institutions for scientific innovation and for addressing cutting-edge strategic issues in the United States for over seventy years. An example of this are the 17 National Laboratories, affiliated with the Department of Energy[8], which address the critical scientific challenges in this field and the complex challenges of large-scale research and development with a multidisciplinary approach, emphasizing the transformation of basic science into innovation. It is important to note that these represent just one of many endeavors; the scientific community in the United States has been characterized as having diverse institutional arrangements, some transdisciplinary, others involving multiple economic and social actors.

Table 2. National Laboratories Affiliated with the Department of Energy, United States[9]

Laboratory name	Areas worked on
Ames	Synthesis and study of new materials, energy resources, high-speed computer design, environmental cleanup and restoration. Located on the campus of Iowa State University.

8 See https://www.energy.gov/national-laboratories

9 This is presented as an example; other centers and institutes

Laboratory name	Areas worked on
Argonne	Argonne has five main areas of focus: conducting basic scientific research; operating national scientific facilities; improving the nation's energy resources; developing better ways to manage environmental problems; protecting national security.
Brookhaven	BNL specializes in nuclear and high-energy physics, energy science and technology, environment and bioscience, nanoscience, and homeland security.
Fermilab	Specialized in high-energy particle physics.
Idaho	Nuclear power, national security, energy and environment.
Lawrence Berkeley	Operates five of the largest laboratories in the system: Advanced Light Source, Joint Genome Institute, Molecular Foundry, National Energy Research Scientific Computing Center, Energy Sciences Network.
Lawrence Livermore	Nuclear energy and basic science.
Los Alamos	National security and fundamental science.
National Energy Technology Applied research	for clean energy production and the use of domestic energy resources.
National Renewable Energy	Energy efficiency and renewable energy.
Oak Ridge	Home to the world's largest supercomputing resource (first supercomputer in the top 500 *Summit*), which is used for multiprogram research. Nuclear physics, materials and defense.
Pacific Northwest	Energy, national security and environment.
Princeton Plasma Physics	Plasma physics and applications.
Sandia	National security, nuclear sciences.

of enormous importance in sectors such as health, education, industry, etc. are not mentioned.

Laboratory name	Areas worked on
Savannah River	Environmental remediation, technologies for the hydrogen economy, hazardous materials management and technologies for the prevention of nuclear proliferation.
SLAC National Accelerator	Particle accelerator physics.
Thomas Jefferson National Accelerator Facility	Nuclear physics.
National Institute of Standards and Technology (NIST)	Its mission is to promote innovation and industrial competitiveness. It focuses on laboratory programs that include science and nanotechnology, engineering, information technology, quantum physics research and precision measurements including atomic clocks. It has won five Nobel Prizes in physics and chemistry since 1997.

In addition to the above, there are other centers of great importance, such as the Smithsonian and the National Botanical Gardens, among others.

Brazil: Research Units

The Brazilian Ministry of Science, Technology, Innovation and Communications has created 16 Research Units, which are responsible for the production, application and dissemination of knowledge, as well as technological development and the promotion of innovation in their respective areas of activity[10]. These units are monitored and evaluated based on their respective Management Commitment Terms (TCG), an instrument of mutual agreement between the MSTIC and the Research Unit.

10 See http://www.mctic.gov.br/mctic/opencms/institucional/paginas/Estrutura_Organizacional.html

Table 3. Research Units, Brazil

Laboratory name	Areas worked on
Centro de Tecnologia da Informação Renato Archer (CTI)	Microelectronics, electronic components, systems, information displays, software, IT applications, robotics, machine vision, 3D printing technologies for industry and medicine, and decision support software.
Centro Brasileiro de Pesquisas Físicas (CBPF)	Research in high-energy, experimental, theoretical and applied physics, cosmology and relativistic astrophysics; scientific training; scientific instrumentation; information and computer technologies.
Centro de Tecnologia Mineral (CETEM)	Characterization of materials, mineral technologies, mineral processing, extractive metallurgy and biotechnological processes, environmental technologies, sustainability of mineral industry, production of reference material certificates.
Centro de Tecnologias Estratégicas do Nordeste (CETENE)	Biotechnology, Nanotechnology, Microelectronics.
Centro Nacional de Monitoramento e Alertas de Desastres Naturais (CEMADEN)	Monitoring and issuance of natural disaster warnings, development of scientific, technological and innovation capabilities to continuously improve natural disaster warnings.
Instituto Nacional de Pesquisas da Amazônia (INPA)	Biodiversity, environmental dynamics, technology and innovation, society and environment.
National Institute for Space Research (INPE)	Space and atmospheric sciences, weather forecasting and climate studies, Earth observation, earth systems science, space engineering and technology, satellite tracking and control, satellite integration and testing, activities associated with satellite sensors and materials, plasma, computation and applied mathematics, combustion and propulsion.

Laboratory name	Areas worked on
Instituto Nacional de Tecnologia (INT)	Technological development in industrial design, materials and product testing, analytical chemistry and materials processing and characterization; applied technologies in catalysis and chemical processes, corrosion and degradation, energy, and evaluation and production engineering; innovation technology; product certification.
Instituto Nacional do Semiárido (INSA)	Biodiversity and sustainable consumption; production systems; water resources; desertification.
Instituto Nacional da Mata Atlântica (INMA)	Biodiversity knowledge; conservation and sustainable consumption; biological collections; education and dissemination.
Instituto Brasileiro de Informação em Ciência e Tecnologia (IBICT)	Information science; scientific communication and dissemination; free access to scientific and technological information; transfer of information technologies; information inclusion and social innovation.
Laboratório Nacional de Astrofísica (LNA)	Management and operation of astronomical observation infrastructure; technological development in astronomical instrumentation; research, teaching and extension in astrophysics; development and availability of astronomical databases.
Laboratório Nacional de Computação Cientifica (LNCC)	Computer-aided medicine technology; computational modeling in petroleum reservoirs, groundwater and CO2 capture; rock fracture modeling; molecular modeling; bioinformatics; molecular model processing; reservoir simulation and management; advanced visualization, participant in the Brazilian technology system (Sibratec).

Laboratory name	Areas worked on
Museu de Astronomia e Ciências Afins (MAST)	History of science and technology in Brazil; social development of science; science popularization and education in non-formal spaces; scientific dissemination for social inclusion; preservation of Brazilian scientists' historical collections, institutions and scientific instruments; archive of Brazilian scientific culture.
Museu Paraense Emilio Goeldi (MPEG)	Biodiversity - biogeography, zoological and botanical systematics; inventory; Amazonian ecosystems - structure, dynamics and conservation; monitoring and management of natural resources; sociodiversity and sociocultural dynamics: anthropology of Amazonian societies, ethnobiology, ethnoecology and ethnomuseology, prehistoric and historical archaeology of Amazonia, indigenous linguistics of Amazonia; land use and land use planning; biotechnology and innovation - innovation and technology transfer, intellectual property and knowledge protection.
Observatório Nacional (ON)	Astronomy and astrophysics; geophysics; time and frequency domain.

France: Institutes

The laboratories of the *Centre National de la Recherche Scientifique* (CNRS) are the "basic building blocks" of the system[11]. Their teams, made up of researchers, engineers and technicians, are the foundation of knowledge production and transmission. The laboratories are mostly mixed research units, with partners from academia (universities, schools, and other research organizations) and industry. The CNRS has more than 1100 laboratories throughout France, forming the local scientific landscape. As well as these laboratories, there are also 37 international mixed units (IMU), a number that has increased considerably since 2010.

11 See http://www.cnrs.fr/fr/le-cnrs#rubric-11

Table 4. Institutes - France

Laboratory name	Areas worked on
Institut des sciences biologiques (INSB)	Bioengineering, biochemistry-structural biology, cell biology, plant biology, development, evolution, genetics, genomics, immunology, infectious diseases, microbiology, neuroscience, cognition, pharmacology and imaging, physiology and cancer.
Institut de chimie (INC)	Chemistry of and for life (exploration and development of new models and tools for pharmacology, biotechnology, medicine, cosmetology, agri-food and phytosanitation). Green chemistry and sustainable, more selective, and safer development. Functionalization of matter (development and control of the properties of materials, particularly for energy, development of nanochemistry).
Institut écologie et environnement (INEE)	Ecology and eco-sciences, biodiversity, impact of global changes, health-environment, resources, ecological and environmental chemistry.
Institut des sciences humaines et sociales (INSHS)	Cultures and societies in history, humankind, societies and the environment, behavior, cognition and communication, contemporary worlds.
Institut des sciences de l'ingénierie et des systèmes (INSIS)	Automation science and technology, electronic and photonic signals and systems, mechanical, energy and process sciences and technologies.
Institut national des sciences mathématiques et de leurs interactions (INSMI)	The different areas of mathematics, mathematical modeling and simulations, interaction with other scientific disciplines, interaction with business and society.
Institut de physique (INP)	Theoretical physics, modeling and numerical simulation, optics, atoms, molecules and quantum physics: fundamentals and applications, condensed matter, materials, nanosciences, states of matter, phase transitions, instabilities, disorder, lasers and plasmas, physics around life.

Laboratory name	Areas worked on
Institut des sciences de l'information et de leurs interactions (INS2I)	Informatics and digital research. One of its main objectives is to position these, with the information sciences, at the heart of multidisciplinary and interdisciplinary issues, based, among other things, on its partnership with INSIS and the interdisciplinary tools of the CNRS.
Institut national de physique nucléaire et de physique des particules (IN2P3)	Particle physics, quark-gluon plasma and hadronic physics, nuclear physics and astrophysics, astroparticle physics, neutrino physics and astrophysics, accelerator research and development, grid computing and data science, nuclear applications in health, energy and environment.
Institut national des sciences de l'Univers (INSU)	Ocean, geography, geology, geophysics, climatology, hydrology, volcanology, seismology, environment, planetology, astronomy, astrophysics.
Institut national de recherche en sciences du numérique (INRIA)	Applied mathematics, computing and simulation, algorithms, programming, software and architectures, networks, systems and services, distributed computing, perception, cognition, interaction, digital health, biology and planet.

Spain: Singular Scientific and Technical Infrastructures (ICTS)

The term Singular Scientific and Technical Infrastructure (ICTS) refers to facilities, resources or services needed to develop cutting-edge research of the highest quality, and for the transfer, exchange and preservation of knowledge, technology transfer, and to promote innovation[12].

12 See http://www.ciencia.gob.es/portal/site/MICINN/menuitem eed4570ef37d2c8fbaa777b9026041a0/?vgnextoid=928d5e f3677c4610VgnVCM1000001d04140aRCRD

Table 5. Singular Scientific and Technical Infrastructure (ICTS), Spain

Laboratory name	Areas worked on
Red Académica y de Investigación Española (RedIRIS)	Information and Communications Technology
Red Española de Supercomputación (RES)	Information and Communications Technology
Red Distribuida de Imagen Biomédica (ReDIB)	Health Sciences and Biotechnology
Red de Laboratorios de Alta Seguridad Biológica (RLASB)	Health Sciences and Biotechnology
Red de Laboratorios de Resonancia Magnética Nuclear de Biomoléculas (R-LRB)	Health Sciences and Biotechnology
Infraestructura de Tecnologías Ómicas (IOT)	Health Sciences and Biotechnology
Infraestructura Integrada de Producción y Caracterización de Nanomateriales, Biomateriales y Sistemas en Biomedicina (NANBIOSIS)	Health Sciences and Biotechnology
Laboratorio Nacional de Fusión (LNF)	Energy
Plataforma Solar de Almería (PSA)	Energy
Centro Nacional de Aceleradores (CNA)	Materials
Centro de Láseres Pulsados Ultracortos Ultraintensos (UPLC)	Materials
Infraestructura integrada de microscopía electrónica de materiales of Materials (ELECMI)	Materials
Red de Salas Blancas de Micro y Nanofabricación (MICRONANOFABS)	Materials
Sincrotrón ALBA	Materials
Bases Antárticas Españolas (BAEs)	Marine, Life and Earth Sciences
Sistema de Observación Costero de las Illes Balears (SOCIB)	Marine, Life and Earth Sciences
Reserva Biológica de Doñana (RBD)	Marine, Life and Earth Sciences
Plataforma Oceánica de Canarias (PLOCAN)	Marine, Life and Earth Sciences

Laboratory name	Areas worked on
Flota Ocenográfica Española	Marine, Life and Earth Sciences
Infraestructura para el cultivo del Atún rojo (ICAR)	Marine, Life and Earth Sciences
Centro Nacional de Investigación sobre la Evolución Humana (CENIEH)	Socioeconomic Sciences and Humanities
Gran Telescopio de Canarias (GTC)	Astronomy and astrophysics
Observatorio astronómico de Calar Alto (CAHA)	Astronomy and astrophysics
Laboratorio Subterráneo de Canfranc (LSC)	Astronomy and astrophysics

National Background

Colombia has a longstanding history of creating centers and institutes. Some developments began at the same time as the country's scientific activity. Policies were defined in different stages, either explicitly in Conpes documents or in internal documents published by *Colciencias*, the National Planning Department, and the National Council of Science and Technology, or implicitly in the calls for proposals and in the *Colciencias* classification and evaluation systems. However, one of the problems has been the frequency of policy changes and the discontinuities that often occurred before policy strategies and recommendations had been consolidated. Another serious problem has been that in the priority-setting process (also discontinued), part of the national effort is passed from one prioritization system to the next, causing exclusions that are more circumstantial than strategic in the long term and can make human and institutional capital crucial (some concrete examples will be given below).

Without intending to conduct a rigorous historical study, below we outline the different periods of development of the centers and institutes, highlighting some of the important moments in their relationship with the national scientific policy of the time.

The National Institutes

Several national institutes were created in different areas of knowledge during the government of President Carlos Lleras Restrepo. They brought together – sometimes very longstanding – institutions that had similar and complementary functions and that corresponded at least partially with those of the new institute. What was common to all of them was their overriding task of contributing scientific research, knowledge, and technological developments to promote social development. They were autonomous institutes on a national level and attached to ministries. Their autonomy was reflected in their independent budgets within the national budget (not as part of a ministry) and their own management bodies, in which there was ministry representation, but which functioned independently. The director was appointed directly by the President and enjoyed (at least in theory) independence in appointing their staff. All these institutions were provided with their own facilities, sufficient staff (scientific, technical and administrative) and state-of-the-art laboratories. *Colciencias* was created institutionally as a result of this same restructuring of the State.

It is important to insist that the explicit purpose was to create research institutions in the various areas, although over time this character was blurred to make them more dependent on the respective ministries, sometimes as operational units of programs which were not necessarily scientific; some even became commercial or social enterprises of the State. The following institutes are worth mentioning because their experience also allows us to understand possible current needs.

Instituto Colombiano Agropecuario (ICA) In 1962, a corporation with the same name was created, which brought together much of the agricultural research capacity that existed in the country in universities and schools. In 1963, it was given the status of a decentralized public institution and began to host various earlier initiatives and scattered institutions. Its most important reorganization took place in 1968, when it took on multiple research and health functions and its budget was significantly increased. By then it was already a very large institute, as it had inherited 19 diagnostic centers from the former *Instituto Zooprolfiláctico*, 52 "extension" agencies that provided technical and scientific advice, eight regional management bodies, and 30 national programs and experimental centers from across the country. In a public-private partnership, the production section of the *Instituto Zooprolfiláctico* became the *Vecol* veterinary input production company.

Despite the fact that ICA had one of the highest academic levels in the country, the research function was weakened to some extent by limitations inherent in public administration. In 1993, a public-private corporation, *Corpoica*, was created, to which the main research centers were attached. The corporation was managed privately, but at various times it was close to a crisis due to a lack of resources, which it received only from projects, services and contracts. This was resolved 25 years later when by law it was given an operating and investment budget included in the general budget of the Nation and became *Agrosavia*, which also works through private contracting, but has its own budget base.

Instituto Nacional de la Salud (INS). The Samper Martínez Laboratory was founded in 1917. It was a private initiative started by two doctors from Bogotá as a result of health problems in their families that could not be solved in the country due to the lack of up-to-date knowledge and technology. In 1928, the State bought it and turned it into a public institution, the Samper Martínez National Hygiene Laboratory. Other initiatives were being developed in the health field, especially in relation to tropical, infectious and immunopreventable diseases. These included the Vaccination Park that produced the smallpox vaccine, the Carlos Finlay Institute that studied yellow fever and produced the corresponding vaccine, and several State laboratories such as the laboratory producing BCG anti-tuberculosis vaccine or the medicine control laboratory. In 1968 they reorganized, built their headquarters, added technical branches of the ministry that were responsible for morbidity statistics, epidemiological control, and rural water programs. It was constituted initially as the National Institute of Special Health Programs (Inpes), which shortly thereafter became the National Institute of Health (INS).

All of its functions required high levels of knowledge. These were basically research, production of complex biological material, highly specialized diagnostics, quality control of food and drugs, and construction of rural aqueducts among others. The INS, as well as the previous Samper Martínez, enjoyed great recognition across Latin America and the Caribbean. Gradually, it became more dependent on the Ministry, both in its management and in the decisions of its programs, which have often been operational and supportive of the Ministry's work; more programs of control and surveillance than of research.

Instituto de Investigaciones Geológico Mineras (Ingeominas), today the Colombian Geological Service. In 1916, the "National Scientific Commission" was created to map the country's geology and to explore its mining resources and study its subsoil. Other related organizations began to operate in the country, among them the Metallurgical Plant of Medellín and the Laboratories of Mining Promotion of Pasto and Ibagué, which were annexed in the 1950s. The National Chemical Laboratory was created in 1928 and was also annexed during the great restructuring of State agencies in 1968, as well as the "mining inventory." It acquired other related functions over time, including those left by the Institute of Nuclear Affairs (IAN), later the National Institute of Alternative Energy (INEA), which was closed in the late nineties. In 1968, this institute was also constituted as a large institute with functions based on scientific research and knowledge, with State and central funding, but with a presence through its branches in many parts of the country. It is also important to point out a relative increase in functions of an operational nature. The disappearance of the INEA is one of the hard-to-believe paradoxes of the Colombian Science and Technology system (to be discussed later), as is the reduction of the National Chemical Laboratory from a research institution to a lower-level unit dedicated to routine analysis services to near insignificance.

Instituto Nacional de Cancerología (INC). The idea of a specialized cancer institute was put forward by French professor Claude Regaud in a conference held in Bogotá in November 1928. The then Minister of Public Instruction presented the Congress of the Republic of Colombia the proposal to create the National Institute of Radium, as part of *Universidad Nacional*. In 1951, it became the National Institute of Cancerology, a specialized national entity attached to the Ministry of Health. From that moment it enjoyed more or less continuous development until it became a State Social Enterprise, but with scope for scientific research and technological development, although mainly functioning as a hospital institution. This is a slightly different case from the previous ones, but it does share the fact that it has been State funded, attached to the Health Ministry, with great initial autonomy and a transformation to becoming a fundamentally service-oriented entity.

National Department of Statistics (Departamento Administrativo Nacional de Estadística - DANE) In October 1951, the National Statistics Office was separated from the General Comptroller of the Republic and a National Statistics Directorate was created as a direct dependency of the Presidency of the Republic. In 1953, under the government of General Gustavo Rojas Pinilla, DANE was created and reorganized in 1968 under the presidency of Carlos Lleras Restrepo. Later on, functions were added, among others, to the *Instituto Agustín Codazzi*, which in addition to cartography and soil studies is responsible for the cadaster. Although this is not a decentralized institute like the others, but an administrative department, it serves as an example because it is also a huge effort, financed by the State, that concentrates on the production of information and knowledge for good governance.

These are just a few examples from the much wider universe of Institutes, as well as that of units specifically dedicated to research within State institutions; one example was the unit for nutritional studies that existed in the Colombian Institute of Family Wellbeing, and which disappeared in the course of history.

Environmental System Institutes

With the creation of the Ministry of the Environment in 1994, a network of attached research institutes was also created. These were the Institute of Meteorological and Environmental Research (IDEAM), the Humboldt Institute, the Amazon Research Institute (Sinchi), and Pacific Environmental Research (IIAP). The Institute of Marine and Coastal Research (Invemar)—previously dependent on *Colciencias*—was incorporated later.

This network of institutes had their own operating and investment budgets (for research) from the beginning, as well as good infrastructure and specialized staff, allowing its continuous and successful operation over the last 25 years.

The National Centers for Sectorial Research (Cenis)

The Cenis are research and innovation centers financed mostly by the private sector and aimed at productive agricultural activity. In effect, although their financing has been defined as private because they are managed by an economic guild, strictly speaking they are a public-private hybrid, since their financing comes largely from specific parafiscal taxes, defined for the beneficiary sector. However, sector management stipulates the direction of research and creates mechanisms for the direct transfer of its results.

Historically, these were created because of agricultural producers' associations' awareness of the importance of research and innovation. The National Coffee Research Center (Cenicafé) was born in 1938, the Forestry Center in 1974, the Sugar Cane Center in 1977, the Banana Center in 1985, the African Palm Center in 1991, the Shrimp Center in 1994, and the Potato Center in 1999.

Its research is mainly applied to and directed at immediate solutions to problems in the sector (although Cenicafé has examples of important basic research), and to the distribution of innovations that increase productivity and product quality. It is an instrument through which the guilds can tackle the challenges and opportunities of the trade opening on which the country embarked at the beginning of the last decade and the free trade agreements. They have infrastructure, personnel, budgets and scopes of different sizes depending on the guild's strength of economic activity. In general, they have been successful because of the close relationship between financing, management and the main users. On some occasions, however, their operation has been disrupted by changes in the policy of the guild's directors or by financial constraints arising from the market.

The autonomous centers

Although they have been called this for many years, and today there is a great list of centers recognized by *Colciencias* with this denomination, they are actually different from each other and emerged due to diverse circumstances, mainly through the will of pioneering researchers highly committed to the country's development. Below is a list of the main cases that exemplify this.

Invemar was created in 1963 by three professors from the Justus Liebig University of Giessen in Germany, who arrived as guests of the Andean Union and decided to create a Tropical Research Institute in Punta Betín, Santa Marta. In 1967, and with donations from the Volkswagen Foundation, it was consolidated as the Colombo German Research Institute; in 1974 it defined its vocation as a marine institute and was directly sponsored by *Colciencias*, which was given the task of defining its vision and mission (which it only did in 1992). In 1993, it became part of the network of environmental institutes of the Ministry of Environment, becoming a public institute with a national budget, although much of its activities are made possible by way of national and international grants. It has strong relationships with universities and the national navy, institutions that have collaboratively built a multidisciplinary and multi-institutional PhD program in marine sciences. At this time, it has joined the system of institutes attached to the Ministry of Environment which gives it great financial strength.

Cideim originated from the cooperation between Tulane University in New Orleans and Universidad del Valle for the study of tropical diseases. In 1975, the program at Universidad del Valle ended abruptly and Cideim continued as a direct alliance between Tulane University and *Colciencias*, which provided funding for its operation until 1985 when it was established as a non-profit foundation with the help of the WHO and *Colciencias*. In 1994, *Colciencias*, as an equity contribution, provided it with the buildings in which it worked. It is supported exclusively by national and international grants. In 2008, it began an alliance with *Universidad ICESI* in Cali and moved to one of its buildings where it currently operates.

CIB is a private non-profit corporation founded by professors who left *Universidad de Antioquia* in 1970. Its focus is on basic, clinical, and biotechnological research, initially in tropical diseases but extending into agriculture and industry. Its financing depends on projects, editorial activity, donations and medical services in its region of influence (mainly Antioquia and Chocó). Recently, and as a result of a financial crisis, it has established alliances with *Universidad de Antioquia*, *Universidad Nacional*, *Universidad Pontificia Bolivariana*, UDES (*Universidad de Santander*), and *Colegio Mayor de Antioquia*, which cover most of its researchers' salaries.

Fedesarrollo is a private non-profit foundation founded in 1970 to conduct research on social and economic policies. Its research is financed by public, private, and multilateral entities through contracts and projects and it tries to maintain a balance between sources of funding in order to preserve its independence and autonomy.

CIF – the International Center for Physics– was founded in 1985 with the support of the Third World Academy of Sciences TWAS (today "The World Academy of Sciences") and the Trieste Center for Physics. It operates at *Universidad Nacional* and many of its researchers are professors there. It conducts research in basic and applied physics, but has expanded its fields to biotechnology and biophysics. As well as being supported by *Universidad Nacional*, it also depends on grants and resources obtained by technology transfer, and consulting and technological developments of a commercial nature.

ICIPC – the Institute for Training and Research in Plastics and Rubber – was created in 1987 as a private non-profit entity aimed at meeting the innovation needs of the plastics, rubber and related sectors and to conduct research and experimental development in the field of natural sciences and engineering (ISIC 7210). Its research is financed by public, private or mixed entities through contracts, projects and the provision of high value-added technological services at national and international levels. Despite the fact that it was created over 25 years ago with the support of an industrial guild, it still has a smaller number of doctoral level researchers than the previous examples.

National policy developments for research centers and institutions

Concern about the role that centers and institutes should play in the country's scientific development is not new, and it is therefore important to mention some milestones of the last 25 years relating to this because they will help to explain the errors made and to propose a more informed policy.

Recommendation of the Science, Education and Development Mission, 1993-1994. This Mission initially stated the importance of the organizations within the science and technology system (Misión de Ciencia Educación y Desarrollo, 1996): "Knowledge, science and technology are almost always produced, disseminated and used in organizations such as universities, research centers, technological institutes and other educational institutions, and increasingly in companies." Among the recommendations made to the government, there are some that are especially relevant for the centers:

> To consolidate the institutional base of science and technology, support should be given to strengthening existing research groups, creating new groups, and establishing research institutes and sectoral technology development centers, promoting the natural sciences, social and human sciences, formal sciences, and applied sciences alike.

National Policy on Science and Technology 1994-1998. This document contained important pronouncements on the centers and institutes and the role they should play, and it proposed strategies, goals, actions and instruments which would have been very beneficial (and had they been carried out, the present document of proposals would surely be very different) (Colciencias-DNP, 1994). Among the strategies proposed, for example,

> Implement an ambitious policy aimed at developing innovation networks that link the productive sector with technology centers; promote decentralization through Regional Programs of Scientific and Technological Development with Regional

Centers of Scientific and Technological Training and Research, Research Institutes and other regional entities and consolidate the centers and research groups working at a level of excellence, and create new centers in the different areas covered by the national and regional programs.

As a measurable goal, it stated: "Guarantee the consolidation and continuity of research centers, and lay the foundations for the creation of 25 new academic centers over the next four years." It also defined actions to be taken and instruments to achieve the objectives. Among these instruments, we could mention the following:

The fundamental institutional instrument will be the Productivity and Technological Development Centers, either of a sectoral or regional nature; business incubators or technological parks, whose primary function is to allow the establishment of new technology-based companies and the establishment of a Co-financing Fund for Innovation and Technical Change, whose purpose will be to finance the Centers of Productivity and Technological Development's technological research programs and projects.

Sectorial centers of technological development (1995). In one of its documents, *Colciencias* draws attention to the need for several types of centers (and the intention to create and promote them) (Colciencias, 1995). The document provides a typology of the centers, defines their possible functions and some financing mechanisms. It defines four types of centers: Sectorial Technology Centers; Regional Centers for Productivity and Business Development; Technology Centers of Public Companies and Technology Centers of Private companies. It also proposes mechanisms for funding, public and private, and parameters for prioritizing and choosing which centers to build.

National Science and Technology Policy 2000-2002. Investment in science and technology fell sharply with the economic crisis of 1997 and in 1998 with the change of government came a reassessment and freeze of ongoing investments. Almost two years after the beginning of the 1998-2002 four-year period, a Conpes document was issued setting out the policy for what remained of the government period (DNP, 2000).

> The proposed strategies were similar to those defined during previous governments, it is important to note that innovation, innovation networks, and the innovation system, have emerged in a more robust way than the research component. The document includes a recommendation, which is interesting here, for the consolidation of technology development centers (CDT) in the following terms: The Technology Development Centers (CDT) will be linked to the real sector of the economy, providing solutions to the country's business modernization needs. The creation, strengthening and support to the CDTs will respond, then, to the needs of the sectors and productive clusters with a greater possibility of building national and international competitive advantages. Their projects should conceptualize and estimate indicators of beneficial environmental impact at biological, physical, social, and economic levels.

However, the instruments to create and promote these centers are missing, especially the necessary funding. In October of the same year, *Colciencias* issued a guide for the operation of CDTs (Colciencias, 2000). This document makes explicit the criteria governing the policy for the new institutional model of CDT. It outlines the characteristics of the CDT as being legally autonomous, but of private or mixed nature and whose activity should focus on improving the competitiveness of the sector and the region in accordance with government plans, in coordination with universities, but for the implementation of business projects.

The centers of excellence 2004. In November 2003, Colciencias proposed that the DNP obtain an external credit to promote various aspects of science, including the creation of "research centers of excellence" (Consejo Nacional de Ciencia y Tecnología , 2004). The document defined them as "A national network of research groups of the highest level, articulated around a common work program in a scientific and technological area considered strategic for the country." At that time, investment was limited to forming networks without their own infrastructure or personnel, taking advantage of existing infrastructure, mainly at the university level. It was an administrative solution involving relatively low investment, which did not result in new centers, but rather nominally organized existing efforts, especially in academic institutions and some of the autonomous centers. Four main criteria were taken into account for the selection of proposals to be financed: a) the existing capacity among the proponents; b) the timeliness of the proposal; c) the quality of the program proposed; and d) the potential sustainability over a period of three to five years. These centers received a one-time budget of $7 million.

The result seen years later was that none of these centers achieved the expected long-term sustainability. A call for proposals similar to the centers of excellence was recently made, entitled Scientific Colombia. Two groups of proposals were accepted, this time there was an important emphasis on doctoral training, but the online scheme is similar and there is some doubt regarding the continuity of the centers as the budgetary allocation is planned as a one-time payout. All these initiatives have been positive as they have allowed projects to be developed, but they were not ultimately able to form longstanding, stable centers.

Proposals for the consolidation of autonomous research centers and Technological Development Centers (CDT), 2007-2010. Several different documents were presented during this period to consolidate and promote the centers, with a very special emphasis on the CDT (Colciencias, 2007). A two-phase model is proposed for the operation of an integrated management system for the centers: First, a stage in which the centers should align with national priorities, consulting the priorities set out in the different STI planning exercises. A second stage comprises a process of allocation according to effectiveness and impact achieved, prioritizing the promotion of CDTs with high effectiveness and impact. Despite the fact that the title includes the research centers, both the criteria and the phases clearly reflect a policy geared towards business competitiveness. Three classes of related centers are defined: the technological development centers (CDT), the technological management centers (CGT) and the regional productivity centers (CRP).

The related documents include proposals for supporting fixed costs and for recognizing significant project overhead. They also define the cost of maintaining 20 to 30 of these institutes until 2012. Unfortunately, these proposals were not implemented either. In 2008, as well as later but sporadically, a number of projects were implemented to provide financial support to the centers that depended exclusively on projects for which not even indirect costs were covered. These projects were very important for the work of these centers, but discontinuity and uncertainty dominated the whole period that followed, up until today. The calls for proposals that followed included a classification system for the centers based on their potentials and their productivity. The predominant fact of this period is that no new centers have been created, some have weakened to the point of disappearance, and others have gone through periodic crises that have required the intervention of other institutions, generally universities, to prevent their disappearance.

At present, Colombia has no clear mechanisms to transfer the achievements of universities or research centers to society, and researchers are expected to go out and look for someone who might be interested in the research they are doing. The centers and institutes – which should be constituted as legally independent entities, bound by private standards – could provide a solution in terms of enabling the flow of knowledge to society. They should be located in different parts of Colombia according to their vocation for development. For example, an energy-related institute may have different branches (wind and solar in La Guajira, clean technologies for the use of fossil resources in Boyacá and Antioquia, etc.)

The institutes must have their own state-of-the-art physical infrastructure and their groups of top-rated researchers. Online institutes cannot be operational in a country that is just beginning to consolidate its research. Furthermore, in order to be attractive for highly qualified scientists from the Colombian diaspora, they must be able to offer special salary regimes. The institutes require high investment and if they are created, their financing by the State must be guaranteed for at least the first 5 to 8 years, during which time they will be teaching in both universities and companies. They should not be made to self-finance from the beginning.

An interesting example is the institute of agriculture in Brazil (Embrapa) that turned Brazil from a food importer into a global exporter. Today, it has about 52 branches in different Brazilian states with a budget of about 1.2 billion dollars, most of which is provided by the State. It has about 2200 PhDs, 3000 MAs, and about 5000 people with BA degrees and technical training in all areas of knowledge.

Two dramatic cases to remember

The record of science, technology and innovation centers and institutes is incomplete without recalling two cases that reveal the very short-term vision in the sector's national policy. The cases are mentioned to illustrate how two entities, that today would be of great importance, were liquidated due mainly to financial inconveniences.

The first case is that of the Institute of Technological Research (IIT), which began operations in Bogotá in the late 1950s as a public-private institution, financed mainly by production guilds. Its task was to carry out research requested by the industry or by agricultural companies to solve their technical and scientific problems. It acquired a good infrastructure of laboratories and an exceptionally well-trained staff for the time. Although it was very efficient and useful for the industry for decades, little investment was made to keep it up to date and at the cutting edge. At the end of 1990, due to the financial situation, the board of directors formed by *Caja Agraria, Banco de la República, Instituto de Fomento Industrial IFI,* and the *Federación Nacional de Cafeteros* decided to liquidate it, instead of injecting resources for its renovation. The building, equipment, library, etc. were sold in parts, and the resources of the liquidation were barely enough to cover the severance pay owed to staff. Paradoxically, this happened at the same time that the country decreed its "economic opening," creating the need to improve its companies' competitiveness.

The second case is that of the Institute of Nuclear Affairs (IAN), later turned into the Institute of Nuclear Sciences and Alternative Energy (INEA). IAN was founded in 1965 and installed the first (and only) Colombian experimental nuclear reactor. In 1993, already with clear awareness of the need to explore and promote fossil-fuel alternatives, it was assigned additional functions and changed its name to INEA. In 1998, in a government that was not clear about the role of science and the need to protect the environment, the institute was closed and its functions divided among other entities. Those who had received the nuclear reactor became very uncomfortable with it, and the research operation actually disappeared. The reasons for the liquidation were the institute's inefficient operation and obsolescence of its equipment. Again, due to very limited vision, instead of deciding to invest and update it so that it would be able to fulfill its important missions, the Institute was closed down.

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Summary of problems identified in policies for science, technology and innovation centers and institutes

Based on the above discussion and consultations with community members, several problems can be identified that have prevented the adequate development of centers and institutes and have interfered with the productive operations of many of the existing ones. A brief outline of these problems is presented here, because they are the ones that must be addressed by a national policy such as the one being proposed.

It is not true that in Colombia there have never been policies for STI centers and institutes; the problem is that they have been continuously changed and none have been fully realized. Although they have been outlined several times in Conpes documents – the policy instruments of top government –, they have (generally) not been carried out due to a lack of resources. For example, the recommendations made by the Mission of Experts 25 years ago were collected in a Conpes document, but as we know, they were never implemented.

Several programs have been implemented to support the centers, mainly autonomous ones, but they have depended on the *Colciencias* administrations of the period, their terms have changed, as have the amounts assigned to them and their demands. For example, the guidelines for the current program require a new rating for centers whereby they must host at least one A1-rated research group for the current year and three for the following year. This means that if a center independently decides to function as a group the following year, it will no longer be classified as a center because even if it splits into two, it could not have any A1 groups because these must have existed for at least five years. This is just one example of the problem of the support policies' discontinuity.

Discontinuity has been seen in other calls for funding. At one point, the emphasis was placed on autonomous centers, at another, on technological development centers (which in another policy were also divided into three classes). There were two different calls for centers of excellence (both wanted networks to apply and not physical centers) and continuity in funding did not occur in any of the cases.

The definitions that outline the different types of centers in the *Colciencias* rating system is not really suitable either. The global tendency is to create different – in many cases unconventional – institutions, putting together diverse partnerships, different disciplines and organizational models. Our centers have to fit into restrictive definitions in order to be recognized, and this limits their potential. We would like to see disciplinary and transdisciplinary organizations, think tanks, and even NGOs performing these functions. The assessment of whether or not to provide financial support should be made based on the quality of the proposal and the applicant's potential to meet it, rather than on the way in which they fit a definition invented in an office somewhere.

The centers needed to support Colombian companies in improving their productivity and competitiveness are practically non-existent; a great effort must be made to create suitable centers or to bring some of the existing ones closer to this role. They must be evaluated periodically and offered support and continuity if they adequately fulfill their function.

The establishment of a network of national laboratories and centers geared towards the Innovation in Colombia Mission is the first ingredient with which a vibrant, transformative and sustainable ecosystem of innovation can be established. Such an ecosystem must build a framework that closely links basic science with innovation at all levels of academia, industry, and R&D. Knowledge and discoveries must be passed on to emerging markets gracefully and with versatility, and this must be supported by innovative training and education models, along with commercialization-driven copyright protection.

Policy proposals

Our proposal is that centers be heterogeneous, and so the policy must also contemplate alternative strategies. One way to consolidate this strategy would be via a Conpes document, led by the new STI Ministry, accompanied by advisors from the scientific community (especially those knowledgeable in the operation of centers and institutes) and based on proposal guidelines.

Accordingly, the Mission proposes that the law allow public institutes and centers to be governed by private law (exclusively in activities related to scientific research) to ensure their administrative agility.

Adequate medium- and long-term government funding mechanisms should be established for such entities with resources that allow for flexibility in covering operational costs. If they have basic funding for this, the institutes and centers can cover the rest of their operations through projects. An international example is the Fraunhofer Institutes in Germany, which receive 30% of their operating budget from national and regional government sources.

For institutions with extensive State funding for operations, such as national public institutes, adequate investment financing should also be sought, preferably from their own sector. This can be awarded competitively based on the quality of the projects.

Institutions with financial support from parafiscal authorities must be assured of stability and continuity, and the fact of their being accountable to the STI Ministry and not only to their guild members must be treated with impartiality.

The policy of overheads granted by public funds must be reviewed. If some centers and institutes are going to depend largely on projects approved by State funds (national, ministerial, regional, and local), we must take into account that these projects must largely cover indirect costs. In the United States and Europe, this calculation is carefully conducted and the amounts depend on the financing institution and the recipient. It is very common for overheads to be no less than 40% of the project cost. Thus, these countries have managed to keep institutions working very actively on research and to radically encourage this activity.

The monitoring and evaluation scheme for research projects with non-reimbursable and competitive government funds must be made more flexible. The project should be evaluated by the quality of its results, while also considering its risk. The initial budget should be used to test the pragmatism and seriousness of the institute or center's proposal, but it should not be taken as an inflexible spending commitment. Research is inherently a risky activity. If the possibility of negative results is not contemplated, it is simply impossible.

An institute's and center's policy must be redefined to include the different actors involved: research institutes, technological development centers, science centers, national laboratories, centers of excellence, etc.

The import of reagents, machinery, equipment and inputs for research needs to be made easier by creating specific-purpose agencies (public-private partnerships), whose function is the import and purchase of reagents and equipment, working in a duty-free zone, and collaborating directly with the IES, research institutes, technological development centers, and national laboratories. They should also have special regulations that allow them to optimize nationalization, purchase, and tax exemption procedures.

It is necessary to establish collaborative work networks in order to consolidate a field of action which supports the continuity of the Institutes and Centers. If Colombia aspires to meet the standards proposed by the

OECD, it must guarantee, through its institutes and centers, an expanded network that links together Colombia's highly qualified and brilliant human talent at regional and national levels.

The spectrum of research lines and areas carried out in institutes and centers should be expanded, alongside an increase in the critical mass of science and technology for the country, and the creation of occupational niches for the growing body of highly scientific and technological human resources. There are many areas that lack adequate centers and, in the medium-term, these should count on centers to aid their development. Some of these centers may be "on demand" (Duque and Mondragón, 2019), which means they should have good capacity to respond to problems in the productive sector in a timely and efficient manner. For the "On-demand centers," it is proposed that the State offer solutions by establishing on demand national institutes of sectorial research with clear policies to attend to the needs of the sector's MSMEs in particular. These institutes will employ full-time technicians, professionals and scientists dedicated to thinking over and providing prompt solutions to the problems of companies in the sector. They will also comprise units for technology surveillance, and legal and marketing consultancy services, which will be at the service of the companies. The institutes will preferably be located in a region where they will be most needed.

In the first 3 to 5 years, these companies will be financed entirely by the State. Once this first stage is completed, the companies will start investing in institutes to advance their research and development according to their specific needs.

The institutes will constitute one of the ways in which STI can be regionalized in Colombia, as they will be located in areas where there is a need for such developments. The initial institutes could be designed according to the most well-organized clusters of sectorial companies. The following are some examples of the needs as detected by the Mission:

- Biotechnology Research Center (Cenbiotec)
- Center for Research on Oceans and Hydrobiological Resources (Cenocer)
- Center for Culture and Creative Industries (Cencuic)

- Research and Development Center for Convergent Technologies and Industry 4.0 (Cetconi)
- Research and Development Center for Artificial Intelligence (Cenia)
- Research and Development Center for Energy (Cenergia)
- Research and Development Center for Life and Health
- National Nanotechnology Research Center

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Reinforcing the scientific ecosystem by integrating public STI institutes

This proposal, put forward by the Mission of Experts 2019's Life and Health Sciences pillar, suggests that the scientific ecosystem can be strengthened by integrating the Colombian public institutes that are involved in science, technology and innovation (STI) activities. The proposal was built from the bottom up in conjunction with the institutes and a multi-disciplinary team. Here we explain how this integration will allow STI activities to be reinforced by generating data and knowledge conducive to Colombia to achieve and maintain the UN Agenda 2030's Sustainable Development Goals (SDG), to which the country has committed. We also illustrate how these Goals are interrelated and how the institutes working together will contribute to Colombia's development, assets, wellbeing, health and scientific progress.

Justification and Context

The knowledge created by research is fundamental to the global economy. According to the World Bank's Knowledge for Development (K4D) program, the countries that will prosper will be those that encourage their populations to develop the skills to become better workers, managers, entrepreneurs, and innovators (World Bank, 2007). Accordingly, existing strengths must be expanded through careful investment in education, institutional quality, and relevant technology. Science is driven by technology and should be guided by human wellbeing. Therefore, strategies must be devised to create new competitive opportunities (technological consolidation) and conducive environments that enable sufficient knowledge to be generated that can be converted into wealth (World Bank, 2007).

Building of the knowledge economy can be guided by four pillars: (i) the economic environment and institutional framework; (ii) education and human resources; (iii) information infrastructure, and (iv) an effective innovation system, composed of organizations that create and promote the adoption, monitoring, and improvement of new knowledge and technology (e.g., STI institutes and universities that conduct research) (World Bank, 2007). As Paul Romer states: "growth is driven by technological change that arises from intentional investment decisions" (Romer, 1990).

The Colombian public sector has at least 21 institutes of diverse legal nature that carry out scientific research, support the creation of technology and develop or encourage innovation in various fields. They employ nearly 150 researchers (3% of the total number of active researchers) and host 80 research groups recognized by *Colciencias*. The legal nature, and therefore the legal framework, of these institutions are varied, comprising State social enterprises, public establishments, mixed corporations or science and technology institutes. Although they all carry out STI activities or are recognized as research centers, only the National Institute of Health and the Colombian Geological Service are science and technology institutes, defined as such by Laws 4109 and 4131 of 2011, respectively.

The work of these institutions is needed both by the public and the State, as it creates knowledge that would not be produced otherwise if left to market forces. This knowledge responds to the demands of development, seeking national sovereignty in various fields, and directly or indirectly pursues the current SDG.

These institutes represent an emblematic public resource that must be bolstered and supported by removing any obstacles that prevent their full development and use. Therefore, it is imperative to establish a new public service system for scientific and technological institutions, alongside those that, without being defined as such legally, carry out tasks of this nature, geared towards innovation, and which in practice are part of the STI System.

A subsystem of transversal integration of the State institutions should be constituted so that these can, through this network, share their experiences and resources, supplement their agendas and enhance their contributions to STI development. To date, there has been a disconnection between these institutions that carry out research, create technologies, and contribute to the formulation of public policy in various fields; some carry out high-level human talent training and others participate in the provision of health services as public service providers and are recognized as Research Centers (ESE). An adequate institutional framework in the area of STI that addresses the requirements for improving these processes and recognizing the role of the STI Institutes as part of the State and in establishing public policy has not yet been established.

Accordingly, these institutions require a new administrative and institutional system within which the full potential of the scientific talent of researchers can be developed, the conditions conducive to research can be created, working under the precepts of the highest and most committed professional ethics. Different disciplines should be integrated to improve knowledge production, application, and evaluation, so that it can be applied effectively and efficiently and, simultaneously, contribute to competitiveness, productivity, monitoring, and evaluation. All of this will require a new way of thinking, as well as budget and project management for these institutions. It even requires a new vision in the entities that will be called upon to manage these institutions.

Maintaining a body of full-time researchers, which exist in several of these institutions, becomes a real management challenge. The model of public service implemented should be capable of attracting, maintaining and promoting the human management of a group of people that have special qualities, and that cannot, and should not, be subject to a common public service regime. Institutions should implement specialized career regimes or their own employment regime, as well as systems of incentives and productivity stimuli, which not only take into account performance, but also the results obtained through research and their contributions to STI.

The institutions that carry out STI work need to have their own legal framework, which allows for conditions that until now have been unfeasible (e.g., having a biannual or tri-annual budget system, which better interacts with the management of an institute's resources for funding research projects). They also need a much more flexible management of resources deriving from contributions from individuals, foundations, corporations, multilateral organizations, and research networks among others. Thus, an institute could have explicit sponsors who play a role in its management, for example, philanthropists, and companies or foundations which promote research could commit to collaborating in the management of resources, donations, or contributions.

In this vein, we must be able to organize research institutes around specific projects, or create laboratories that specialize in certain topics, working with great flexibility in order to establish a form of collaboration that is guided by generosity, trust, and discipline.

The contracting arrangements for these institutions will require special rules, which, although these already exist, are not well known and are often confused with contracts governed by Law 80 of 1993, which has distorted the agreement scheme and ignores the particulars of science and technology. The contracting regime must provide legal security to those who apply it, since no change will take effect unless clear rules are established to encourage and promote the regime's implementation. It is pertinent to consider here the provisions of Law 29 of 1990 and Laws 393 and 591 of 1991, issued to define differences between science and technology contracts from ordinary contracts.

In short, a new concept of public service must be applied and new contractual, budgetary, organizational and business management arrangements must be put in place under new parameters. The new STI system must revolutionize the way in which this type of entity is conceived, based on constitutional principles that have not been fully enforced to date. The new STI Ministry must be a natural ally and lead these processes with a new alternative vision.

General Guidelines of the Proposal

a) The current National Development Plan, contained in Law 1955 of 2019, has proposed specific measures to strengthen the STI Fund of the General System of Royalties, and in this way forge a better connection with the country's regions. It is important to highlight the instruments and strategies that emphasize inter-institutional articulation, including universities, companies and, in general, all the sectors of the National System of Science, Technology and Innovation, in the goal of achieving an investment of 1.5% of the GDP in STI activities by the end of 2022.

b) None of this is possible without a new institutional framework to strengthen and integrate the national institutes that conduct STI activities, as indicated in the "National Competitiveness Report 2018-2019" (Consejo Privado de Competitividad, 2019). Thus, issues that have created obstacles for the legal processes of STI institutions, as summarized previously, must be overcome. These include the areas in which their public function, and their contractual, budgetary and monitoring and control regimes operate.

Scientific Component

This proposal will facilitate technological development and innovation, benefiting from highly qualified human resources and responding to the need to offer both labor and structural means to the growing number of researchers in the country, to develop STI projects of national relevance and global impact (see Table 6). It will also build on what has already been constructed: instead of procuring new facilities and buildings, the current infrastructure will be used while its technological capacity will be strengthened by 1) using of the basic facilities of each institute for common purposes, and 2) the implementation of robust equipment and state-of-the-art technology.

Table 6. General indicators of the proposal and their respective goals

Indicators	Targets
Interdisciplinarity and scientific convergence.	Governance for integration, an appropriate legal and administrative framework for research, respecting the identity of each institute. Mobility of researchers. Researcher's statute (legal framework). Greater capacity for understanding availability, deficiency, how best to take advantage of strengths and minimize risks and weaknesses.
Technology implementation and enhancement. Problem-solving capacity.	Synthetic biology, omics, bioinformatics, genetics, epidemiology, nanotechnology, statistics, artificial intelligence, biobank. Data acquisition and storage. Social sciences, behavioral changes, implementation and scaling of solutions.
Education. High level training.	Accredited Teacher's and Doctorate programs. Internationalization.
Scientific production.	Increase the quality and quantity of publications. Topics: biodiversity, health priorities (infectious and neglected diseases, tropical diseases, chronic non-communicable diseases, mental illness), climate change, bioeconomy, disaster risk management, social appropriation of knowledge, and others, all leading to the achievement of the SDGs.
Technology production	Patents, device development, drugs, and other products.
Innovation	Spin-off innovative companies and incidental benefits, increase in productivity and competitiveness. Development of innovative solutions deriving in communities (social innovation).

There is a need for a long-term science policy with a solid legal framework that allows for efficient governance, which creates trust and sustainability, and includes universities and private enterprise.

Sustainability will be ensured by establishing public-private partnerships and spin-off companies, accessing competitive national and international resources, carrying out STI activities financed by State and private actors, attracting public and private investments that stimulate the creation of companies and technological production and innovation, while promoting social innovation.

This proposal will contribute greatly to sustainable development in the medium and long term, and will be highly visible; it has an academic, educational, scientific, experimental, and technological development component, and the capacity to mobilize and involve numerous and diverse actors: universities, government, private sector, and civil society; it is built on a foundation of collaboration and permanence, and encourages regionalization and internationalization. Finally, it is based on interdisciplinarity and convergence.

The contextual document for this section elaborates on the proposal's rationale, its contribution to the sustainable development goals and its legal, administrative and scientific basis.

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Flagship Initiative: National Creative Incubator Network

Within the framework of the discussions surrounding the Mission of Experts' Creative and Cultural Industries pillar, held between March and June 2019, several obstacles were identified in relation to the creation, production, circulation and commercialization of cultural contents. The following are some of the most relevant:

- There is a huge gap between major cities and the rest of the country in terms of infrastructure and training provision for the different links in the CCI value chain. Many of the country's municipalities do not have the minimum spaces and resources.
- Many of the existing spaces for the creation and circulation of cultural content at the national level are unconnected with processes of support for entrepreneurs (cultural centers, etc.) and few have active links with universities or other types of academic institutions.
- There is a very low level of associativity in the CCIs, as well as a low valuation of the "non-creative" roles in the value chain (technicians, managers, intermediaries, etc.).
- Universities and academic institutions in general are seen only as trainers of talent, when they have the potential to produce knowledge, generate content, circulate it and provide advisory services to CCIs on legal, business and creative issues.

These considerations point to the need for collaborative and articulated work between the State, educational institutions, productive sector organizations and civil society. While this is described in the science, technology and innovation literature as a "quadruple helix," it is important to note that the interconnectedness needed in the creative industries is not the same as that required in other sectors. There are even differences between the four actors that make up the quadruple helix. While in technological innovation we refer only very occasionally to universities and companies, in the creative industries it is more pertinent to talk about educational institutions and organizations related to the content production. This is because the type of knowledge that gives value and makes these industries competitive is not strictly speaking scientific knowledge, but knowledge produced in the processes of artistic creation. This means that innovation in this case is mainly derived from creative processes, which include research as a tool for problem solving, but which aim primarily at generating content that achieves circulation, appropriation and that becomes part of the culture, modifying perceptions, tastes, subjectivities, emotions and world views.

In this sense, it is important to emphasize that in the CCIs, the processes of knowledge generation, development, transfer and innovation occur on different time scales from those involved in technology transfer. To give just one example, an artistic product can be created, circulated and consumed in the same instant (think of pieces of an improvisatory nature), but the process of innovation that it sparks, that is, possibly changing sensibilities, can last for long periods of time. In contrast, a technological development based on years of research can be transferred, commercialized, and become obsolete in a short period of time.

With this in mind, a model of articulation between these four actors of the CCIs would have to take advantage of the closeness that exists between the processes of content creation and circulation, instead of segmenting these activities. Unlike other innovation processes, cultural contents can be validated right from the start with real audiences. However, it is noteworthy that only recently have these activities begun to take into consideration the leading role of the public in the creative process. The possibility of having a permanent, one-way relationship between creators and audiences that is fully integrated into the process of creating content is a particular characteristic of innovation in CCIs.

Creative Incubators

The Mission of Experts' Creative and Cultural Industries pillar proposes an emblematic initiative that foments a relationship model for the CCI quadruple helix, based around physical spaces. The initiative understands that the permanent feedback between consumption and cultural production as a privileged place where the State, universities (and academia in general), companies and emerging enterprises, and civil society can converge. Unlike the traditional perspective of a linear chain with specialized roles, we understand that the creation of symbolic value and economic value in the creative and cultural industries takes the form of a "value-generating ecology" (Hearn, Roodhouse & Blakey, 2007) that involves a fruitful and multidirectional relationship between all actors, almost simultaneously.

In this sense, it is not useful to think about clearly delimited production processes of goods and services that must be distributed and marketed until they reach a final consumer by means of a transaction. On the contrary, it is a matter of understanding the active role of audiences, users and consumers in the co-creation of cultural content, in a process that involves the shaping of tastes and identities, technical sophistication, market formation, and other processes.

In a context such as this, it is possible to think of physical spaces in which experimentation and creation, and the incubation and acceleration of creative enterprises and the circulation and appropriation of content can occur at the same time, something that would not be easily understood in other industry sectors. This type of space could have a simultaneous impact on the construction of creative capacities and on the cultural dynamization of its environment, optimizing the time and resources of all actors involved. To this end, the following actors should be involved:

- Universities should participate, not only as providers of talent, supplying either their graduates or student entrepreneurship initiatives, but also as content producers through creation and research + creation projects.
- Entrepreneurs, who through calls for funding can find a space for both the development of their creative proposals and for the validation of content, feedback from the public, and consolidation of value proposals and business models.
- Established entrepreneurs who require new talent and content for their operations and who may be interested in supporting the incubation and acceleration of creative projects.
- State entities, whose functions include promoting creation, supporting business initiatives, and boosting the creative economy, and who, beyond the granting of resources, can play an articulating role.
- The public, audiences, users and civil society organizations that want to access innovative creative proposals and play an active role in generating content.

The proposal consists of joining these actors together around physical spaces, which function simultaneously as: 1) creation laboratories, 2) incubators or accelerators of creative and cultural enterprises/projects, and 3) centers which are open to the public, with original and permanent cultural programming. This triple function must be constituted in a model that can be scaled up or down, according to the installation capacities, human talent, and the productive direction of each local environment. Thus, a cultural center may, for example, prioritize the implementation of the model around a traditional musical practice, for which it would need at least a rehearsal room and a small auditorium for public presentations, and eventually, equipment for audio recording and editing. Likewise, an incubator with more resources in a major city could bring in different artistic expressions under the same roof, focusing on innovative interdisciplinary proposals, with the use of state-of-the-art technologies.

The spaces—existing or new—that meet the conditions of this model may be given the name 'Creative Incubator' and form a national network of this type of institution. Entities in the cultural sector may choose to implement the model, which should allow them to access benefits (to be determined) and commit them to a series of responsibilities that must be fulfilled in order to maintain the label. These responsibilities should include sharing good management practices with other Incubators and facilitating the circulation of content generated in other Incubators and in their own.

The relationship model must, at the same time, serve as a model of sustainability, insofar as it establishes the minimum commitments that the different actors must make. These commitments would be stipulated as follows:

Universities and academic entities: when joining a Creative Incubator, these must commit to dedicating human resources, paid by the hour, to undertake consulting and mentoring work and conduct research activities. Likewise, the academic entity must be able to identify relevant entrepreneurial initiatives and cultural projects in one or several creative areas that correspond to the strengths of the local environment, both in the proposals of their students, as well as in those coming from other actors.

Consolidated companies and investors: when joining a Creative Incubator, these must commit to providing resources for its maintenance. In exchange, they will be able to work closely with the entrepreneurs and have privileged conditions for the licensing of content and access to information regarding the human talent.

Entrepreneurs: these must pay a minimum amount to receive the support services and make clear commitments that guarantee their continued participation in the processes. It is important that they maintain the intellectual property rights of their creations at all times, since the ideas that the develop will be based on these intangibles. They must, therefore, commit, through clear mechanisms, to contributing to the solidity and quality of the Incubator's cultural program.

Local authorities: As direct beneficiaries of the cultural and economic dynamism that the Incubators can produce, the local authorities are obliged to contribute to their support in proportion to the contributions of the private sector.

Audiences and users: Although some of the public events will be free, promoting a culture of paying for cultural services should be understood as a fundamental part of building the country's cultural and creative industries. Thus, different forms of compensation should be employed and progress made towards users financially remunerating artists by accessing the Incubators' cultural programs.

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Financing

In this section, we examine STI financing in Colombia, review international experiences in STI financing, set out rules for the allocation of funds, propose a broad structure of programs to be administered by an STI Ministry (based on a theory of change), discuss the role of private financing and the destination of royalties, make an order of magnitude estimate of the investment that could be executed in the STI Ministry, and discuss the role of combined financing as the axis of the financial structuring of STI projects.

Funding STI in Colombia

The Science and Technology Observatory (OCT) uses two indicators of investment in STI:

- Investment in R&D that, over 18 years of measurement, increases from 0.14 % of the GDP to 0.25 %. This is the indicator used by the OECD and UNESCO to measure the national effort in this activity. It is extraordinarily low when compared internationally, as will be shown below.
- Investment in science, technology and innovation activities (ACTI), including activities indirectly or incidentally related to STI development, such as doctoral scholarships, scientific dissemination projects, among others. This indicator increased from 0.38 % to 0.68 %, over 18 years. We can see that in the last six years, investment in ACTI has stopped, and even suffered a slight decrease.

Figure 9 compares the investment of various countries using the standard R&D indicator. While Israel and Korea invest almost 4.5% of GDP, and the OECD average is around 2.5%, for Colombia, it is only 0.27% below Brazil, Argentina, Mexico, Costa Rica, Ecuador, and Uruguay among others.

Figure 8, extracted from the OCT Indicator Report 2017, shows the evolution of both indicators:

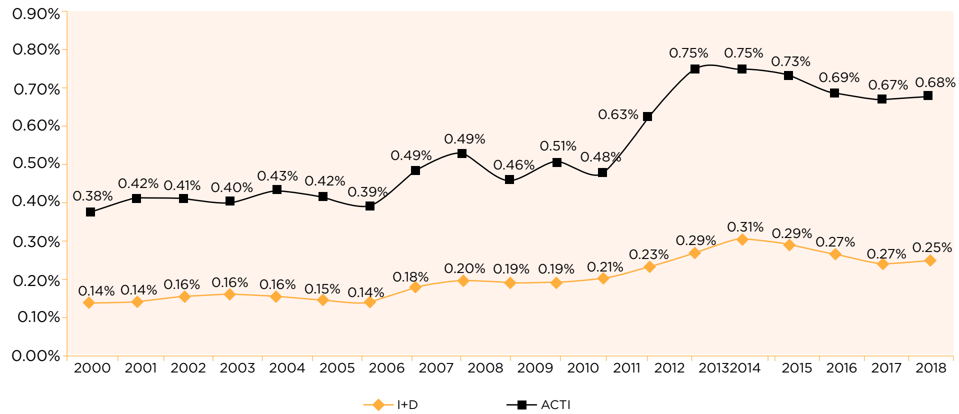
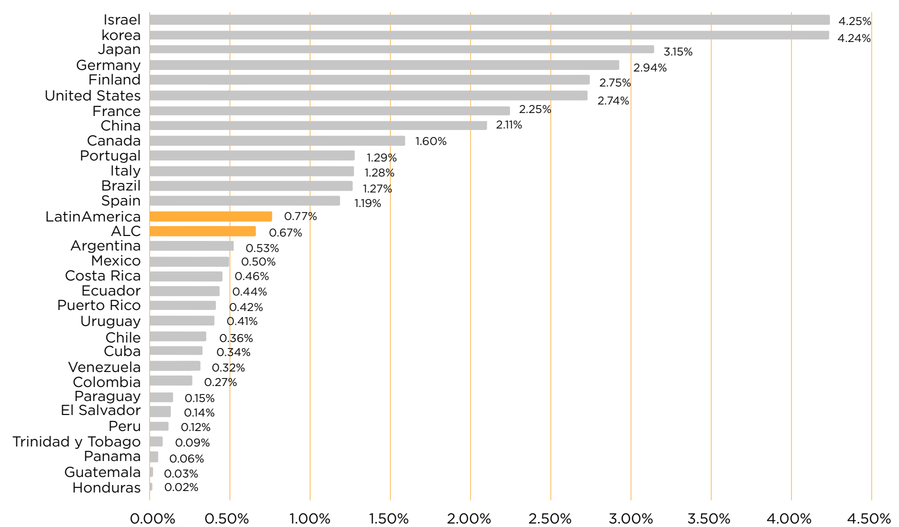


Figure 9: R&D investment indicator as a percentage of GDP in selected countries
Source: Red Iberoamericana de Ciencia y Tecnología, 2018



The current government has recognized this situation and addressed it in a special chapter of the guidelines for the National Development Plan 2028-2022, proposing the investment path shown in Figure 10 (DNP, 2018).

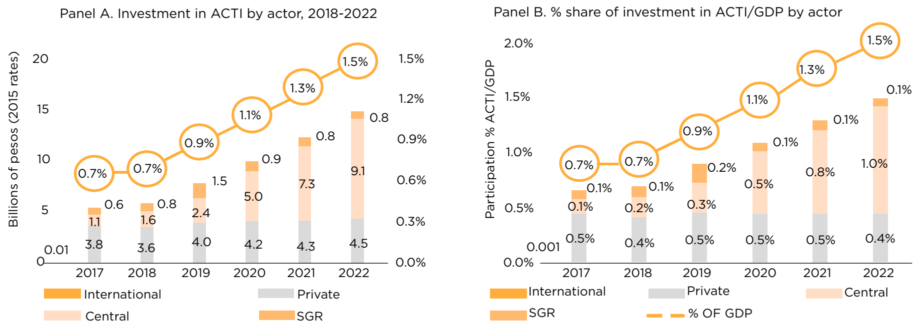


Figure 10. NDP 2018-2022 proposal for investment in ACTI by actor
Source: Based on MHCP

Some international experiences of STI financing

Industrialized countries have traditionally funded the bulk of their basic research and research and development (R&D) with public resources from two sources: business tax and estate tax (United States, Germany); and natural resource revenues, where they exist (Norway, Canada). Part of the general tax funds have financed research institutes or laboratories and another part has been destined to finance proposals from universities.

For example, emphasis of US academia on raising private resources since the 1980s to finance the entire production and commercialization chain for new ideas is based on both tradition (the MIT and Stanford's self-definition as entrepreneurial universities) and necessity (reduction in the proportion of public funding in the last four decades).

Current debates in developed societies revolve around assessing the impacts of change in funding sources on the three products of universities: teaching, certified knowledge creation, and real problem solving (Just and Huffman, 2009). The disciplinary effect of public funds on the increase of basic publications and the positive increase in patents through interaction with the private sector should not be surprising. Nor should it be surprising that, for universities with a history of mainly public funding for many decades and an emphasis on indexed publications, a tradeoff between private funding and publication productivity has been detected.

In the United States, opinions over the financial role of patents are divided. Scotchmer (2004, 235) argues that the University of California system received $13 million for patents in 1999 (after costs), less than 1% of the $1.5 billion received by the university from the federal government. According to Scotchmer (2004, 235-236), an average American university receives about 69 invention disclosures per year, of which it patents half. University patent licensing offices received an average of $6.6 million per year. This average is misleading because it includes a few exceptionally successful cases such as Stanford or Berkeley, when licensing offices typically do not cover their costs. The lesson for Colombia is simple: encourage patents, but do not expect them to become a source of funding for STIs.

Financing rules and STI programs, the risks of public investment

The economic literature recommends (Foray, 2006): (i) that the public sector finance STI that does not have high private profitability, but that does have high expected social benefits; (ii) that the public sector should not finance STI with low private profitability and whose social contributions, including all their externalities and long-term potentials, are lower than the cost of public funds (opportunity cost of taxes in the more socially profitable alternative); and (iii) that the private sector finances the high private return STI (see Figure 11).

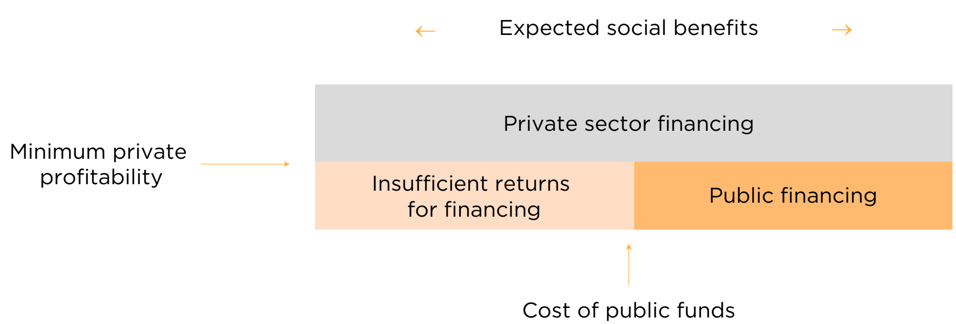


Figure 11 STI Financing
Source: Foray (2006, 127).

Public funding must guard against the following risks: neglecting basic science; funding frontier research without building broad international links; and crowding out investments: those that would be made anyway even without State investment.

An international evaluation found evidence that the tax incentives offered in Colombia to larger companies generate income that does not result in increased investment in R&D, and therefore is not justified (Parra, 2013). Recent interviews conducted by members of the Mission with some of these companies confirm this assessment.

Four incentive policies are recommended:

- Limit tax incentives to small and medium enterprises (SMEs). These incentives should be allowed to be granted as tax credits with no expiration date so that SMEs that do not pay many taxes but aspire to grow are more motivated.
- The creation of new technology-based companies and incubators should also be supported, either through tax incentives or through direct support from the State as co-financier or risk capital manager, especially when they are export-oriented.
- Design special lines of credit with shared risk for SMEs.
- Promote risk capital managed on a delegation basis by private banks with experience in funding for high-risk technological projects with the potential to open new markets for products and services.
- Co-finance R&D in large companies for basic research, contributions to research and sectorial centers and institutes, and launch calls for large companies to serve as anchors in projects with SMEs.

Theory of change and general STI program structure

Correa (2014) presents the general logical framework of the final purposes of the World Bank's STI investment, with an input-output-output-impact (I-O-O-I) sequential model. In the model, the focus of STI investment is on increasing the economy's productivity through better products and services, which are the result of a mix of public and private investments in four types of programs (see Figure 12).

The four channels to be managed in the new STI Ministry are, according to the outcomes shown in Figure 12:

- C1. Research of excellence, which refers to research conducted with public funds and focusing on the creation of basic knowledge (high component of public good, high risk) under the logic of the "Entrepreneurial State" (Mazzucato, 2013).
- C2. Collaboration between industry and researchers and technology transfer, which combines the creation of applied knowledge, the systematic commercialization of joint public-private efforts, two-way collaboration between science and industry, and the effective transfer of public research outcomes. It is a channel that can be managed through co-financed missions + centers (whose advantages for Colombia are presented in other sections).
- C3. Innovation by business R+D. Two types of activities are grouped in this channel. Firstly, private investment to increase the incremental productivity of firms and increase their capacity to absorb new technologies. Secondly, technological startups that can be financed by co-financing mechanisms and tax incentives.
- C4. Adoption and non-R&D based startups. The adoption of frontier technologies that are not produced domestically increases

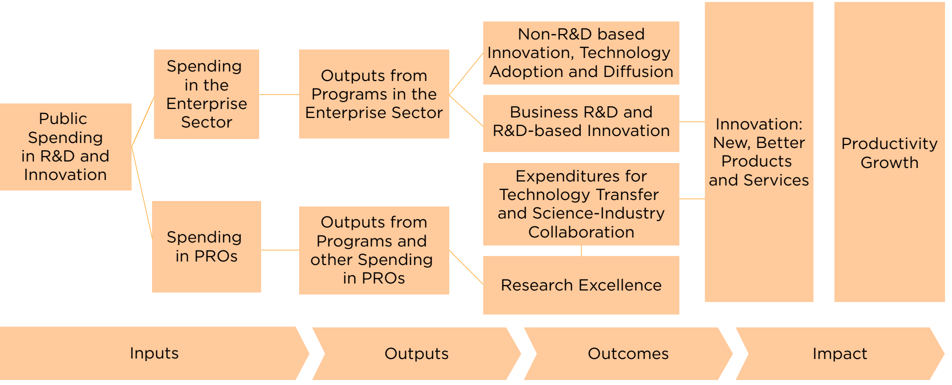


Figure 12. Theory of Change by STI Activities and Funding
Source: Correa, 2014, 10.

productivity. General purpose technology can be adopted to innovate business models (use of STI to reconfigure value chains). As discussed in the previous subsection, the public sector can open special lines of credit and co-finance initiatives with greater externalities and transversality.

These channels are broad and flexible enough to accommodate initiatives in innovative aspects such as, for example, (research + creation) activities originating in the artistic and creative areas.

Uses and sources of payment in STI

In Table 7, The STI Ministry's four program groups are shown in the rows, and the payment sources in the columns.

Table 7. Uses and Sources: Ministry Management Framework

		Sources					
		National budget	Regional and municipal public resources	Sector specific funds	Royalties	Private	Donors
Uses	Technology adoption and dissemination						
	Innovation by industry (R&D + startups)			{orientation + $ + incentives + management}			
	Academia-industry collaboration in mission centers						
	Basic science of excellence (creation)						

Source: Authors.

The relationship between basic science and innovation

There are important links between public investment and innovation. The production of basic science behaves as an "option" in which the productivity of publications takes off abruptly at the threshold of 150 publications per million inhabitants in 1998, as shown in Figure 4. The threshold doubles every eight years. When projecting for Colombia, today, between 28,000 and 30,000 articles per year would be required to increase the flexibility of research patenting.

What is the role of industry funding and what should be done with the royalties?

Colombia is far removed from the world's technological cutting edge. According to Acemoglu, Aghion and Zilibotti (2006), developing countries should simultaneously adopt and transfer technology if they are to come closer to the technological frontier.

Public policy-oriented private financing is important: in Norway, as documented by Gulbrandsen and Smeby (2005), industry funding leads to better indicators in collaboration with other researchers and industry, more scientific publications, and more entrepreneurial results. This trend is largely explained by the implementation of a public policy to transform a natural resource economy into a knowledge-based one, mixing incentives and obligations for technology transfer to foreign firms, creating technological universities and rewarding researchers' industrial achievements. This case is much more interesting for Colombia than examples of industrialized countries that have not had natural resource booms.

Royalties are income earned through non-direct effort (seeming to fall from the sky) and can be captured by rent-seekers. Hartwick (Hamilton and Hartwick, 2005) derives a simple rule for sustainable growth in countries that have natural resources. The rule states that to maintain positive consumption rates (the definition of sustainable development) in the long term, all income from natural capital must be continually reinvested, in exchange for consumption. As stated by the World Bank (World Bank, 2011, 15), the availability of non-renewable resources in poor countries presents a unique opportunity to finance development and reduce poverty. However, international experience is not encouraging in this regard: where strong institutions do not exist, the "resource curse"[13] is likely to rear its head.

Using an institutional quality index (a number between 0 and 1, where 0 is the worst score and 1 the best), Mehlum, Moene and Torvik (2006) find a close relationship between increased natural resource abundance and economic growth for a sample of 87 countries. With institutional quality above 0.93, foreign exchange income from exports of natural products contributes to growth and, with quality below 0.93, the opposite occurs (predatory policies prevail).

In the work of these authors, Colombia's institutional quality index appears as equal to 0.53, higher than Peru (0.32), similar to Mexico (0.54) and Venezuela (0.56), and lower than Chile (0.63), Australia (0.94), Norway (0.96), Canada (0.97), and the Netherlands (0.98). In Colombia, a major effort should be made to defend the allocation of royalties to science and technology by allocating these resources to the new STI Ministry. Royalty monies should help solve the problems of the country's regions in the context of broad consultation processes to identify and prioritize needs, but resource management must be centralized.

Order of magnitude of investments and allocation of uses and sources

Figure 13 presents a model for coordinating the private sector response to the public STI funding effort and the public response to the private sector funding effort. Private investment has an S form: initially, it responds slowly to the

13 The resource curse occurs in institutionally weak countries that receive abundant export money flows from mining or hydrocarbon products. In a context of institutional weakness, the other sectors of the economy contract, the effort to diversify and innovate is reduced, and an unstable political system is formed as a result of the struggle between different groups to benefit from the income from these resources.

public effort and only takes off when public investment has removed initial R&D risks, consistent with the evidence presented in Figure 12. Meanwhile, the public investment response takes the approximate shape of a straight line.

The intersection of the two responses at the bottom corresponds to the current situation in Colombia (low quality trap), where the sum of the State's and private actors' contributions is negligible. The intersection in the upper right-hand side corresponds to a high-quality equilibrium, after the threshold of public investment that activates a vigorous response from the private sector has been exceeded.

The R&D investment path would follow two phases. Phase 1 ('public patient capital') is characterized by high input from the public sector and Phase 2 ('private R&D take-off') by a surge in private investment. Tables 8 and 9 show the respective levels and percentages of investment. At the end of Phase 1 in 2028, it could reach 1.20% of total investment in R&D as a percentage of GDP (where public investment would be 0.80% and private investment would be 0.40%) and, at the end of Phase 2, it could reach 1.80% of total investment in R&D as a percentage of GDP (where public investment would be 0.85% and private investment, 0.95%).

In the absence of tax and royalty resources, the public sector should be willing to assume a debt of at least USD 300 million in the first phase mentioned.

Figure 13. Model of private and public investment in STIs
Source Todaro *et al.*, 2013

Table 8. R&D Investment Phase 1

	Phase 1: Patient Public Capital										
	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
GDP billions of US	$ 330.23	$ 338.71	$ 348.88	$ 360.04	$ 371.56	$ 383.83	$ 396.87	$ 410.37	$ 423.91	$ 437.90	$ 452.35
R&D Public % of GDP	0.08 %	0.15 %	0.22 %	0.30 %	0.37 %	0.44 %	0.51 %	0.58 %	0.66 %	0.73 %	0.80 %
R&D Private % of GDP	0.10 %	0.18 %	0.21 %	0.23 %	0.26 %	0.28 %	0.30 %	0.33 %	0.35 %	0.38 %	0.40 %
% of GDP Total R&D	0.24 %	0.34 %	0.43 %	0.53 %	0.62 %	0.72 %	0.82 %	0.91 %	1.01 %	1.10 %	1.20 %
Total Amount B of US	$ 0.79	$ 1.14	$ 1.51	$ 1.90	$ 2.32	$ 2.76	$ 3.24	$ 3.74	$ 4.27	$ 4.83	$ 5.43
Public Amount B of US	$ 0.26	$ 0.51	$ 0.78	$ 1.07	$ 1.37	$ 1.69	$ 2.03	$ 2.40	$ 2.78	$ 3.19	$ 3.62
Private Amount B of US	$ 0.53	$ 0.62	$ 0.73	$ 0.84	$ 0.95	$ 1.07	$ 1.21	$ 1.35	$ 1.49	$ 1.65	$ 1.81

Source: Authors.

Table 9. Phase 2 of R&D investment

	Phase 2: Private R&D Take-off									
	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038
PIB US billones	$ 467.28	$ 482.70	$ 496.69	$ 511.10	$ 525.92	$ 541.17	$ 556.87	$ 573.02	$ 589.63	$ 606.73
I+D % Público del PIB	0.81 %	0.81 %	0.82 %	0.82 %	0.83 %	0.83 %	0.84 %	0.84 %	0.85 %	0.85 %
I+D % Privado del PIB	0.46 %	0.51 %	0.57 %	0.62 %	0.68 %	0.73 %	0.79 %	0.84 %	0.90 %	0.95 %
% del PIB Total I+D	1.26 %	1.32 %	1.38 %	1.44 %	1.50 %	1.56 %	1.62 %	1.68 %	1.74 %	1.80 %
Monto Total US B	$ 5.89	$ 6.37	$ 6.85	$ 7.36	$ 7.89	$ 8.44	$ 9.02	$ 9.36	$ 10.26	$ 10.92
Monto Público US B	$ 3.76	$ 3.91	$ 4.05	$ 4.19	$ 4.34	$ 4.49	$ 4.65	$ 4.81	$ 4.98	$ 5.16
Monto Privado US B	$ 2.13	$ 2.46	$ 2.81	$ 3.17	$ 3.55	$ 3.95	$ 4.37	$ 4.81	$ 5.28	$ 5.76

Source: Authors

Combined finance and other financing instruments

The diversity of sources and appetite for risk requires sophisticated financial engineering. The new Ministry will be required to lead the structuring of projects through blended finance. Table 10 shows funding instruments by funding objective (with strong participation by the centers) and Figure 14 shows instruments according to the funding needs and their risk for individual projects.

Kremer and Peterson Zwane (2005) suggest that public funding for innovation can be supplemented by a commitment to public payment for attributable products in development. This mechanism rewards the development of technologies chosen by policy makers and can be successful if payments are structured on an adoption-dependent basis. The authors propose this alternative when a choice must be made between push and pull programs. Push programs finance research inputs and are appropriate for basic research or when the final product cannot be specified. Pull programs pay for outputs and are useful in meeting specific needs.

Venture capital is associated with the need to quickly bring technological innovations to the market and redirect capital flows towards high performance businesses. Businesses that are financed through venture capital assume risks for which debt instruments are not designed. Venture

Table 10. Financing instruments by funding objective

Funding objetive	Instrument	Potential target groups
Capacity building	Block grant, project, programme (thematic or open), Centre of Excellence (COE)	Research group, organisation
Internationalisation	Stipend, project, programme, COE	Individual, organisation
Commercialisation	Award, expert support, venture capital	Research group, organisation, Individual
Collaboration between public research organisation and industry	Voucher, R&D tax credit, programme, project, COE	SMEs, large firms
Strategic research (e.g. major challenges)	Project, programme, COE	Research group, individuals, UI consortia
Career advancement	Project, stipend	Young scholars usually recently graduated PhDs
Career renewal	Pro·ect, stipend	Senior research staff, R&D staff

Source: OECD, 2014.

capital creates value by connecting sophisticated financiers on the one hand, and entrepreneurs trying to start and grow their companies on the other. Venture capital investors reduce the time needed for an entrepreneur to understand that a proposed business is not profitable, or to understand the conditions under which it could be profitable and, therefore, finance it.

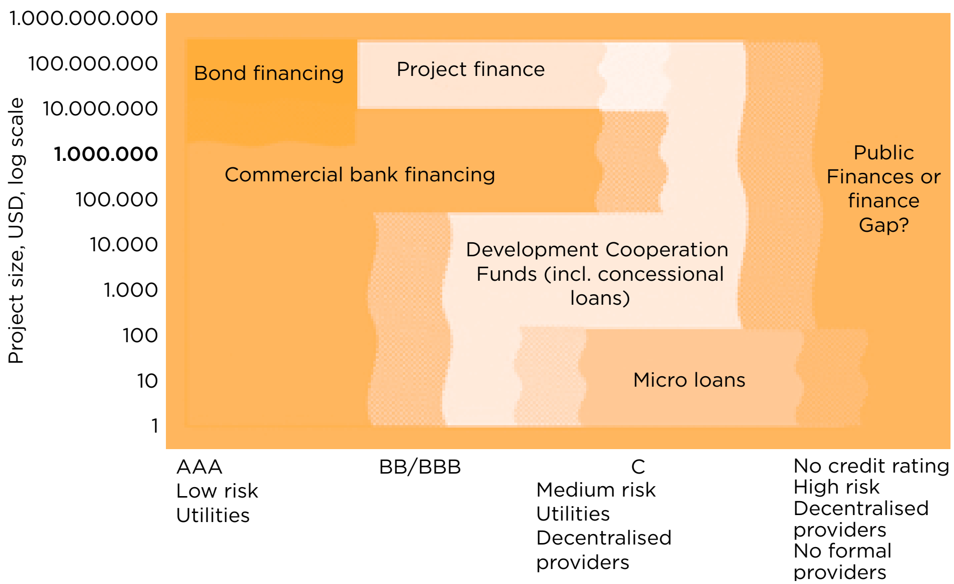


Figure 14. Financing instruments by type of project
Source: Gietema van Oppenraaij and Fonseca (2017) for the

2017 International Amsterdam Water Week

The STI Ministry should expand its arsenal of instruments with attractive initiatives at international level. Biodiversity, climate change, SDG, and other high visibility initiatives have the potential to bring philanthropic and donor input to the table on a cathartic basis. For example: conservation funds; biodiversity bonds, etc.

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The role of knowledge in regional development and the articulation of local knowledge and development initiatives

The gaps in educational opportunities and the asymmetries and inequities in the distribution of resources, infrastructure and services show that, despite the progress made in recent decades[14], we must continue to stand together to achieve the goal of regional progress based on knowledge.

Today we know that one of the keys to achieving regional development is to understand the link between knowledge and innovation, in order to promote sustainable development (Karayiannis, E., Barth, T. & Campbell, D., 2012) and focus attention on how societies learn, and what to do to promote learning, including learning how to learn (Stiglitz & Greenwald, 2014).

14 The concern is not new. Already in 1998, Fernando Chaparro, director of *Colciencias*, presented the report "Knowledge, Innovation and Construction of Society: an agenda for the Colombia of the 21st century." The report emphasized the importance for Latin American countries to guarantee the stabilization of strategic ecosystems, in a way that does not endanger the environmental services they provide at the global, regional and local levels, nor weaken their capacity to produce goods and services required to satisfy basic human needs. Similarly, this report highlighted the importance of the preservation and development of environmental protection policies, the need for changes in the forms of production and consumption habits, the introduction of clean technologies in many areas of production, among others. Additionally, the report highlighted the importance of knowledge in regional development, the need to build capacity and technology, the need for centers of strategic and prospective thinking, the results of departmental innovation systems, and the need to promote research groups and centers.

We need to implement a cooperation and knowledge management system that enhances the links between university, business, State, civil society, and the environment, in order to exploit the possibilities of each territory and establish cooperation networks of an interdisciplinary and intersectoral nature.

Indeed, the link between university and business has gained ground worldwide and has shown benefits in innovation and knowledge management. Companies and governments around the world increasingly consider universities as integrators of public policies and as sources for the creation of relevant cultural content. On the other hand, it is exciting to include the environment as one of the axes of this model of five-fold articulation, recognizing the rights of the natural world and its key role in any designs for development. Creating a culture of inter-regional work with these five factors involves understanding the benefits of knowledge networks and the possible tensions that are often evident in practice, caused by dealing with different epistemic actors located in different cognitive and normative frameworks, as well as in possibly divergent institutional cultures. In any case, this level of cooperation—known as the Quintuple Helix—can permanently reconfigure the scope of the network and gradually realign the expectations of the social actors involved, especially civil society actors.

It should be noted that the combination of knowledge, know-how, and environment in an "inter-institutional" and "transdisciplinary" framework provides a model for monitoring our balance with nature and thus pursuing the sustainable development that is required. However, the use of the knowledge accumulated in different disciplines, and by different actors and institutions implies not only technical, budgetary, and design challenges, but also requires an understanding of the epistemic-political features that mark the geopolitical, socio-historical, and cultural differences among the territories (Escobar, 2014). It is only on this cultural and anthropological basis - usually relegated and neglected - that we can clearly and fairly define future scenarios that bring together the collective will and resources of civil society, industry and academia.

In this sense, the challenge for the next thirty years is to promote economic growth and structural change based on the endogenous potential of the territories, establishing conditions for a social exchange of knowledge with the rest of the country and with the international community. Science, technology and creativity based on knowledge are fundamental to this undertaking. The promotion of this interrelationship, especially the interface between artistic/cultural creations and developments in science and technology, can give rise to creative solutions to the problems afflicting national society.

In this vein, we must promote research on resource and regional patrimony to contribute to the design of sustainable alternatives in the regions, beginning by recognizing their world visions, their forms of cognition and their ways of inhabiting the territories. This is essential, to the extent that behind many of these worldviews and life-forms lie non-dualistic visions of life and outlooks that can be inspiring. An example of this are the relational ontologies of the Kogui, Arhuaco, Wiwa and Kankuamo groups, who conceive of territories as living entities, as spaces endowed with memory and as articulators of the sacred and the mundane (Escobar, 2018). These worldviews and knowledge that conceive life as a complex fabric between the human and non-human and that reveal the communal foundations of sociability, will be fundamental to find strategies of transition towards models of development that allow new forms of coexistence and greater caretaking of the Earth. We have access to living and active ancestral knowledge, which can stimulate the creation of other possible future scenarios that, even if they may seem unrealistic utopias, are foundational to making such alternatives credible and achievable across the country.

As suggested by Escobar, rethinking the "territorial country" means creating strategies to defend the territories (Escobar, 2014). An ecological strategy would "reduce the loss of biodiversity" and "restore ecosystemic integrity," and include "communities' right to ecologically and culturally appropriate socio-economic strategies, centered on *Buen Vivir*" (Living Well) (p.122)." A social strategy would ensure respect for the communities' rights (DESC), including the right to their territories. Political strategies must prioritize the protection of ethnic/territorial organizations, protect their leaders from harm, and strengthen the communities' own forms of government and their autonomy. A cultural strategy should "guarantee the conditions for the exercise of communities' identity and cultural practices" (Escobar, 2014, 122).

On the other hand, there is a need to promote smart specialization through contextualized policies and the investment of resources in programs that complement national productive lines of work in order to hone domestic capacities and obtain inter-regional advantages by promoting activities based on regional capabilities and preventing all regions from focusing on similar themes or niches.

These policies can focus on related diversification (encouraging activities that require similar capabilities)[15], on unrelated diversification (activities that require differentiated capabilities for implementation)[16], or on a combination of both.

The following table summarizes the conditions required to apply each of the approaches:

The success of smart specialization policies depends on the will of public policy makers, the institutional context, the degree of political autonomy, the business culture and the government's commitment. Their implementation also requires the identification of new opportunities in nearby environments and an understanding of how the regions have evolved and that capacities (knowledge, skills, networks, and institutions) condition new regional activities, and that regions tend to diversify into new economic activities related to pre-existing activities.

Finally, recognizing that our natural and cultural ecosystems are expressed in forms of knowledge that are revealed both in artistic and cultural expressions (worldview, lifestyles, music, dance, gastronomy, poetry, etc.) and in the production of goods, services, manufacturing, and industrial products, is the basis of a new narrative on the country's possibilities and on our identity.

In this sense, it is vital to promote a grammar of recognition that allows us to understand our cultural difference as wealth and possibility.

15 For example: Cars, motorcycles, trucks.
16 For example: Agrobusiness, Pharmaceuticals, textile sector.

Table 11.

Características del territorio	Políticas de diversificación relacionada	Políticas de diversificación no relacionada
Large urban regions	Provides opportunities to move into complex activities and requires similar capabilities	If there is a wide variety of unrelated activities and a well-developed research and innovation infrastructure
Former industrial regions	Provides opportunities to break innovation roadblocks and move into more complex activities	To escape the trap of a low complexity economy. Pushing more complex activities into unrelated diversification may be the only option.
Peripheral regions	Provides opportunities to develop new activities.	

Source: Authors

To this end, we must encourage the creation and circulation of regional cultural content, needed to promote knowledge of the country's cultural diversity, to provide sustainable conditions for productivity in local cultures, and to improve collective self-esteem. Cultural diversity is one of the keys to the intelligent regional specialization that the country requires as well as to recognizing the ways in which, through our own solutions from a technological, artisanal, cultural, and scientific perspective, our regions can offer innovative models of solutions to problems that are widespread in the world, which can be replicated and applicable in the creation of new types of knowledge. Therefore, positioning a country strategy for the future requires investment in regional development and the mobilization of local resources. Raising living standards and social conditions, increasing the possibilities for individual and collective fulfillment, incorporating human, economic and natural resources of each region in more efficient productive processes of direct social benefit, are goals that can be achieved by decisively assuming the multidimensionality of regional development.

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The international dimension of knowledge: Networks, diaspora, collaborations

While knowledge has no boundaries, it can be found primarily in the minds of people who, while residing in one country, often travel and migrate. For decades, developing countries have been concerned about the brain drain phenomenon that depletes their capacity to incorporate knowledge into their academic and productive activities. The first strategies to curb this phenomenon were to establish regulations so that scholars studying in other countries would be required to return. In a second stage, incentives were provided for the return of highly qualified nationals. Since the 1990s, there has been a change in how the problem is approached, and the location of scientists and engineers abroad has begun to be seen as an asset for the country, which could help the internationalization of local scientific activities, the admission of students from the country into internships or doctoral programs at leading institutions abroad. It could also support scientific initiatives and research groups emerging in the country. With the advent of digital networks, the possibilities of establishing productive links with national scientists established abroad were enhanced.

In the 1990s, Colombia experienced a singular set of circumstances, when a network of about 1200 nationals living abroad was established and consolidated, who then collaborated among themselves and with research groups in their respective fields in the country (Meyer *et al.*, 2001). The network fostered lasting links. Personal rather than virtual relationships predominated in its most fruitful years. Policy changes, inflexibility and a lack of focus on communication in the network's digital spaces caused it to wither and eventually disappear. But the formal network had opened a door and drawn a path for Colombian scientists who wanted to contribute to the country's development from abroad without having to return.

Colombian diaspora networks and collaborations of expatriate Colombians with local host groups allow them to expand access to knowledge, quality science education, publications and peer-to-peer collaborations. They also inspire future generations of Colombian scientists and innovators working in science, technology, engineering, arts and mathematics.

The benefits of the networks are exceptional (Arthur Zimmermann, 2016); in taking advantage of what the different classes of public and private actors have to offer, they promote knowledge's value as a productive factor. The programs that promote them can provide systemic value to the relationships that are established among the actors and take advantage of the potential of the interconnectivity inherent in new information and communication technologies.

Managing networks and diaspora must be characterized by the building and maintenance of trust among its members; active communication and exchange of experiences of common interest; the gradual development of the capacity to learn and assimilate new options; and the preservation of an appropriate environment, driven by strong institutional support.

We have also worked with a number of initiatives and calls for mobility implemented by *Colciencias*, *Innpulsa* and other government entities. As well as the call for funding *Es tiempo de volver* - It's time to return, intended to employ Colombian PhDs in universities, research centers, technological development centers, and companies via post-doctoral stays. A group of Colombians integrated back into the country, while another group returned to their host country, perhaps revealing that universities and companies lacked the capacity to absorb these talents and that the government, beyond the subsidies of the first few months, does not have a sufficiently solid and well-founded program to ensure their retention.

Today, a more significant role is emerging for the diaspora and for alumni associations and university graduates from other countries: under the guidance of government agencies, these networks can play an important role in science diplomacy.

Contact and interaction with these networks for academic, work, and personal purposes opens up ample opportunities to support the researchers that make up these networks and their projects, including the provision of infrastructure and equipment. Science diplomacy can promote international cooperation, bilateral and multilateral collaborations in science, research, technology and innovation to find solutions to national or international problems of common interest such as climate disasters, global warming, biodiversity loss, pandemics, and cyber security among others.

Science diplomacy complements but does not replace other mechanisms of internationalization, many of which have been employed by Colombian institutions for many years. Scientific diplomacy has an active academic, research, and business community in different parts of the world. Many of these countries and their institutions would be in a position to assist Colombia in the area of cooperation and dissemination of good practices.

The Mission proposes that cooperation and coordination mechanisms be formalized and expanded to create and strengthen networks, the scientific diaspora, and collaborations with Colombian scientists and experts abroad. This, with a view to increasing the quality of scientific research, and increasing its contribution and impact on the development of a knowledge-based economy. There is a willingness on the part of Colombian scientists, professionals, and experts abroad to share knowledge.

At the same time, a Colombian science diplomacy project should be established and developed to help open possibilities for Colombian talent abroad, to open spaces for scholarships, research, internships, resources and new job opportunities for Colombian professionals, scientists and experts, and to make it possible for Colombian researchers to move closer to the global frontiers of knowledge and participate in research programs, contributing knowledge from a Colombian standpoint. For this, the Mission proposes the establishment of missions and diplomatic positions specialized in promoting exchanges in education, research and innovation with different countries and regions and with the potential participation of the private sector.

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The social appropriation of knowledge

Science is part of a nation's culture. Ensuring that science and knowledge are circulated among the entire population is essential in a society that aspires to give knowledge a prominent role and at the same time prevent a culture of post-truth.

In Colombia, there is little infrastructure designed for the social appropriation of science. Very few planetariums and science centers have been built in the last fifty years, and, although some can be found in the main cities (*Planetario de Bogotá*, *Maloka* and *Parque Explora*), the rest of the country has no significant infrastructure for the popularization of science (Puerta, 2019).

The Mission believes that children should have the right to interact with science. In some countries this right has been established, particularly in terms of issues such as the origin of the world and life on Earth or the causes of climate change. To illustrate this lack of infrastructure, in comparison to Colombia, Japan has 950 planetariums, the United States has 350, Germany has 95, France has 75, and Brazil has 45.

Integrating science into general knowledge aids individuals and families in their daily decision-making processes and information analysis, and is also important for widening choices and improving personal living conditions (Puerta, 2019). Science and technology can inspire us at an early age, when scientific vocations and an appreciation for knowledge begin to take shape. Society's awareness of the close relationship between knowledge creation and environmentally sustainable social and economic development must be developed from childhood.

Proposals for communication - dissemination - culture

Knowledge needs to have truly permeated our society before it can be effectively used to address the country's problems. The entire society must know and take ownership of the SDG and take shared responsibility for their fulfillment for the survival of the planet and humanity.

In order to better disseminate science and scientific culture, inclusivity is key in all instances and for all of society's actors. The following proposals are presented for each case:

The community at large

- Invest in quality mass-media production with original, cultural and scientific content (especially audiovisual content). It is interesting to see how sometimes a scientifically well-founded TV program can be more successful at disseminating science or protecting the environment than any regulation. In Brazil, for example, the soap opera *Pantanal* alerted people to environmental problems. These efforts can be accompanied by the Ministry of Culture and universities.
- Improve the infrastructure for the circulation of cultural and scientific content produced across the country, thus ensuring its wide inter-regional dissemination. Only 5.7% of the country's municipalities have movie theaters, making it important to take advantage of other powerful media such as television and radio. The same is true of spaces for stage productions that have a minimum amount of equipment and technical resources. Another important aspect is to encourage proximity and cross-fertilization between art and science, as this can make experiences in specific areas of knowledge more powerful and open up new fields of research, exploration and experimentation; for example, the Genoma Music Project. On the other hand, the emblematic project of the Cultural and Creative Industries pillar, Creative Incubators, makes it possible to develop joint ventures between art and science, as well as forums, debates and conferences.
- Create a network of planetariums and other science centers across the country, such as the Museum of Cultural and Natural History. The most efficient instruments for the popularization and social appropriation of science include collections, natural history museums, botanical gardens, planetariums, interactive centers,

fairs and events with citizen participation and good quality nationwide science popularization programs.

- A number of science dissemination programs have been implemented in Colombia but with limited coverage. The idea is for culture and science to reach the greatest number of people in the country, and this requires building planetariums and science centers, which families and school children can attend daily to learn about science, technology and culture (Puerta, 2019).

Promote citizen science programs by implementing efficient mechanisms for citizens and civil society researchers to participate directly in knowledge creation through dialogue and online citizen science forums. One option is to promote these strategies through science parks and the Museum of Natural and Cultural History, thanks to the multiple tools made available by new communication and computer technologies for exploring, for example, natural resources and life support systems in different regions, as well as topics that relate to the daily lives of citizens such as chemistry and cooking.

Educational Institutions and Higher Education Institutions

- Changes should be made to the curriculum at all levels, including early childhood, that portray the concept of science as a form of knowledge building. This should cover the twelve years of school education. Two projects were implemented by the previous Mission: the Young Scientists Program and the General Education Program called ‘Cosmology’, which failed due to lack of continuity and support from the Government. The overall objective is to encourage a true scientific culture in the students from an early age that will help them to understand how the world and life works, as well as the usefulness of science for the development of our society and our future. Another strategy is to create “love, passion, fascination” programs about science for teachers. In other disciplinary fields, it is important to create experiences based on the senses that guide appropriation using the emotions; for example, the Journey through

Music Project (*Proyecto Viajeros de la Música*), which created a network of more than 1000 teachers in Bogotá. Support should be given to the creation of joint programs between educational institutions and institutions dedicated to scientific training through pedagogical routes, development of materials, participation in activities in the field, and insertion of students in institutional practices. All such actions can strengthen appropriation of any area of knowledge, as in, for example, the Pedagogic Toolkit Project (*Proyecto Maleta Pedagógica*). It is important to create networks for teamwork between the Ministry of Education and the STI Ministry to strengthen models similar to those implemented in programs such as the school city – city school (*escuela ciudad – ciudad escuela*) program.

- Government funds are needed for universities to mentor basic and secondary education institutions and accompany their scientific and cultural teaching. This can encourage field work in educational institutions by including scientists in different activities in schools, such as conversations on topics of interest or the promotion of science fairs. Beyond changes to the curriculum, the ongoing relationship between scientists and educators must be reinforced. To foster links between researchers, teachers and students in basic and secondary education, it is possible to implement programs involving researchers, master's and doctoral students in different activities at educational institutions, such as conversations on topics of interest (for example, in a similar vein to the Scientists go back to school (*Los científicos vuelven a la escuela*) at Parque Explora) or the promotion of science fairs. From this, a research model must be consolidated as a pedagogical strategy. This has so far been led by the Waves (*Ondas*) Program, and it must be renewed and reinforced.
- Improve science communication.

    - Introduce courses in science and understanding of statistics in the general journalism curriculum.

- Create specialization and master's courses in science communication, short courses or diploma courses in science for journalists, and create short courses or diploma courses in journalism for scientists.
- Fund internships for qualified science communicators to gain experience in research centers and universities.

Decision makers and entrepreneurs

- The Ministry of Science, Technology and Innovation must establish communication channels with decision makers from other sectors of the government; for example, frequent meetings with senators.
- The Ministry of Science and Technology must establish agile and timely channels of scientific communication with those who have the capacity to develop regulations, make decisions or apply innovation.
- The Ministry of Science, Technology and Innovation must demand accountability from decision makers and political authorities regarding the incorporation of science, research and culture as engines of development into their political agendas and programs.
- An example would be the decisions and actions related to the search for solutions to the climate crisis, global warming and the reduction of biodiversity, all caused by human activities. Likewise, decision makers should be briefed and informed so that they can contribute to the fulfillment of the commitments made in the Paris Agreement, mainly in relation to the achievement of the SDG.

Scientific Community

In all its public calls for funding – and preferably also private ones – the country's Science, Technology and Innovation System should include a requirement for the researcher and their team to commit to scientific dissemination and popularization tasks through non-scientific channels. This, in order to communicate to the general public the importance and need for the proposed research, along with its results, explained in a simple way and with accessible language. Between 2012 and 2016 less than 1% of the products of the country's research groups were shared and socialized in spaces for citizen participation in STI. This is of special concern since leading countries had a greater number of publications indexed with collaboration from companies and a greater scientific impact on these companies (PND, 2019). The scientific community must also participate more actively in the public debate on its specialty topics and raise awareness of sustainability in society.

Transfer

By fostering relationships between universities/research centers, the government and the private sector, little by little, society will perceive the importance of science and technology. They will have seen evidence of how research results have important applications in the medium and long term, and that the growth of the productive innovation infrastructure has a direct impact on the country's population through employment and environmental, social and economic wellbeing in the regions. The great challenge is to extend these benefits to the whole of society through the social and cultural appropriation of STI in its broadest sense. We must take advantage of the availability of technologies with the potential to positively impact various dimensions of people's quality of life.

Proposals

a) Implement a system of incentives for companies, for example, through tax benefits (reinforcing those that already exist), which not only derive from investment in technological innovation, but also from financing studies at universities, from hiring people with doctorates, among others.
b) Formulate a series of actions to bring universities and the organizations closer together, design a governance scheme and funding schemes for research aimed at companies. For example, it would be a good idea to rescue the "business panels" that are organized in the regions (mostly annually) as a mechanism for bringing companies and universities together and creating joint plans.

These initiatives should be supported with more State instruments. There are a few University-Business-State initiatives that have emerged as platforms for making new contacts, but they need to be improved and expanded. Instruments of direct financing by the State are required, so it is necessary to design different plans based on co-financing or loans for knowledge-based innovation processes.

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Failures and necessary changes in policy formation and implementation

The Government can lead the STI agenda with four sets of measures: (i) defining policies and programs with horizons beyond a period of government, ensuring a continuous and broad dialogue with stakeholders, and implementing impact measurement to achieve social support and legitimacy; (ii) increasing public funding in basic science and in co-financing of pre-competitive research and development and startups; (iii) creating a governance of the STI Ministry that creates spaces for dialogue among actors to define research agendas, incorporates instruments to develop projects (centers + missions), and plays a strong role in obtaining funds, incentives, and structuring projects; and (iv) reducing regulatory barriers that inhibit project development.

The first measure will mean that public policies and their regulations will exclude short-term sector policies, which are easier to implement than long-term, multi-sector, integrative policies, whose fundamental goals are the social sustainability of society. Long-term regional and national policies should be the result of management and planning in conjunction with society, allowing for participation and agreement among the different stakeholders, in order to guarantee their legitimacy (Guhl & Leyva, 2014). In addition, the fact that national development plans are not well articulated throughout the different spatial dimensions of a country leads to the belief that they respond to short-term political interests and that they have been imposed authoritatively on the regions and municipalities (Guimarães, 2003). The second measure, as argued by Mariana Mazzucato, should arise from the understanding that there is no alternative to growth and that taking risks has great social returns. The third group of measures is largely presented in other sections. This section outlines proposals focusing on the general framework for State action on STIs and on proposing measures to reduce regulatory barriers.

General framework of action for the development of STI

Given that each government has a four-year horizon, there is a risk that STI activities of high social value, which have long gestation times, will be neglected. Strategies that can help STIs gain a long-term perspective include the following:

a) *The use of Missions with extensive and linked goals*, which could be connected to the SDG; this would also give science, technology and innovation activities (ACTI) international visibility. The Conpes-SDG, in which the national 2030 goals are prioritized, transcends the present government and should be articulated with at least the next two national development plans. By doing so, it can be consolidated into an environmental management model that integrates the responsibility of the public sector, private sector, and civil society in achieving the SDG. In fact, along with commitments made long ago—essentially an argument for what has not been fulfilled on a global scale—the SDG pose two fundamental challenges: (i) linking environmental and sectoral policies with common sustainable development goals for the next 12 years, and (ii) regionalization of the SDG to take into account the particular sustainable development needs of each region. It should be noted that the Conpes-SDG document prioritizes 156 SDG indicators and 147 goals, but commitment to the SDG is the most ethical route to take, as many environmental promises that have been signed but not fulfilled have already been ignored.

b) *The implementation of mechanisms for dialogue with broad social and economic sectors to agree on long term programs*, according to the proposed structure of the STI Ministry presented in the governance section. These programs must respond to the collective needs or goals of the country's regions, which implies, as proposed by Muñoz-Gaviria (2011), a consensus among the actors in the recognition of these goals and for which democratic spaces must be created, where the State will participate as a facilitator. Thus, the government must be able to advance the needs identified as priorities by society in the political agenda or propose others, with participation and consensus as a fundamental premise, so that the resulting public policy enjoys legitimacy (Muñoz-Gaviria, 2011). It is worth mentioning again that these programs cannot be linked to four-year government policies. In terms of solving problems, this is a very short period of time that in Colombia's case has not provided solutions, as the governing parties and their agents become short-sighted or develop solutions to issues that, in most cases, are circumstantial. This has meant changes every four years, according to the particular interests of the government in office or the supposed fulfillment of its government plan.

c) *Evaluating and measuring the impact of STI policies and investments is essential to ensuring their legitimacy and continuity*. The types of evaluation can cover a wide range of issues[17]. Because resources are scarce, it is crucial to focus on three fundamental aspects on which the survival of the Ministry and the STI programs will depend: (i) the production of scientific knowledge, (ii) impact on economic productivity, and (iii) ability to multiply and manage resources through combined financing. This, in turn, will lead to recommendations that seek to increase the effectiveness and efficiency of the actions of the ministry or government in power. Assessment processes must move away from the traditional scheme of being the last step in the life cycle of the implemented policy. On the contrary, they should be transversal and carried out before, during and after the implementation phase. Colombia traditionally measures actions, but not impacts, the latter being the most relevant. For example, the Ministry of Environment and Sustainable Development (MADS) wrote a report for the DNP in 2018, on the progress of its environmental policies in 2017; and expressed the following:

17 Evaluation of design; of consistency and results; of processes; of impact; complementary; strategic; of performance; of cost-effectiveness; of beneficiaries' perception; of gender perspective.

> The analysis of the progress of the actions associated with the goals or strategies of thirteen policies presented in the second semester of 2017, presented an average of 94% progress compared to what has been programmed in the current period. We can see that each of the policies has been worked on in terms of its related actions. However, it should be noted that the follow-up reports fail to take into account the impact where the beneficiaries are located (population, sectors, territories, among others), as well as the purpose of the regulations and their implementation.

The lack of knowledge in terms of the impact on the beneficiaries (population, sectors, territories, among others) can lead to a deterioration of State institutions, natural resources, and insurmountable conflicts between different actors in society in general. Carrizosa (2014) points out, in an insightful analysis of the current situation, in the specific case of problems in environmental management, that,

> Over the last twenty years, there has been deterioration due to two types of enrichment: illegal and easy. The former affected everything from site-specific deforestation control activities to the normal functioning of entire corporations, and today it is still a major and direct factor in environmental deterioration in regions affected by gold extraction or deforestation to plant crops or turn coca into cocaine. Easy enrichment continues to influence the ongoing confrontations between economic projects that use natural capital to obtain quick and high returns and those which enforce regulations that protect ecological heritage.

a) *Rationalization and integration of Conpes documents,* allowing the different public policy instruments, as well as the entities from different sectors that will lead their implementation, to be better articulated. For example, between 1967 and 30 June 2019, 4144 Conpes documents were issued (see Figures 15 and 16)[18]. Between 2016 and 2019, 194 economic Conpes documents were issued and between 2011 and 2015, 90 social Conpes documents were issued[19].

18 See https://sisconpes. dnp. gov. co/SisCONPESWeb/
19 See https://www.dnp.govco/CONPES/documentos- conpes/Paginas/documentos-conpes.aspx.

While the MADS records on its website that between 2006 and 2018, 19 Conpes documents were issued on environmental issues and renewable natural resources.

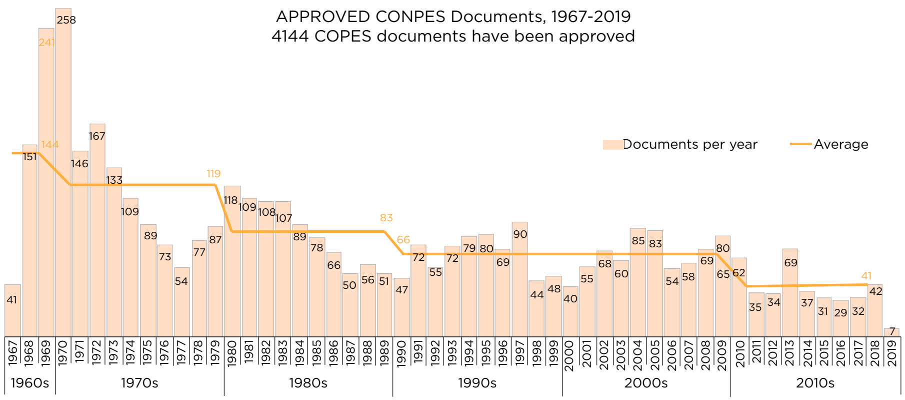

Figure 15. Conpes documents approved between 1967 and 2019
Source: https://sisconpes. dnp. gov. co/SisCONPESWeb/.

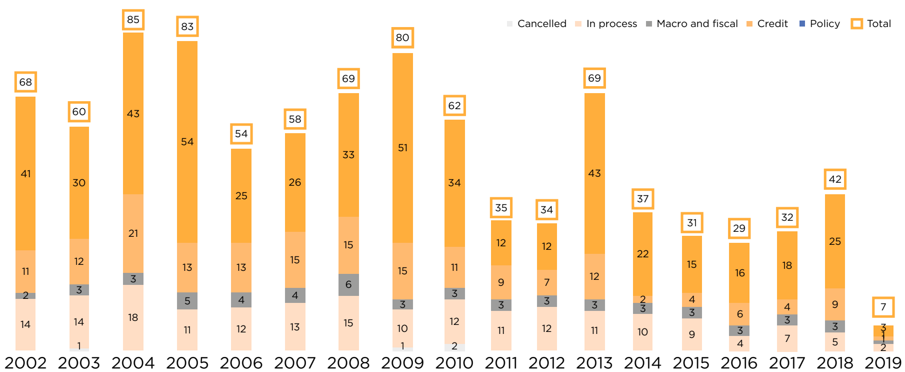

Figure 16. Conpes documents CONPES approved from 1967 to 2019
Source: https://sisconpes. dnp. gov.co/SisCONPESWeb/.

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Reduction of regulatory barriers to the development of science in Colombia

In practically all of the consultations and forums held between the Mission of Experts and the scientific community and other civil society agents, it has been pointed out that inadequate regulations and the consequent bureaucratization of administrative processes are serious impediments to R&D activities. The lack of a tradition of scientific research in Colombian public administration, and the fact that those who create the norms and apply them do not have experience in the field of science or know of any successful foreign models, has led to cumbersome regulations and customs that further complicate the administration. This is aggravated by the fact that in Colombia, the public administration approach is more concerned with preventing improprieties and criminal activity than with promoting efficiency.

In an environment of great fear of corruption, it may seem contradictory to advocate for trust and efficiency as guiding parameters. However, at some point we must recognize that if there is no trust, it will be near impossible to promote science, and if Colombia's administration is lacking in efficiency, it will not be competitive in a global environment that promotes invention and innovation as the foundations of the economic competitiveness of nations, regions, and communities.

Thus, we believe that it is important to make the country realize that these procedures diminish our ability to conduct research and therefore put us at a competitive disadvantage with the rest of the world. In an environment of mistrust, inefficiency is promoted, and the country's huge advantages are diluted, and sometimes paradoxically become additional impediments, as has happened with the restrictions on using natural samples – genetic biodiversity resources – in scientific research. Following a description of the different normative barriers, we will propose some modifications through which we can attempt to overcome them.

a) Framework for the administration of scientific projects and programs. Science and technology laws (Law 29 of 1990 and its regulatory decrees and Law 1286 of 2009) have opened up the possibility of applying a framework of private administration to science, technology and innovation projects. Some institutions have taken advantage of this prerogative, which gives them greater agility in operations that would be severely hampered if they were subject to the limitations of public administration.

   It is not a question of wanting to have special privileges, but of recognizing the specificity of research activity. A research contract is very specialized; it will demand the purchase of hundreds of sophisticated inputs, often from the single supplier that manufactures them, or there might be subtle differences in the equipment that, if missed by the non-specialist, could make a purchase a total loss. Sometimes the compatibility of branded equipment from a single supplier, a reagent's degree of purity, or one's trust in a maintenance service, is much more important that the usual cost/price and specifications analyses. The appropriateness of an acquisition can make the difference between success or failure. However, the use of the private administration framework has been very limited.

Colciencias itself has only partially used it, and universities and public institutions have been overly reluctant to try it. One of the reasons for this is that control agencies, public prosecutors, comptrollers, and public officials do not fully understand these provisions and see them as a means of escaping control and a risk factor for corruption, rather than a necessity for efficient and competitive work.

This lack of trust, which sometimes takes the form of disciplinary, fiscal and even criminal investigations, intimidates administrators, who therefore prefer not to take risks, giving up the option of greater efficiency and competitiveness. This same fear makes decision making more difficult, often resulting in unnecessary internal consultations and the need to be given clearance, so that responsibility (or blame) can be shared.

Consequently, an instrument that would simply put our researchers on an equal footing with their colleagues (and competitors) from other countries is left unused.

Recommendation 1. Take up the provision of Law 29 of 1990 (developed in Decree-Law 591 of 1991), Law 1286 of 2009 and its regulatory decrees, and Law 80 (Article 24c allows direct contracting for S&T) to apply the private contracting framework to STI projects. Regulate this provision explicitly and in detail. The regulation needs to be so explicit that it leaves the control agencies with no doubt as to the feasibility of its use.

b) Budget period. The Francisco José de Caldas Fund is not subject to the annual budgetary period. The General System of Royalties S&T fund has adopted biannual terms (somewhat better than annual terms, but still insufficient). The reason for these provisions is that science, technology and innovation activities cannot be subject to such short periods. Research rarely lasts one year; it usually takes several, more so if it is of national or regional impact. Annual periods do not ensure implementation, but often lead to poor execution. The need to hire or buy in a hurry before the expiration of the term induces bad spending. Often there are periods of paralysis at the beginning of the year that last for months and are highly wasteful of professional work time and lead to lost opportunities. Scientific work demands continuity, without which great efforts are often lost and work has to be restarted.

Despite these considerations, most State budgets for science, technology and innovation are subject to single-year budget periods. This is true for ministries, governorships and municipalities, national and regional institutes and centers, and even for higher education institutions that conduct research and which also apply civil works procurements, prohibit advance payments, and sometimes demand monetary compensation.

Again, it is not a question of requesting special privileges, but rather of recognizing the specificity of an activity that is hindered by short budget execution periods that in the long run lead to direct losses and disadvantages in competitiveness and opportunity.

Recommendation 2. Regulate multi-year implementation periods for scientific research activities and for the public institutions that carry them out, and apply science and technology procurement rules in all public institutions.

c) The presentation of projects, and terms of calls for funding. Calls for funding and presentation conditions should respond to policies and be fixed by non-general guidelines or instructions. An exception to this has been the science, technology, and innovation projects financed by royalties. At the moment, those projects that are generally of high complexity must be formulated with the Adjusted General Methodology (MGA). MGA could be appropriate for National Planning Department investment projects, but these are very different in nature from science, technology, and innovation ones. The imposition of an alien system on STI activity creates serious management restrictions, and ultimately harms the project rather than aiding its organization. It reduces projects' flexibility, and their capacity for responding quickly and imaginatively to the problems that arise, which in research are usually unexpected. Monitoring of implementation is equally cumbersome and totally incapable of distinguishing between what is a failure and what is only a recursive change in the face of unpredictable problems. In fact, the inadequate execution of these resources (which recently led to a temporary reform of the Constitution to allocate a part of those resources to the construction of tertiary roads) was not due to a lack of projects and ideas. The percentage of project approval in the normal *Colciencias* system is very low, at less than 8%, and in many calls for funding there have been projects that have been technically approved but which cannot be financed due to lack of resources. The main reason for low project implementation is undoubtedly due to the format required to present and monitor projects, concerning which researchers receive no training whatsoever, leading to them feeling overwhelmed and intimidated and preferring to refrain from making proposals at all.

Recommendation 3. Adjust the regulations for the presentation of projects for science, technology, and innovation activities only. Modify the MGA system used in projects financed by royalties, with the agreement of the STI Ministry. Make it so that the equipment and supplies acquired are the property of the executing entity.

d) Project monitoring. Project monitoring financed by *Colciencias* and other state institutions is inconvenient, and generally contradictory to the very purposes of the project. There are two evaluations that are conducted separately, the first is a technical evaluation conducted by the financing entity that superficially studies whether the “measurable” commitments have been fulfilled. There is no analysis of the quality of the results and restrictions are introduced that could create inconveniences, and even have negative ethical implications. For example, if a project proposes that a student should be trained to a doctoral or master’s level, the researcher is practically forced to approve his or her thesis even if the student does not meet the requirements, because otherwise the failure is regarded as being the researcher's. If researchers propose to publish a certain number of articles, they are obliged to publish that number, even if, in other circumstances, they would prefer not to do so until they have better consolidated the results. In this way of evaluating, a really remarkable result that in other areas would be highly valued, would not compensate for the non-fulfillment of a minor condition.

The second evaluation is financial and is conducted by an independent body that manages the funds: a trust or a management fund. This evaluation uses the initial budget not as an indicator but as a contractual commitment of expenditure. This leads to absurdities such as requiring the purchase of obsolete equipment because it was proposed years earlier when the project was written, not knowing that better equipment would be developed, or prohibiting the purchase of inputs not included in the original proposal because the research needs changed as a result of results obtained. In short, the analysis is very rigid, and does not take into account the high levels of uncertainty that research can give rise to, especially if it is a cutting-edge project. The current system discourages the presentation of original ideas (which carry a greater risk) and encourages routine and repetitive proposals.

Recommendation 4. Modify the scheme for monitoring and evaluating research projects in accordance with the flexibility that scientific research processes should be granted. Projects should be assessed by the quality of their results but in a very flexible way, considering the risk implicit in this kind of research. The initial budget should be used in the evaluation to check the practicality and seriousness of the proposal, but it should not be used in the evaluation as an inflexible spending commitment.

e) Counterparts and overheads. Research overhead is a policy that was introduced in the United States and Europe to stimulate research activity. Funding agencies (mainly from the government, but also from private funds) add a sum that can be between 40-60% of the real cost of research and that can be used by the executing institution to cover indirect expenses, but also to reinvest in common infrastructure (buildings, libraries, equipment, networks, etc.) that will benefit scientific activity in general and not just the specific project at hand. Despite making projects more expensive, this initiative has made researchers very attractive to institutions because they improve their financial situation and their scientific and academic potential.

In transnational loans and grants and in international cooperation projects, the recipient country is often required to cover part of the project costs, usually staff and indirect costs. This is called the nation's counterpart funding.

The first research efforts organized from within *Colciencias* in the second half of the twentieth century were supported by loans from the IDB and the World Bank, and counterpart funding was required but applied to the institution receiving the funding. The overhead figure was not included, and it is only very recently that *Colciencias* projects have started to recognize some indirect costs, but at less than 10% of the value of the project, which in most cases does not even cover the real indirect cost.

Thus, in developed countries the overhead system promoted science by making researchers very desirable to institutions, while our system makes researchers much less attractive as they have to request additional funds and counterparts to complete the cost of their projects. The overhead policy is undoubtedly successful. Although it makes projects more expensive, it provides a stimulus that, in a very short time, compensates for the higher costs with developments and innovations.

Recommendation 5. Adopt the overhead system (in amounts that realistically cover indirect costs at minimum) for projects financed by the State from its different funds.

f) The concept of risk investment in research. Our legislation does not contemplate the possibility of incurring risk. An official who takes on risk can be investigated by the control bodies and punished very severely. Every state-owned company is required to carry out a preliminary study, and if the results of the work are different to those projected, the person responsible can be accused of having conducted a flawed study. This may be convenient in construction contracts, but it is fundamentally opposed to the very nature of research which is a risky activity in itself. If one could predict the outcome of a research project with a preliminary study, then to actually conduct the research project would be unnecessary.

The only way to propose a safe research project is to renounce originality and revolutionary ideas. A project that repeats in a new location what has been discovered in other places can be useful because it provides location-specific results, and a partial modification to something developed elsewhere can be useful because it advances science incrementally. But something totally new and different is always high risk. A radical innovation can be completely excluded by this system.

Something similar happens with funding and investment in innovations and inventions. There is no way to know whether these will work before making the investment. In fact, there are fields, such as the development of therapeutic molecules, in which it is known that a very small fraction of the molecules tested become a marketable product. Of course, the return on them is considerable and in the long term compensates for the cost of failed attempts, but there is no way of knowing what the successful attempt will be without testing many that turn out to be unsuccessful.

This necessarily leads to the conclusion that the safety standards to which the State's public works projects are subjected do not suit research and innovation projects, and are in fact a very serious impediment to their success.

Recommendation 6. Review of the standards or guidelines that require preliminary studies in the case of research and innovation projects. Consider establishing risk funds to support science, technology and innovation projects.

g) Intellectual property regime. In 1980, the Bayh-Dole Act was enacted in the United States, according to which, beneficiaries of State funds for research and development activities have the right to patent inventions and grant licenses to companies. These beneficiaries are mainly universities, research institutes and centers, and the researchers themselves. The purpose of this law was to promote the exploitation of the results of state-funded research by transferring ownership to the institutions that did the research, which were then free to negotiate such ownership with companies. The law has been debated and should be evaluated.

Recommendation 7. Analyze and rethink the intellectual property regime considering the following parameters:

- The role of copyright must be re-evaluated to allow the effective transfer of knowledge to society.
- Incentives for patents produced in universities and research centers should be linked to transfer via mechanisms such as licensing, spin-off creation, and others. Permanent incentives to patent without seeking transfer should be re-evaluated.
- Intellectual property policies should promote Open Science, which is the global trend in the face of the emergence of multinationals that make use of data produced with public resources.
- Higher Education Institutions must offer permanent training in intellectual property and copyright.
- The National Government must encourage the creation of Knowledge Transfer Offices, avoiding monopolies and encouraging competition in higher education institutions and in the regions to support the transformation of the country into a knowledge-based society.

h) Management and licensing of genetic resources. Non-commercial contracts for access to genetic resources or derived products for basic science in biodiversity. Colombian regulations for biodiversity studies have strangled non-commercial basic sciences dedicated to the study of genetic resources and/or products derived from wild species, ordering the mandatory signing of an access contract before initiating research activities. This contract issued by the Ministry of Environment and Sustainable Development (MADS), not designed for the exercise of basic science-related activities, is usually ineffective, complex, and time-consuming to issue (taking one or more years) despite recent modifications in the use of institutional framework contracts. It also impedes research efforts, which are subject to drastic sanctions such as costly fines, public disrepute, and even imprisonment of the offending scientists.

The processing and approval of this contract for access to genetic resources and derived products, applies to all areas of basic knowledge for non-commercial purposes, with the exception of molecular systematics, molecular ecology, evolution and biogeography (Decrees 1375 and 1376 of 2013, Article 4, paragraph 1 and Article 2, paragraph 5, respectively). However, a later MADS Resolution (1348 of 2014), expresses the tacit prohibition of research in the first two areas mentioned (a contradiction in the law), pointing out that basic research (molecular systematics and ecology are basic areas) cannot be conducted on native species (wild, domesticated, cultivated or escaped from domestication) without the mentioned contract, nor can there be access to products derived from them such as DNA, RNA, nor micro and macromolecules produced in their metabolism. How to study molecular ecology and systematics without isolating the products of species' metabolisms is not clear.

Nor is it clear that Colombia's scientific participation at the cutting edge of knowledge is limited unless the aforementioned contract is signed. For example, for the study of omics, in which access to genetic material (DNA and RNA), proteins, enzymes, micro or macromolecules allows us to learn about the genome, proteome or metabolome of species and functional genomics, and based on this knowledge we can optimize strategies and plans for species conservation and management. Thirdly, it is not clear why a contract has to be signed to use three-dimensional models to study genetic resources, to, for example, predict the structure and function of proteins in order to understand gene-disease interactions, or to access valuable knowledge on biogenetic pathways in species that provide the foundations for the much sought-after sustainable use of our species. These are just some of the stages required prior to starting the bioprospecting process in pursuit of a sustainable bio-economy, to which the country has committed itself in the National Development Plan 2018-2022. These are works of basic science that can support the initial platform of the sustainable bio-economy, but that are needlessly being tied up by procedures to access genetic resources. Simply put, without basic science in biochemistry, biology, chemistry, pharmaceutical chemistry, and microbiology among others (advances in the chemistry of natural compounds), Colombia will not contribute to global scientific knowledge, despite having one of the greatest biodiversities on the planet. What a contradiction! We have this megabiodiversity at our fingertips, and to study it will be a mammoth task.

Recommendation 8. Reform MADS decree 1375 of 2013, article 4, paragraph 1, which regulates the collection of specimens from biological collections for non-commercial scientific research, and decree 1376 of 2013, article 2, paragraph 5, which regulates basic scientific research carried out with a permit to collect wild specimens of species of biological diversity for non-commercial purposes, and clarify in paragraph 2, Article 2 of Resolution 1348 of 2014, that basic scientific research for non-commercial purposes cannot be considered as accessing genetic resources nor derived products.

i) Import barriers for reagents, equipment and research inputs. One of the low-cost initiatives for the State that could provide significant support for scientific research would be the rationalization of legislation related to the import of elements necessary for scientific research and the institutional coordination of the entities responsible for this legislation. Today there are several different ones, e.g., DIAN, national customs, Invima, INS, etc., and these each make different demands, which makes research more expensive and less competitive, and puts people with little specialized knowledge in charge of technical affairs that require great expertise.

Recommendation 9. Rationalization of requirements for importing materials and laboratory equipment. Effective mechanisms should be created for the nationalization of equipment for scientific research and exemptions to them. The DIAN should have a liaison mechanism that provides direct contact to universities and scientific institutions. This office should have the technical capacity to understand both the scientific and administrative aspects of nationalizations. The importation of scientific equipment should be subject to different priorities. Tax exemption mechanisms should be made before payment, not after payment, as these cause projects to incur financial imbalances. Exemption should be total and automatic as they are State resources for a research project.

There should be an openness to the import of controlled inputs. Currently, there are limits on an average of 500 substances in liters and grams. Import regulations should be more flexible when materials or equipment are destined for universities and research centers and institutes, and supported by research projects.

j) Licenses and technical standards for production. Companies that work on technological developments, especially the pharmaceutical firms and those that produce special equipment, encounter enormous limitations and difficulties in obtaining licenses, causing them to lose any possibility of competing nationally and internationally. In the case of the pharmaceutical and biotechnological industries, Invima licenses and registrations, especially for new products, are extraordinarily difficult to obtain and their issuance takes a very long time. Industries that produce new high-tech electronic and mechanical equipment face the serious challenge that, by definition, technical standards do not exist for a new product that is not on the market, and in the absence of that standard they cannot certify compliance. Designing and approving a standard takes such a long time that entrepreneurs are generally discouraged from undertaking the process, and, if they do, by the time the standard is issued, they will have lost all competitive advantage.

Recommendation 10. Review the State's registration and licensing processes for new products. In the case of Invima for pharmaceutical and biotechnological products, and in the case of the technological industry, the difficulties with and the obligation of obtaining technical standards for new equipment and the way these are issued must be reviewed.

k) Public-private partnership regime.

Recommendation 11. Public-private partnership mechanisms have been explored little for the creation of consortia in the development of strategic programs, such as the missions themselves. Since Decree-Law 393 of 1991, this possibility has been regulated. Effective mechanisms should be established to encourage this type of association through tax exemptions and legal security. Participation in large international and national projects with public-private partnerships cannot follow the same rules as infrastructure projects.

l) Researchers' Statute. Researchers working in public institutes and centers whose main mission is scientific research are subject to the same framework as civil servants as defined by the National Department of Public Service. This implies, first of all, that their salaries are very low, much lower than those paid at public and private universities, their career track does not allow them to be evaluated for advancement based on their productivity, and there is no real or normative equivalence with those who exercise similar functions in public academic fields. It has often been proposed that a research career path be created with characteristics that are different from those of a civil servant, and that responds to the specificity of this work and encourages ties with State institutions that carry out research. Today the situation discourages these researchers who end up migrating, as soon as they can, to other social sectors, often abandoning promising careers and wasting important training efforts.

Recommendation 12. Establish a research career in public STI institutions that includes a category for support technicians, with specific salaries and possibilities to advance in the career through productivity evaluation, within the National Public Administration System.

m) Investment by ministries and other public entities in scientific research. The possibility of increasing the allocation of State budgets for scientific research is hampered by the chronic lack of resources (which will not change in the coming years). Most ministries need to conduct serious research in their field; some do so sporadically, others expect it to be funded by outside resources, which may not exist, or which would detract from the financing of other equally important issues. Ministries can be understood as large companies with complex goals. Regardless of location, such a company is destined to fail if it does not devote a part of its investment budget to research. It would probably not be too burdensome to stipulate that a percentage of the investment budget should be dedicated to solving the problems of ministries and other entities, which require an increase in the knowledge available to them. Usually, a technological development must be presented as a purchase of equipment with all the difficulties that this entails. This allocation would involve only a small percentage of the budget and with the coordination of the STI Ministry could be seriously enhanced by teaming up various ministries who have similar or complementary problems. Articles 4 and 7 of Law 29 of 1990 give the Ministry the tools it requires to act in this direction.

Recommendation 13. Establish as a rule that a percentage of the investment budget of ministries and other public entities be dedicated to scientific research.

Recommendation 14 Review the indicators used by *Colciencias*, the Science and Technology Observatory, and other entities in order to adapt them to the national reality and the changes of the modern world.

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Reflections on each area of the Mission's pillars and proposals for reform

Reflections of the Bioeconomy, Biotechnology and the Environment pillar and proposals for reform

Main conclusions and recommendations for the Biotechnology, Bioeconomy and Environment (BBMA) pillar:

a) The bio-economy constitutes the conceptual and political framework for Colombia's sustainable socioeconomic development, and supports it using a territorial approach and biotechnologies that add high value to the country's extraordinary biodiversity.

b) Scientific knowledge for the implementation of the SDG, a territorial approach, the conservation of biodiversity, and the sustainable use of ecosystems are the fundamental pillars of environmental management and the development of the bio-economy.

c) Biotechnology is the key tool for discovering and developing an extraordinary range of processes, bioproducts, and innovations and for boosting the productivity and efficiency of agriculture and bioenergy, guaranteeing Colombia's food security, and solving environmental, health, and industrial problems.

d) Climate change and the destruction and degradation of ecosystems are the main cause of biodiversity loss, as well as a threat to development and quality of life. Accordingly, we must promote STI in order to understand the causes and consequences, and propose solutions to these challenges.

e) Investment in STI should be increased in BBMA areas, with an emphasis on supporting National Environmental System research institutes, research groups in universities, and national and regional public and private research centers.

f) The search for solutions to Colombia's environmental problems requires the establishment of specific research programs focused on relevant issues such as water, forests, and reducing deforestation.

Context

For the Bioeconomy, Biotechnology and Environment (BBMA) pillar, the development of the Bioeconomy should be the key public policy that contributes to the fulfillment of the Sustainable Development Goals (SDG), as well as the achievement of the sustainable, inclusive and comprehensive development of the country's different regions and the wellbeing of their communities. This approach comprises not only the sustainable use of Colombia's natural resources, but also requires knowledge of its biodiversity for the conservation and restoration of the country's ecosystems, and the implementation of sustainable biotechnology-based production systems through cascading processes that maximize the potential of biodiversity.

The BBMA pillar defines the bio-economy as "the production, use and conservation of biological resources, including related knowledge, science, technology and innovation, to provide information, products, processes and services in all economic sectors, in order to move towards a sustainable economy" (GBS, 2018). As a State policy, this strategy provides the mechanism required to take advantage of all available natural resources by incorporating knowledge and innovation into production, as an accelerator of the country's territorial development. This approach therefore harnesses environmental and nature-based solutions, whose main tool is biotechnology (use of organisms, processes or biological systems to obtain goods and services).

The adoption of the bioeconomy framework is strategic and timely in integrating the goals for environmental sustainability and human wellbeing, informed and guided by advances in scientific knowledge and technology. The bioeconomy constitutes a model of socioeconomic and productive development that reduces dependence on fossil fuels and promotes production through the use of knowledge on biological resources, processes and principles in all sectors of the economy: agriculture and bio-inputs, food, fibers, new materials and compounds, pharmacology and health products, cosmetics, industrial bioproducts and bioplastics, products based on biomimetics, bioengineering, and bioenergy among others.

The bioeconomy requires accelerated transformative change that combines advances in environmental, biological, chemical, physical and digital sciences (World Economic Forum, 2018), divided into six tracks: (1) sustainable use, valuation and conservation of biodiversity resources; (2) eco-intensification for sustainable agriculture; (3) biotechnological applications (products and processes); (4) ecosystem services; (5) efficiency in value chains; and (6) biorefineries and bioproducts. In order to achieve this change, articulation of State institutions, the STI system, the government, industry and civil society must be guaranteed.

At the same time, the bioeconomic approach will improve the quality of the environment and promote the population's wellbeing, which gives knowledge added social value. The rationale of this comprehensive approach to the sustainable use and management of natural resources is a thorough understanding of the spatial-temporal dynamics of the country's ecosystems and living organisms (including social systems) and their interactions. This knowledge should constitute the basis for a scientifically informed process of decision making and definition of public policies that allow for social, environmental, and economic sustainability in Colombia.

Scope

Colombia's natural capital, with its immense biodiversity, is the country's main asset and it represents the most extraordinary present and future wealth. Consequently, it is essential to bolster scientific research and innovation to improve knowledge of this natural capital and use it for restoration, conservation, and sustainable use. As such, the aim of the

BBMA pillar is therefore to maintain the health, diversity, and services of ecosystems and life support systems, while ensuring their sustainability. The scientific research required for productive change within the bioeconomy involves a wide range of fundamental sciences (hydrology, climatology, oceanography, meteorology, biogeochemistry, geomorphology, pedology, earth system sciences, ecology, biology, genetics, physics, chemistry, bioengineering, mathematics, probability and stochastic processes, and computer science), socioeconomic sciences, and a broad spectrum of engineering and research tools including omic technologies (DNA and RNA sequencing, proteomics, metabolomics, etc.), big data, artificial intelligence, machine learning, deep learning, the Internet of things, computing, robotics, nanotechnology, and synthetic biology among others.

The interdisciplinary approach necessitates a scientific research agenda that includes (1) data monitoring, collection, storage, and quality control, in addition to inventories and collections of natural resources; (2) diagnosis and understanding of mechanisms, processes, and chains of causality, as well as their feedback; (3) capacity for prediction/prognosis and design of new processes and products; (4) tools, models, and cooperation between science and technology to transform basic knowledge into productive processes; (5) pilot projects; and (6) interaction and articulation with private enterprise and State agencies in the field to incorporate knowledge into sustainable productive systems.

Regionalization

By the same definition, the development of the bioeconomy requires knowledge of the geophysical environment and the biodiversity it supports regionally and locally. This requires strong support provided by the funding of scientific research, technological development, and innovation programs in different Colombian regions and territories by national, departmental and municipal governments. In addition, academia, the private sector and society must be actively involved. An effective cooperation mechanism would be the establishment of academia-industry-State-society committees to help define the STI agenda in the country's different regions.

Internationalization

Science, technology and innovation have no borders, which is why we have to advance in terms of Colombia's active participation in networks and scientific research groups of the highest level around the world, given the complexity and global nature of environmental problems. It is fundamental to establish and improve international cooperation agreements between Colombia and other countries, with top-class research centers and laboratories. This will promote the transfer of knowledge, giving it an added value: scientific discussion among peers and enhanced research results, in addition to reinforcing technological development and innovation in BBMA issues. This also opens up possibilities for Colombian research to adapt new products, tools or processes developed for northern countries to the conditions and demands of the tropics with the potential for export to other tropical countries.

Proposals and actions

Adopt the United Nations Sustainable Development Goals (SDG) as a framework for the Mission and establish a Bioeconomy, Biotechnology, and Environment agenda

Importance of the proposal: Ensuring the incorporation of the SDG into Colombia's research agenda is an unavoidable and urgent commitment to biodiversity conservation, environmental management, and sustainable development. This action will promote development in the context of the bioeconomy. Support of renewable energies, alongside biomass cascading system valuation strategies and the fundamental research that supports this, constitute a factor for the mitigation of climate change and, especially, deforestation and the reduction of Colombian biodiversity in all its forms and habitats.

Goals: To establish mission-oriented research agendas, combined with fundamental research on natural resources.

Mechanisms through which the goals will be met: To achieve the above, we must: i) Strengthen our knowledge of the functioning of Colombian ecosystems and their components (biodiversity), in order to establish prevention and action tools to mitigate global climate change, and ii) define regional priorities based on knowledge of key habitats in the different regions for their sustainable development. In addition, we must define the research agenda (policy and technology roadmap) of the STI Ministry and, in particular, generate stable and sustainable funding strategies through the Caldas Fund to promote translational research in the areas that are important for Colombia, specifically in the areas of BBMA (SDG + Bioeconomy, Biotechnology and Environment).

Relationship with other disciplinary pillars: The fundamental thrust of the research, based on both curiosity and missions, is of interest to all pillars.

Funding

a. Incentives for private sector investment in the bioeconomy, biotechnology, and the environment

Importance of the proposal: Research will be improved in areas of capital importance for Colombia, such as biotechnologies and the environment.

Goals: To establish clear and attractive incentives for private sector investment in the bioeconomy, and in environmental conservation and restoration projects.

Mechanisms through which the goals will be met: Green bonds, tax exemptions, innovation bonds, support and advice for entrepreneurship (spin-offs and start-ups), opportunities to work in pilot plants and demonstration plants located in centers in accordance with the Fraunhofer institutes' model, so that small companies can share the risks entailed in the investment needed to determine whether a process works.

Relationship with the other disciplinary pillars: This is an initiative of interest for the Convergent Technologies, Oceans and Water Resources, and Basic Sciences pillars as the knowledge obtained is very useful to them.

b. Allocate a percentage of the cost of projects with environmental licenses to regional environmental issues or use mechanisms such as those provided by the Autonomous Planning Regions (RAP) for projects of regional interest.

Importance of the proposal: This action will allow improved informed decision making based on scientific evidence produced by research on environmental issues.

Goals: To allocate a percentage of the cost of projects requiring environmental permits to finance environmental research projects and programs in the regions.

Mechanisms through which the goals will be met: Laws and ordinances will have to be passed in Congress and in assemblies and municipal councils, respectively.

Relationship with the other disciplinary pillars: This initiative is also of interest to the Oceans and Water Resources and the Basic Sciences pillars.

Regulation

Importance of the proposal: Research on biodiversity and ecosystems will be facilitated.

Goals: To review and adjust regulations relating to the knowledge of ecosystems, biodiversity, its conservation and use: monitoring, collection, access to genetic resources and derived products.

Mechanisms through which the goals will be met: Adjustment of the decrees relating to the collection of biological material and contracts for access to genetic resources and derived products (proposed in annexed documents on the pillars and their use). Ideally, researchers would have a single entry point to the system and to the information on the requirements they need for a particular research project.

Relationship with the other disciplinary pillars: Initiative of interest for all the pillars that study and are engaged in the sustainable exploitation of Colombian biodiversity.

Regionalization

Importance of the proposal: It will improve regional capacity for a knowledge-oriented bioeconomy through research in biotechnology and the environment.

Goals: To define regional research priorities in environmental and biotechnological issues according to their capacities and needs so that they can be integrated into national STI priorities.

Mechanisms through which the goals will be met: Definition of the structure of the STI Ministry, and, in particular, the funding agency that will manage the Caldas Fund to push forward research in future transnational topics for Colombia (biotechnology and environment) in the regions (RAP mechanism).

Relationship with the other disciplinary pillars: Initiative of interest for the Oceans and Water Resources and Basic Sciences pillars.

Institutions and governance

a. Improving the National Environmental System (SINA) institutes, botanical gardens, and biological collections

Relevance of the proposal: The system's capacities for research and *ex situ* biodiversity conservation will be improved. This action is fundamental to improving research work on ecosystems, life support systems (water, air, soil, forests, biomes), biodiversity and its preservation, and social appropriation.

Goals: To enhance the research work of the SINA research institutes, the botanical gardens and the management of biological collections for *ex situ* conservation purposes and knowledge of biodiversity using advanced biological and computational tools.

Mechanisms through which the goals will be met: Sufficient budget allocation for the creation of a state-of-the-art research structure with PhD researchers, laboratories, monitoring tools and high-level computation capacities. Collaboration between the country's universities and research centers is considered fundamental, as is the signing of international agreements with countries and leading research institutions in these areas; e.g., a centralized institute of omics with decentralized units.

Relationship with other disciplinary pillars: This initiative is of interest to the Oceans and Water Resources, Basic Sciences, Creative and Cultural Industries, and Social Sciences, Human Development and Equity pillars.

Institutional actors: The BBMA pillar proposes that one or more of the institutions participate and align their goals

Research Institutes should

- participate in the creation of research agendas for the proposed flagship missions.

- establish partnerships with universities for research training.
- create and improve open access real-time databases (biological and environmental).
- establish alliances with research centers in Colombia and other countries to promote regional and global agendas.
- promote citizen science programs to study biodiversity and the environment, raising public awareness and making progress towards a " knowledge-based society."
- engage with the ancestral knowledge of traditional communities on environmental issues in research programs and promote dialogues on knowledge.
- create a network of efficient and timely technology transfer offices linked to research centers and universities.
- establish robust laboratories, instrumentation, and ecosystem monitoring systems in the regions (regions, gradients, biomes).

Schools and educational centers should

- include courses on the environmental dimension and the SDG from early childhood.
- train teachers in issues concerning environment, science, and technology.
- participate in citizen science programs for the study of biodiversity and the environment, and take action (e.g., collecting, planting, forest restoration, etc.).
- include the ancestral knowledge of traditional communities on environmental issues in the educational curriculum for basic primary and secondary education.
- bolster education programs on knowledge, conservation, and sustainable use of natural resources beginning in primary and continuing into secondary and higher education. Update and incorporate information technologies, satellite imagery, and online university courses (MIT, Harvard, iDiv, etc.) to strengthen curricular content in environmental sciences.

Universities should

- implement graduate programs in environmental sciences and, in general, education programs on knowledge, conservation and sustainable use of natural resources and life support systems.
- introduce the concept of bioeconomy into educational programs with trained and qualified teaching professionals in topics such as: biotechnology, engineering, economics, bio-business, and environmental legislation among others. Courses in bioeconomic management.
- promote a blended university/company doctoral program and simplify the process for employing PhDs on the staff.
- encourage the creation of master's and doctoral programs in science communication to facilitate the transfer of knowledge from researchers to decision makers and society.
- support the acquisition of high-capacity computer systems (modeling and forecasting of ecological, hydrological and climate processes).

Private sector companies should

- participate in the production of research agendas for the proposed flagship missions.
- identify and support STI projects for the development of the proposed missions.
- establish internship programs for undergraduate and graduate students. Send staff to universities or research centers for training courses in state-of-the-art technologies (lifelong education).
- Support the dissemination of the importance of biodiversity and the environment for Colombia.

Six regional workshops were held as part of the work of the BBMA pillar to identify opportunities and barriers, and design proposals and recommendations. The workshops were held in Quibdó (April 22), Villavicencio (May 13), Pereira (May 24), Bogotá (June 5), Tibaitatá - Bogotá (June 27) and Leticia - Amazonas (August 16), and participants included representatives of national, departmental and municipal government entities, public and private academic institutions, peasant associations, indigenous communities, unions, businesses and entrepreneurs, and civil society representatives. A wide range of relevant issues were discussed in order to design proposals for a BBMA science, technology and innovation policy. The central document of the BBMA pillar summarizes the results of the regional workshops.

The members of the BBMA pillar thank the following students from the *Universidad de los Andes* for their collaboration in preparing the minutes of the workshops: Wilmar Camilo Fonseca González, Laura Vanesa Rodríguez Arcila, Catalina María Bernal Murcia, Laura Bibiana Zuluaga Pineda, Lina María Rubiano Arias, Édgar Francisco Otálora Bohórquez, and Martín Ramírez.

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Reflections of the Basic and Space Sciences pillar and proposals for reform

Context and Scope

Basic science is fundamental to building scientific knowledge, and also in its application to the development of technologies and innovations. Today, applied sciences, including the social sciences, are unthinkable without fundamental theories derived from the basic sciences to support them. Nature is expressed in the language of the basic sciences and mathematics, and our relationship with it depends on our ability to understand it. Knowledge gives rise to society's capacity to respond to problems that are likely to arise in the future, but that we may not yet imagine. The societies that have been most successful in solving their problems are those that have developed a high capacity to produce fundamental basic knowledge, and citizens and leaders in science generally make informed decisions that are more successful.

However, many people in Colombia still wonder whether, as an undeveloped country with so many pressing unmet needs, it can afford to invest effort and resources and seemingly not solve any of these neglected areas. With this question in mind, we decided to begin our work at the Mission by writing a statement in which we argue why it is important for Colombia to develop and improve its capacities in the basic sciences. Continuing with our work at the Mission, we collected ample information via two surveys and consultations in forums and meetings of different kinds, concerning the opinions and expectations of Colombians for the development of basic sciences. We exchanged ideas with businessmen interested in research and innovation in two forums and with university rectors, researchers from independent centers, members of the air force that put the Colombian satellite into orbit, a NASA astronaut and numerous academics from the country's various cities and regions. With these inputs, the experience of the members of the team studying the pillar, and by analyzing multiple documents that reveal our current place in science, technology and innovation (STI) in the national and global framework, we defined our country's problems and opportunities in the sphere of basic and space sciences, and way forward to achieve economic, cultural and social development based on knowledge. We propose State policies that drive the country towards an accelerated path to development that marks the beginning of the solution to enormous problems of inequity and shortages of all kinds that we are subject to today.

State of the field of Basic Sciences in Colombia

Colombia's capacity to conduct research and carry out scientific production in the basic sciences[20] is concentrated in only four regions: the Capital, the Eje Cafetero, the Pacific region, and the Caribbean region; with Bogotá, Antioquia, Valle del Cauca and Atlántico hosting the vast majority of the groups and institutions that work on science. There are 778 classified and recognized research groups in these regions, of which 247 are in Bogotá, 123 in Antioquia, 65 in Valle del Cauca, and 28 in Atlántico. There are a total of 2467 classified researchers working in this field, of which 38 are researchers emeritus, 498 are senior researchers, 541 are associate researchers, and 1390 are junior researchers. Scientific production between 2008 and 2017 (according to the Scopus[21] indexing services in the area of natural and exact sciences - OECD) shows an upward trend, from 2656 articles and 3487 documents in 2008, to 8651 articles and 11,130 documents in 2017.

These publications focus mainly on earth and environmental sciences, biological sciences, mathematics, computer and information sciences, chemical sciences, physical sciences and multidisciplinary sciences.

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20 Scienti Platform, call 781 of 2017

21 Bibliometric Analysis of Colombian Scientific Production 2003-2015, Chapter 4, Scimago

Proposals and calls for funding

Taking into account the above considerations, analyzing our strengths, weaknesses, potential prospects, and the country's needs, we arrived at the proposals that are presented below and that cover different topics that we consider critical for the nation.

Proposals in education

The first topic we addressed, and that cuts across the entire Mission, was education. Without decisive actions that change the course of education in the country, the impact of science will be minor. The disciplines in which this pillar is concentrated will always be necessary, regardless of the professional framework in which they are applied. There will never be a new science that does not use mathematics, nor will any technologies ever emerge that do not depend on physics, chemistry, biology, or earth, atmospheric, and space sciences.

These sciences must be present in early childhood education and throughout the formative process; they are also important as part of continuing education throughout life, and in the shaping of decision-making criteria and skills in society at large. The proposals in education are organized into five groups, designed to: a) impact teaching quality; b) create impacts where education and research benefit each other; c) impact the quality of education; d) promote equity in access to education, and e) promote the impact of science education on society in general.

The first two groups of measures are included in the general section of this document (section 3) and refer to how to improve the quality of teacher training and how to create impacts that are mutually beneficial for both education and research. These problems largely define the final education quality, particularly in rural education, where sometimes a school has only one or two teachers; in which case its limitations (if any) affect the education of all children in the community for a long time. Another proposal is to promote the interconnection between research and science education.

The third group of recommendations refers to the formulation of measures that will impact the quality of science education; for example, the design of instruments (such as joint advisory committees) to reconcile the initiatives of the STI and Education Ministries; the construction of networks of educators and educational institutions; the creation of a council or committee for the design of science curricula at preschool, basic, middle, secondary, and higher education levels; the establishment of well-funded, long-term programs to promote national and international cooperation and the mobility of teachers and students; the design of educational plans and objectives differentiated by level - basic education should develop curiosity about nature and technology, and secondary education should encourage a scientific world-view and complex reasoning skills.

The fourth group of proposals for education refers to measures intended to promote equity of access. The goals set for science – of attaining greater social, economic, and cultural development – and the goals achieved through education – of producing moral and happy citizens – are not possible without a resolute policy to promote equal access to education at all levels. For this reason, those of us in charge of this pillar propose a program that explicitly addresses the problems of regional disparities in education in mathematics, natural sciences, second language, IT and new technologies, which should be paid for in the national budget. Specifically, we propose an investment in public education both financially and in other ways that will aid its growth. Support for students needs to be improved, and low-income students need to be able to receive state and regional funding to sustain their trajectories. We also highlight the need to convene universities to consider a change in higher education institutions' admission systems to compensate for inequalities in students' earlier education. Society and the government are called upon to open the discussion on the benefits and possibility of establishing affirmative actions that compensate for ethnic, gender, and regional inequalities.

In the fifth set of proposals for education, we considered measures that are needed to boost the impact of science education on society in general. It is necessary to create new accredited research centers and institutes at which doctoral and master's theses can be researched. Some of these centers should be dedicated to research for problem solving and be mission-oriented, rather than guided by disciplines as is generally the case. Another proposal concerns the need to have a program of continuous financial support for autonomous centers of excellence that, at the moment, work, survive and even succeed in Colombia almost miraculously. We suggest that a return plan for Colombian doctors abroad be designed, which would also be open to foreigners who want to join Colombian institutions. We stress the importance of promoting business-university-State-society relations through direct economic contributions, internships for students in companies and the availability of venture capital to support initiatives that derive from these interactions; it will also be indispensable to study current public administration regulations that treat risk as a criminal activity.

We also suggest that a project be established to disseminate the scientific work taking place in the country, in schools and among the general public. There is a need to advance general education programs for the public, science and statistics courses for schools of journalism and social communication, and to maintain a lifelong learning system in science for working journalists. The importance of setting up planetariums and museums in regions that lack them is also emphasized. Finally, educational strategies that lend an ethical and civic dimension to education must be developed through traveling seminars, scientific, philosophical and literary publications and artistic creations, with the support of universities, researchers and schools of journalism and social communication.

General proposals in different areas

The following is a brief presentation, without evidence (this can be found in extended documents concerning this pillar), of general long-term proposals and more immediate specific projects.

Among the general and long-term proposals, we highlight the need for sustained and increased STI funding by the State (without diminishing the importance of contributions from other sectors). We emphasize that a new ministry must be consolidated to configure the STI system and within it, two figures must be appointed that have been used elsewhere in the world to make sure that science influences political decisions: the

Chief Scientific Officer and a permanent advisory committee on scientific matters for Congress.

Within this framework, it is essential to develop and support the regional STI institutions. We suggest the restructuring of administrative rules that hinder the management of STI activities. We believe it is important to expand the strategic research capacity with disciplinary and transdisciplinary centers and institutes and with a national program for the renewal of robust laboratory equipment. Colombia should create working relationships between universities and companies, such as the "on demand sectorial research institutes," which would be in charge of creating scientific and technological knowledge and finding ways to innovate products and processes that companies need to improve their productivity and competitiveness. We raise the need to create the Colombian Space Agency and, finally, we consider that it would send a powerful message of commitment to the country and a guarantee of continuity over time, if the Government were to decide to present a Mission draft law for approval by Congress, which would acknowledge some of these critical points and which require regulatory changes.

A second group of less generalized proposals advise the formal existence of a program of basic and space sciences in the structuring of the national STI system; the consolidation of a program of scientific diplomacy; the maintenance of a broad and permanent program of doctoral scholarships, as well as programs for mobility and national and international cooperation. It also proposes that a system be set up that facilitates national access to bibliographic databases (currently limited to the few universities that manage to cover their onerous cost), and that researchers be supported in copyright and patent processes.

We have proposed the following specific projects for more immediate execution: curricula that cover science, social science, technology, and the environment should be reviewed; support should be offered to projects in basic science studying the country's energy transition to less polluting systems; projects on outer space, from potential satellites to ground stations, should be restarted; and the impact of the Waves (*Ondas*) science outreach program should be evaluated in order to support and improve it.

Proposals for governance and for obsolete and inefficient regulation

In practically all the consultations and forums that the Mission of Experts has held with the scientific community and other civil society actors, inadequate regulations have been pointed to as a serious impediment to STI activities. The lack of scientific research in public administration has led to a cumbersome regulatory framework that complicates and, in many cases, paralyzes the implementation of research projects.

Many of these concerns were taken on-board and possible solutions were proposed (see annexed documents concerning this pillar); the most important regulations to amend are those related to the to the administrative frameworks of scientific projects and programs, the budget period and the project presentation processes and terms of calls for funding.

Of particular importance are the observations on regulations in the study and use of living organisms, in the sense that contracts should not be required for access to genetic resources and products derived from biodiversity for basic science research without commercial purposes. Another aspect to simplify is the transport and export of biological material if technical analysis services are needed. Here only a report to the MADS and the required paperwork should be needed. Obstacles were identified in the import of reagents, equipment and inputs for research, and a need for a public-private partnership framework was identifies, along with special status to be conferred to researchers employed by non-university government agencies.

Relationship to other pillars

The Basic and Space Sciences pillar will be present in practically all the mission-based research proposals and flagship projects that are presented. It is difficult to imagine, for example, biotechnological and bioeconomic proposals without the support of molecular biology and genetics; proposals about energy and its convergent industries without physics, chemistry, and geology; or marine sciences without chemistry, biology, and earth and atmospheric sciences.

Thus, it is not surprising that many of the proposals in this pillar coincide with those of others. This reinforces their importance and relevance. All pillar share concerns about regulations that interfere with the implementation of projects, such as those that complicate access to genetic resources and derived products, and which have only been resolved for some of the basic non-commercial areas.

Specific project to support areas where the country is behind in terms of development

Professor Serge Haroche, Nobel Laureate in Physics and international member of the Mission, has presented a proposal for a program in which several of the pillars could be involved and which is aimed specifically at creating centers of excellence. These will specialize in areas of science in which the country is weakest, but which will also be fundamental for its future development. Very briefly, in the words of Professor Haroche:

In all countries of scientific excellence, young students are encouraged at some stage of their lives to visit other universities in their country or abroad to broaden their experience, expose themselves to other ways of doing science and encourage their creativity. For countries that are sending their brilliant minds abroad, these programs are profitable only if they return home and eventually contribute locally to the development of science and education. In Colombia, many of the excellent scientists who have been granted scholarships abroad have stayed in the host country, instead of returning home because of the lack of means to initiate independent and competitive research here. In order to change this state of affairs, the Mission proposes an ambitious program that will train a group of undergraduate or graduate students to work in prestigious universities abroad, at master's or doctoral level in strategic areas for our country under the supervision of national and foreign mentors. After graduation, Colombian students should receive assistance finding a postdoctoral position, either in the country where they studied or in a different one. Once this stage has been completed, the Colombian government must commit to providing funds to the Colombian university or company that will eventually hire the young scientist when they return to the country. This will ensure that the young scientist will have a job and enough start-up funds to set up a laboratory and start his or her scientific career. This program takes seven or eight years, but has been proven to be highly beneficial for development in European countries, and in India, Israel, South Korea and Brazil. More details of the program can be found in the Basic Sciences pillar documents.

Reflections of the Social Sciences and Human Development with Equity pillar and proposals for reform

Context and emphasis

Human development is not just economic progress as measured by income growth, industrialization or social modernization. It refers to people's potential: what they can be and do, the activities they can engage in, and the social protections that can provide them with wellbeing. Amartya Sen, 1998 Nobel Prize winner in economics, proposed that human development should be seen as "the process of expanding the freedoms that people actually value" (Sen, 1999). From this perspective, in addition to widening opportunities, human development must consider the circumstances that affect people's ability to transform opportunities into wellbeing for themselves and their community.

We consider that the Mission entrusted to the Social Sciences and Human Development with Equity (CSDHE) pillar must identify critical challenges for human development in Colombia, which can be addressed using education, social sciences, and innovation.

Goal

The CSDHE pillar emphasizes some of the crucial elements of proposals focusing on Colombian human development: equity; human development and progress on the Sustainable Development Goals (SDG); economic growth; and individual wellbeing, democratic citizenship and social cohesion (Nussbaum, 2000).

In order to contribute to the goal of human development in Colombia, the CSDHE pillar proposes four strategic axes of intervention:

- Gaps in education and those affecting access to science and technology need to be reduced, and this will help make socio-cultural equity and economic growth – two fundamental components of human development – compatible.
- The social sciences should be developed in relation to the magnitude of the problems we face both nationally and globally, as they aid our understanding of social, political and cultural phenomena and lead to transformative innovations across the country.
- A system of sustainable transformative innovation should be set up to offer social actors' a tool for local development based on knowledge.
- A comprehensive national system which fosters innovation must be devised to increase demand for innovation in production sectors.

Proposals and calls for funding

The group's proposals for the development of these strategic axes focus on the support of individuals, organizations and communities, as decentralized and self-organized agents of the knowledge system. The proposals are based on the recognition of the fundamental role played by the State in initiating and guiding development, as well as in creating incentives that promote the participation of individuals, organizations, and communities, drawing from their knowledge, practices and aspirations.

Closing gaps in access and quality of education

Equitable and quality education is one of the central tools with which Colombian society can achieve human development, in a broad sense that implies people's greater wellbeing through widening opportunities and skills acquisition. Although there are multiple challenges that education faces in Colombia that all deserve attention, we propose a focus on four of these because we consider them to be radically important in ensuring equity and closing gaps. We are also aware that we will have to follow strict procedures, with pilot schemes that can be scaled up, but that achieve important goals in short timeframes.

a. Access and quality in early childhood care

Early childhood is a crucial stage in human development. As pointed out by Fraser Mustard (2002, 2003), 90% of the brain's neuron connections are established between pregnancy and age 5. In Colombia, there are multiple challenges given that 11.7% of children under 5 years of age live in extreme poverty (ICBF 2018); 65% do not receive a formal initial education in any form, and those who do receive low quality education; only 48% attend a Child Development Center.

The CSDHE pillar proposes that the State program *From Naught to Forever* (De Cero a Siempre) (Law 1804 of 2016) be improved and adequately implemented, through strategies focused on the family and the community. Research, Education and Family and Community Development Centers should be developed as spaces of intersectorial articulation (education, health, culture, assistance, ICBF) between academia, the government, private enterprise, and the community, and between the different social and institutional actors that are currently responsible for early childhood, to promote the production of knowledge towards a characterization of this population's needs in order to solve them through innovative interventions that recognize good local practices. It will start with five pilot schemes in regions with very different characteristics on a staggered schedule.

b. Internationalization and diversification of secondary education

Given that the problems in the area of education are as much about diversity as they are about coverage, the CSDHE pillar concerns increasing young people's options to access secondary education in a flexible and diverse manner. The specific way in which flexibility and diversification are created will be determined by local, regional and national characteristics and capacities to ensure quality secondary education with a local impact, promoter of innovation and encouraging lifelong learning.

To meet this goal, the proposal is to take up and expand regional innovation experiences that articulate education-knowledge-development. These include *Innovar* centers, which are responsible for providing face-to-face, blended and distance learning, as well as vocational, technical, technological and university education. In addition, transfer channels, ICTs and partnerships with the production sector must be guaranteed for this project so that *Innovar* and its partners and other experiences can provide quality education for local development and reduce educational abandonment. The *Innovar* centers will be connected to the Regional Centers of Research, Innovation and Education.

c. Promotion of social-emotional skills, citizenship competencies and education in historical memory

The bulk of education policy around the world focuses on developing cognitive skills that involve mental processes such as reasoning, learning and memorizing. However, research in psychology, neuroscience, education, and economics has shown that social-emotional skills, including citizenship competencies, are crucial not only in themselves, but also because they positively affect many desirable life accomplishments, including individual wellbeing, cognitive development, and job success. The development of these skills is particularly relevant in countries that have been subject to armed conflict, where education in historical memory can reduce the consequences of violence. Some of these programs will be part of the curricula of teacher training colleges and educational institutions with bachelor's degrees to train new educators; other programs will be geared toward the ongoing training of working teachers, educational agents, families, and community members.

d. Significant expansion of teacher education programs

Diversification and universal access to secondary education, as well as quality access to early childhood education and the need to break the cycles of childhood violence, imply a significant expansion of teacher training based on new evidence and experimental pedagogies. To this end, the CSDHE group proposes a parallel system of teacher training, together with the creation of networks of teachers wanting to update their knowledge, developed as the following double strategy:

- In order to train the teacher trainers themselves, the CSDHE team proposes that a Higher Institute for Research in Education and Advanced Teacher Training (ISIE) be created to run educational research programs and train teachers to disseminate a culture of quality research throughout the system. Its graduates will promote close links between research, innovation, consolidation of networks, and training.
- So that practicing teachers continuously hone their skills, the team proposes that sub-regional networks be formed that will be linked to the Regional Centers of Research, Innovation and Education. These will provide a space for the exchange of knowledge among teachers on research and innovation on pedagogy and didactics.

Social sciences in the transition to a knowledge-based society

In Colombia, the social sciences have not managed to connect the production of knowledge, its use and social appropriation, its dissemination and discussion with other actors, and the training of researchers that the country requires to tackle its challenges.

For a long time now, the social sciences have been supporting the country's development and understanding and dealing with society's problems. During the nineties, the production of articles and books grew significantly. A study from that time showed the close correlation between the themes of the social science projects funded by *Colciencias*, the *Instituto Colombiano de Antropología* and the

Fondo de Salud with the content of the documents of the National Council of Economic and Social Policy, Conpes (Velasco *et al.,* 2007). The last two decades have seen a sustained decline in the production of both articles and books. Nevertheless, the right conditions are in place for the social sciences to expand their scope and consolidate their progress. In addition to their contribution to the formation of critical political subjectivities, the social sciences have been developing important lines of research. Colombia has become a center of interest for social scientists from all over the world interested in conflict and post-conflict studies, whereby a community of national researchers from different disciplines has been forming around this theme. Important advances can also be observed in other specific areas.

On the path set out by the Mission towards a society based on education and knowledge—the ultimate goal of the Mission's proposal to Colombian society—a new field of social sciences appears, which can be approached from different disciplines and above all from an interdisciplinary perspective. That is, to understand the personal and social phenomena related to knowledge and its circulation, and the impacts that different trends and technologies can have on the life of individuals and communities. The critical perspective of the social sciences is indispensable to ameliorate the risks stemming from changes in the technological paradigm and mutating economic and political scenarios, such as threats to people's identities and privacy, to community ties, and to the stability and resilience of national societies. The Mission calls on Colombia's social scientists to reverse the downward trend in research and publications in this field over the last two decades, in order to expand the study of the consequences of long periods of violence faced by many regions, and to open new fields of study around the transformations involved in building a society that adopts education and knowledge as the basis of its economic growth and its development.

To activate the social sciences, we propose:

a) That periodic calls for funding be made to research groups, teachers, and communities in themes of education, human development and the SDG. Colombia's recent history makes it a laboratory of universal interest and the country's social science communities can share the knowledge gleaned from their research.
b) That networks of professors be created to aid knowledge appropriation and their participation in large-scale research processes.
c) That new mechanisms for measuring production be created, and that these be fit for purpose and from a perspective of open, situated, and transformative science.

d) That specific calls for funding be established to train researchers in social sciences and open workspaces for researchers for the incubation of transformative innovations in the regions.
e) That specific calls for funding be opened to investigate the risks that convergent technologies present for the identity and privacy of individuals, the environment, and the life of communities.
f) That some corporate social responsibility programs be linked with the support and social science research conducted at universities, in order that their impact be rationalized and made visible.
g) That when technical education is brought to the regions, it is important for it to be contextualized locally, and social sciences can play a valuable role in this process.

Fostering a system of transformative innovation for local development founded on knowledge

The Mission of Experts proposes that flagship missions be created that relate to three major challenges: Productive and Sustainable Colombia, Biodiverse Colombia, and Equitable Colombia. However, for these missions to advance, more has to be done than to simply focus on producing academic knowledge. In this vein, it is crucial to implement bottom-up strategies to bring about transformations suitable for Colombia's different regional contexts. While scientific knowledge and capabilities are relevant to addressing challenges and the SDG, we suggest that they need to converse with local knowledge, actors, and needs if they are to have a greater impact.

We propose that the mission approach should be implemented together with the bottom-up principles of transformative innovation (Schot and Steinmueller, 2018). This can be carried out via experiments (pilots) such as Seeds for Change (*Semillas de Transformación*). The experiments can be case studies like those discussed in this report, led by civil society and small producers, as well as high-tech projects such as digital transformation led by entrepreneurs. For transformation to take place, these experiments must be connected and coordinated across regions. The new Ministry should take responsibility for creating these connections between projects in different regions, for coordinating activities, organizing learning through missions and projects, and supporting training in transformative project management and formative assessment of transformations. This can be done by creating a national program of experimentation with a strong regional focus. Here, the Ministry can work with several Colombian universities which have begun to explore principles of transformative innovation and with the Transformative Innovation Policy Consortium (TIPC), of which the Colombian Government is a part.

The country cannot grow or solve its current problems without innovation that includes, but is not limited to, the technological field. Transformative innovation can complement technological innovation, so that socio-environmental contexts become dynamic and strategic drivers of growth and long-term competitiveness. This methodology proposes a series of interventions for the human development of citizens, regional economic growth and competitiveness based on a concept of multisectoral and multidimensional innovation. The development of transformative innovation allows knowledge produced in academia to be connected with successful experiences and local knowledge in response to the challenges of regional development and, therefore, with the country's sustainable development. From this perspective of innovation, we seek to contribute to the advancement and progressive achievement of the SDG in Colombia.

Transformative innovation proposes three strategies within the framework of a national and regional program for the implementation of the SDG:

a) Initiatives of bottom-up participation and empowerment are definitive in producing transformations in different local or regional contexts.
b) Evaluating pilot projects at a local level is part of the communities' learning process.
c) Analyzing the relationship between scientific knowledge and social needs can guide the scientific research system, while contributing to solving recurrent social needs.

Regional innovation system carried out by social actors

Through sustainable transformative innovation, our intention is to eventually set up socio-technical systems that address niche social functions and regional socio-environmental contexts, in order to turn them into dynamic and strategic directors of long-term growth and competitiveness. This policy must be intentional and guided by collective priorities, with multiple potential avenues for development and allowing for a continuous process of learning and critical evaluation. This strategy will be implemented by the Regional Research and Innovation Centers.

Innovation

The CSDHE pillar proposes a comprehensive national system that fosters innovation and so increase demand for innovation by the production sectors. In order for ideas to be developed as productive opportunities and become added value, the private sector must see that it is in its interest to innovate, and then have the capacity to do so. Colombia needs to rebalance its innovation institutions' resources and focus to improve the competitiveness of the private sector. The new STI Ministry should push for the institutional change the country needs to foster innovation, organizing its efforts around the following axes: 1) The private sector as the main target of innovation policy, 2) A broad vision of innovation that takes into account both national and international opportunities, 3) Ensuring that research institutes are clear as to their purpose and offering them support to create an incentives structure, and 4) Ensuring that the different elements of the system are integrated. Institutions that seek to promote innovation must have adequate funding and focus on overcoming barriers to innovation within the private sector, on producing high-quality basic and applied research in universities and expert groups, and on promoting intermediary spaces for the pairing of university researchers with businesses.

a) Institutions for innovation: integrating and aligning systems. It is important that a coordination process be established among the current system's main actors, in which the new STI Ministry will have to work closely with related ministries to create a network of public research institutions, designed in such a way that the incentives provided are geared towards producing high-quality research for industry in both physical and human capital development.

b) Increase production sectors' demand for innovation. By combining competitiveness, education, infrastructure, and the regulation and promotion of trade, Colombia will be able to create new knowledge and new productive practices. To this end, a series of training policies should be applied in companies to improve management quality and develop technical capacity. This would allow them to integrate and identify new technologies, use them in an innovative way and rebalance institutional resources. This would ensure that Colombian companies demand new technologies and develop innovation processes, allowing them to compete with greater autonomy.

c) Human Resource Development (HRD). HRD is key to driving technological innovation and corporate competitiveness in the industry, however, the Colombian Government must promote education in HRD through a socio-cultural system that recognizes the value of knowledge, guaranteeing its benefits. To this end, four strategies are proposed as follows:

- Establish a national system of HRD strategies (Mission/Vision/Strategic goals), with the proactive development of government policies that support corporate activities for HRD and specialized institutions in HRD management.
- Promote the consolidation of cooperation between industry and academia.
- Encourage companies to participate in voluntary HRD innovation.
- Set up an extensive management training program for innovation that includes modules on the internationalization of education in development, a second language, and business ethics.

Relationship with proposals from other pillars

The proposals of the Social Sciences and Human Development with Equity pillar focus on education and innovation. There is a close relationship and complementarity with the education section of the other pillars, especially those of Basic and Space Sciences and Convergent Technologies and Industry 4.0. The proposals on policies and instruments for promoting innovation are especially concerned with Convergent Technologies and Industry 4.0, Bioeconomy, Biotechnology and Environment, Energy and Oceans.

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Reflections of the Life and Health Sciences pillar and proposals for reform

Context and scope

Colombia's biggest health goal is to create, within the next 25 years, the conditions in which all Colombians of all ages enjoy a healthy life and optimal levels of wellbeing, thanks to the different stakeholders' use of science, technology, and innovation (STI) in a wise and generous manner.

For this to happen, we must overcome inequality, corruption and lack of trust. In Colombia, poverty and unsatisfied basic needs persist, making our country one of the most unequal on the continent, preventing all Colombians from having levels of health and wellbeing in accordance with the principles of equity and social justice.

To overcome this challenge, we must adopt science and technology and broaden the concept of innovation in health. This must be understood as a process of change, using the best available knowledge to create far-reaching transformations, not only in the health system, but in general wellbeing and at all levels of society.

It is important that the conceptualizations employed in this pillar are clear, and that it provides a guide for the country's efforts:

- Health is considered to be, "the ability to adapt and self-manage, in the face of the physical, emotional or social challenges of life" (Huber *et al*, 2011).
- Wellbeing is considered to be "the ability to judge whether our life is going well or not" (Sumner, 1996; Molyneux, 2007).

State-of-the-art of health and wellbeing STI in Colombia

Colombia can boast a variety of experiences in innovation that have created health and promoted optimal levels of wellbeing for all people at all ages. In 2018, an integrated network of health services offered by 35 organizations in Bogotá (Compensar), made it possible for 88.6% and 93.1% of its 1.3 million members to self-report positive levels of health and wellbeing, thus ranking first among the health systems of the remaining 36 OECD member countries. The key to achieving these results with a mere 25% of average OECD spending (USD 500 per person annually)—equivalent to USD 860 when adjusted for purchasing power parity—was trust among service providers, professionals, and health service users.

While experiences such as this establish the basis for the country to be at the forefront of innovation in health and wellbeing worldwide, the national panorama, in general, is still far from optimal. The journey we took through different parts of the country has allowed us to highlight the extremes of inequality between regions and in particular between urban and rural areas. There are areas where the social determinants of health and wellbeing are either insufficient supply of drinking water, inadequate basic sanitation, lack of electrical energy, limited access to current TICs, low educational coverage or low-quality education, loss of ancestral knowledge, food insecurity and lack of food sovereignty, or precarious connections over land or by river. Correcting these social determinants of health needs urgent attention in order to ensure our society's wellbeing.

Although chronic diseases represent 69% of the disease burden in Colombia, in rural and suburban areas a large part of the population continues to suffer from infectious and neglected diseases, almost all of which are preventable through socioeconomic and ecoepidemic approaches and the application of simple sanitation or protection against environmental conditions (20th century science and technology).

It is therefore unrealistic to think that the consolidation of an STI system in health, however robust and solid, can overcome these and other conditions. What we need is State presence and the implementation of programs and strategies that comply with the principles of equality and justice that we claim to defend, so that the search for social equity is no longer just a discourse. However, what the STI health system can do is use the best available knowledge, in addition to producing relevant, contextualized and interdisciplinary knowledge, to reduce the gaps and support decision makers and the health system as much as possible.

Proposal

The proposal is to consolidate the health system within a model of wellbeing based on the use of scientific knowledge, which promotes a transformation of that system and responds to the needs mentioned. The proposals are intended to help reduce inequality and inequity, and to advance on the goal of all people living full lives.

We want to start a conversation between the existing health systems and the STI health system based on these proposals, in order to unify discourses that, in practice, occupy separate spaces and follow different trajectories. The health system, as part of a broader system of wellbeing, should be the source of the questions, problems or challenges that require new knowledge for their solution. The STI system, on the other hand, can produce new knowledge and promote the use of the best knowledge created anywhere in the world, resorting to the fundamental principles of scientific activity and the technological infrastructure available today and that will emerge over the next 25 years, to take advantage of existing opportunities or to solve pressing problems and needs.

In the following section, we present the proposals of the Life and Health Sciences (CVS) pillar. They are divided into five program lines and are based on deliberations and documents created by pillar members, the analysis of the Great Health Survey and the results of eight national conversations with key actors in the health sector. The proposals are intended to lead Colombia, over the next 25 years, to being positioned globally in the top decile of all selected indicators, with health self-perception and wellbeing being the main ones.

Program lines

Determinants of health and wellbeing for all (environment, infrastructure, gender equity, food security, peace of mind)

It is of utmost importance to research and address the environmental and social determinants of health. Only by doing this will we have a comprehensive vision of our communities, as health and wellbeing depend not only on the advances of scientific and technological research, but also on psychosocial, cultural and environmental factors. STI will contribute to ending inequality in Colombia by improving the wellbeing of the Colombian population.

a. Goals

Reduce those determinants that are considered to be negative and increase those that contribute positively to health and wellbeing through the amassing of baseline data, their study over time, the mechanisms that produce and reproduce them, and the formulation of strategies to address them. In terms of public health, the priorities proposed are: (i) mental health, both in the general population and among health professionals; (ii) programs and campaigns for the promotion of comprehensive health and disease prevention; (iii) equal and increased access to health technologies. Patient associations should be regulated and empowered to make joint decisions. Community health should also be reinforced by recognizing local knowledge and practices.

b. Actions

- Develop a national program to cover the next fifteen years that addresses the determinants of health and includes: (i) the identification of the best national and international experiences; (ii) selection of indicators and goals; (iii) standardization of the collection of reference data; (iv) characterization and evaluation of the structure and capacity of health services; (v) identification of the best national and international experiences; (vi) definition of a model specifically dedicated to wellbeing, which complements the existing health system with actions and goals for its implementation.

- Bolster the National Family and Community Health and Medicine Program.
- Connect primary health care to STI advances, as well as to ancestral health-related knowledge and practices.
- Develop a hardware (computer centers, remote access with PCs or tablets) and software infrastructure, through high-speed communication networks, that will connect remote areas of Colombia to the main centers and to groups of innovators, as well as to the country's doctors and scientists.
- Optimize the Territorial Integrated Action Model (MAITE) through efficient management which will coordinate actions among the agents involved in the health and wellbeing system, in turn improving health and wellbeing conditions.

Creation of care and knowledge production networks in health and wellbeing

It is important that the model be people-centered at both individual and community levels. This model changes the disease-centered paradigm to a new vision of the system that considers health as a skill and an important component of the population's wellbeing.

a. Goals

For at least 90% of the population to report positive self-evaluated levels of health and wellbeing by improving skills to adapt to and manage the physical, mental, and social challenges of life. For this to happen, the health system must be geared towards preventing the preventable, controlling the controllable, alleviating what is relievable, curing the curable, transcending the inevitable, and always providing support. The wellbeing system, for its part, should focus on all aspects of life beyond the medical field.

b. Actions

Implement a model of comprehensive healthcare networks, based on the trust built in Bogotá. In order for this to be possible, the following is required: i) Forge an agreement with all EPS and IPS on the adoption of this model for the provision of health and wellbeing services to the country's population; ii) select a common set of indicators to be used by all actors; iii) develop and approve a code to promote and reward transparency and ethical behavior, and punish acts of corruption and impunity; iv) instigate the collaboration of health actors on joint projects; v) evaluate the implementation of the model of the integrated care network to reorient the health system model towards holistic comprehensive care that contributes to optimal levels of wellbeing.

Involve and empower individuals and communities by providing them with the opportunity, skills, and resources they need to be knowledgeable and jointly responsible when they use the system's services.

National health research policy and other health policies

The guidelines for a National Health Research Policy in Colombia, which are still pending, should become the roadmap for a socially legitimate instrument that will make it possible to align interests; mobilize resources; and coordinate the actions of public and private institutions, and of other actors and social sectors committed to research; innovate in health and wellbeing, and disseminate and use its results in the country.

The STI policy should focus on system innovations and productivity, but above all, on the use of knowledge to ensure that the right to health is effectively guaranteed, and to engender real transformations in social systems and to enable all people, of all ages, to live a full life.

a. Goals

Policy must raise the standard of multidisciplinary research and its impact on health and wellbeing and innovation efforts by involving scientists, professionals and the public in common ambitious projects; reinventing medicine to position it as part of a truly health-oriented system and within a broader framework of wellbeing for all.

Policy Lines

- Public health research.
- Basic, interdisciplinary and convergence research.
- New technologies and digital networks for high level health care.
- Clinical research.
- Social innovation.
- Bolstering innovation in health and wellbeing.
- Dialogue on knowledge on health and living well.
- Translational research to promote optimal levels of health and wellbeing.

b. Actions

- Evaluate and characterize health policies in Colombia and come up with recommendations to modify them when necessary.
- Formulate the national policy (bills, Conpes and Confis) for collaborative research and innovation for health and wellbeing (PIISB) and the involvement of all the system's actors. The policy should direct the research and innovation agenda in health and wellbeing in order to promote the coordination and creation of networks. The policy should facilitate participation in the global community, avoiding an isolated and introspective view of research, technology, and innovation.
- Create a statute for researchers and innovators in health and wellbeing.
- Create and implement efficient and effective mechanisms to reduce the impact of corruption and other systemic factors with adverse effects on budgets and their execution, and the delivery of services.
- Configure a health policy and system that incorporates interculturality as one of its pillars.
- Create national programs based on the translational 5P's model (Population, Prediction, Prevention, Personalization and Participation) for the study and management of different conditions or situations that affect individual or collective health.

- Reform Decree 1437 of 2014. The role of the National Council of the STI Health Program should be clearly defined and include wellbeing. Credible and recognized researchers and innovators should be part of the National Council.
- To follow up on previous efforts to have Colombia recognized in Latin America as one of the top three countries in research and innovation in health and wellbeing.
- Evaluate and disseminate these efforts so that over the next 25 years, they produce the best model of state policy in health and wellbeing research and innovation for the world to learn from.

Sovereignty for health and wellbeing

Many people suffer unnecessarily and die prematurely because of a lack of health technologies, medicines, vaccines or effective diagnostic tools, or because of the insistence on providing medical answers to social problems. The reasons range from high product costs to product shortages due to a lack of market incentives for producers to keep their products on the market. These circumstances cause countries to take measures to ensure access to vital health technologies for their inhabitants making sure that products are available and can be accessed.

a. Goal

To establish health sovereignty in health technologies, which will make it possible to control threats to health from external events that can affect the supply of essential health products, as well as the unnecessary expenditure of resources that could contribute to wellbeing.

b. Actions

- Formulate and implement an *industrial policy in health* that promotes the production and development of innovative products of public health interest (chemical and biological synthesis medicines, phytomedicines, advanced therapies, medical devices), in order to avoid the country's technological dependence. The policy must include: i) technological upgrading; ii) transfer and exchange of knowledge among the system's actors; iii) improvement of the entire innovation and production system; iv) establishment of a fund for innovation in health and wellbeing in accordance with the best national examples (National Foundation for Innovation, Canada). Funding for innovation in health and wellbeing should contemplate the different phases of product development, which include preclinical evaluation, clinical evaluation, scaling up, production and research insurance, as well as parallel efforts in areas that require social efforts, beyond the limits of medicine.

- Consolidate the innovation units in universities and research centers in different parts of the country that simplify technology transfer in health and wellbeing.
- In cases of public interest, the country should use public procurement of health and wellbeing technologies including medicines.
- Design instruments to achieve technology transfer agreements with international companies to produce medicines or other products locally if there is a shortage of them, or if there are shortages projected in the next five years or if they are of public interest, with a guarantee of public purchase of the products.
- Promote the production of master products in hospitals and public institutes.
- Update clinical research resolution 2378 of 2008 and health research resolution 8430 of 1993, to define clear rules for clinical evaluation, Good Manufacturing Practices and sanitary registration of medical devices (including software), nutraceuticals, phytotherapeutics, advanced therapies and synthetic biology derivatives developed in the country. The process must include the healthcare community to evaluate the consequences of the regulation, which must be efficient and guarantee legal, technical and social confidence.
- Create a regulatory framework for the local manufacture and validation of diagnostic reagents and kits.

Reform of the educational model, from teaching to contextualized learning with an emphasis on areas of health and wellbeing

The STI-based transformation of the Colombian health system will only be possible if health professionals and citizens in all regions participate in the opportunities offered by knowledge for the promotion of full human lives on a planet where the rights of other living beings are respected.

Accordingly, the curricula and pedagogical strategies of the health and welfare training process must be adjusted or reinvented to respond to new opportunities, new challenges and social and technological developments, for which open spaces for discussion and creation are required.

a. Goals

To support the health system's citizens and actors in developing their abilities of co-creation and making them co-responsible for the health and wellbeing of all, based on learning models that integrate and align health knowledge produced locally and globally.

b. Actions

- Implement the "Cosmology Project" proposed by the previous Mission of Experts, adapting it to health and wellbeing.
- Create an observatory for the training of the nation´s human talent in health and wellbeing at all levels, analyzing the distribution of human talent across the national territory, the design of strategies to update it, its distribution in strategic areas, and the creation of activities to promote this population's wellbeing.
- Develop learning programs at all levels, including patient associations, community groups and social leaders.
- Implement the recommendations made by Ascofame in medical education at undergraduate, and graduate medical-surgical level, and in lifelong professional development (Ascofame, 2018), in order that these become models of state-of-the-art learning, going beyond the clinical vision of health.

- Support the implementation of inter-institutional programs to create community health and wellbeing trainers, especially in rural areas.
- Develop a program for early childhood, primary, secondary and high school education to transform children's and young people's perceptions about their participation as responsible citizens of a sustainable society and a health and wellbeing system.
- Build interactive health parks or educational centers, especially in those regions with limited participation and access to knowledge.
- Implement a strategy for all hospitals linked to universities to be accredited as university hospitals (Resolution No. 3409 of 2012, of the Ministry of Health and Social Protection).

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Reflections of the Sustainable Energy pillar and proposals for reform

Public policy in STI for sustainable energy

The global energy transition is propelled by new businesses originating in venture capital ecosystems. The drivers are, above all, actors from outside the sector who provide platforms (not just products); services (rather than assets); capabilities (not just strategy); a pull approach (offering unregulated products, as opposed to the push approach of selling kWh or MMBTU protected by regulation); economies of scope (with which they can overcome the advantages of the economies of scale of those established); and flexibility (not just efficiency).

The country's energy policy must migrate towards Integrated Resource Planning to build a balanced portfolio of primary energy sources and integrate the demand side with principles of circular economy. As part of the responsibilities acquired in COP21, the country should not discard the contributions of any primary source. The responsible and technical exploitation of non-renewable resources is an opportunity to convert natural capital into human capital and technology-based industries.

Regulation should design incentives and sandboxes, and encourage change in market architectures to remove barriers to the entry of new technologies and business models, stimulate competition in markets, and foster the adoption of decentralized energy architectures.

The science, technology and innovation (STI) policy in energy is designed, in accordance with Acemoglu, Aghion and Zilibotti (2006), to simultaneously promote accelerated adoption, development, and transfer to come closer to the technological frontier. To this end, it must support the basic research, adoption, development, and transfer of technologies in demand management in large consumer sectors (transportation, industry, and residential sector); the creation of export-oriented technology-based industries in Latin America in niches where there are advantages and opportunities; the optimization of conventional energy production technologies and the development of advanced computing capabilities to simulate processes, new business models, and regulatory alternatives.

Technologies with downward cost patterns (solar, wind, storage) will start to be adopted. Transfer and development will target industries with the potential to export technology to tropical countries. The adoption and development of cleaner technologies and decreasing costs will naturally reduce greenhouse gas emissions in a country that consumes little energy and that has exceptionally clean electricity production compared to global levels.

The missions and centers proposed by Mission of Experts 2019 – whose characteristics and advantages are presented elsewhere in the central document – will become the means by which the STI policy is developed. One of the proposals is the creation of an Energy Center, which will implement projects or missions aligned with the STI policy objectives that, in an environment of uncertainty, coincide to a great extent with energy issues that require immediate action in Colombia (blue circles). These issues have been identified by the World Energy Council and are presented in Figure 17.

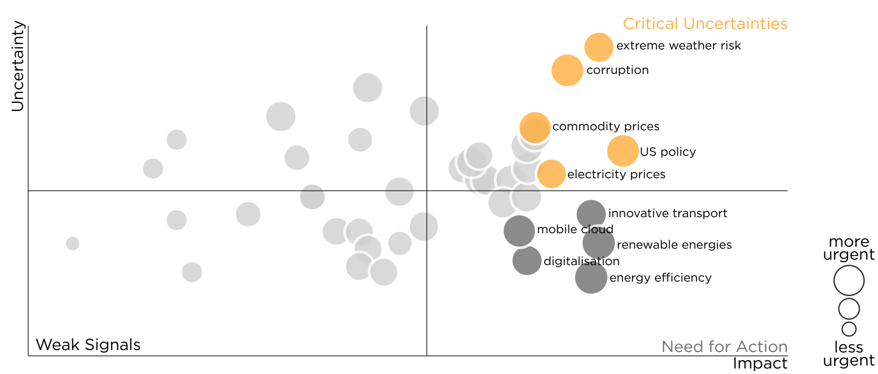

Figure 17. Energy problems and prospects for Colombia
Source: World Energy Issues Monitor (2019) Colombia.

Global trends

Global trends in energy are developing under the following circumstances: (i) the impacts of climate change; (ii) the 'inevitable' technological advance of solar and wind energy, storage and artificial intelligence; (iii) the irruption of new business models financed by private capital and with access to real time data intelligence; (iv) the convergence between the decentralization of energy solutions, use of information and communication technologies (Internet of things), and electrification processes; (v) advances in the interchangeability of energy carrier components, which allows biomass waste to play a greater role in the future energy portfolio; (vi) advances in technology and the creation of world markets in natural gas, which make it the 'hydrocarbon of the energy system'; and (vii) the great potential of hydrogen to provide dense and clean energy.

The Sustainable Energy pillar team reviewed the state of technologies competing for leadership in international energy supply with increasingly clean and economical solutions. To this end, they sought the opinions of experts in different areas, whose contributions are included below. The only two clear medium-term trends in the global energy context are the convergence between digitalization, electrification, and decentralization, and the reduction in the use of coal that does not combine supercritical technologies and CO2 sequestration and capture. Most primary energy resources have their comparable advantages and disadvantages (in cost, continuity, density, pollution, local availability). Different technologies compete for use in solar cells and batteries.

In the future, centralized and decentralized systems must coexist under alternative market architectures. There are currently no network externalities similar to those of telecommunications that generate fast and singular convergence to electricity, as there was in the migration from fixed to mobile telephony. There is no magic solution in sight. There is no perceived "singularity."

For now, there is no revolution, but rather evolution. However, the unpredictable advance in technologies of definitive relay, such as hydrogen, nuclear fusion and the new modalities of nuclear fission energy can deeply alter the entire energy matrix. These could complement non-conventional renewable energy sources (NCRE), which lack energy density.

In the long term, there is no clarity on what the mix of primary sources will be globally in the long term, nor what the ratio will be between centralized and decentralized resources in any country. Regulation must be flexible enough to allow for experimentation and anticipate the change in market architecture so that the value of decentralized energy resources (RED) and new technologies can be harnessed. Regulations should minimize opposition from established interests.

Colombia in Energy[22]

Colombia has small reserves in oil (1800 million barrels of proven reserves, 1 per thousand in the world) and natural gas (3.7 American trillion, also 1 per thousand in the world), but it has 4881 million tons of coal that represent 0.5% of the world's reserves. It also has large potential for small and medium hydroelectric resources, and comparative advantages in NCRE and biomass.

Colombia's per capita energy consumption is very low: 39.7 GJ/capita, compared to 79.7 GJ/capita in Argentina, 59.1 GJ/capita in Brazil, and 92.3 GJ/capita in Chile. Colombia's total consumption is 16.6 MTOE in oil, 11.2 MTOE in natural gas, 5.8 MTOE in coal, 12.8 MTOE in hydroelectricity and 0.5 MTOE in renewables. Despite low energy consumption per capita, Colombia stands out in terms of hydroelectricity worldwide (representing 0.6% of total consumption).

Developed countries' energy transition is shifting towards "radical decarbonization." Our provisions, problems, and opportunities are different from those of industrialized countries that rely heavily on fossil fuels. In Colombia, as part of the obligations of COP21, energy policy must help create a portfolio that is efficient in terms of costs and risks, and it

22 Figures taken from bp Statistical Review of World Energy 2019. Available at: https://www.bp.com/content/dam/bp/business- sites/en/global/corporate/pdfs/energy-economics/statistical- review/bp-stats-review-2019-full-report.pdf

must foster the adoption of frontier technologies in commerce, industry, housing, and transportation, taking advantage of abundant and clean primary resources.

Figure 18 shows the COP21 base scenario of the evolution of consumption and greenhouse gas emissions at the sectoral level, according to the UPME (2019). Demand management, the use of more efficient devices and the penetration of RED can explain the lower proportion of emissions output by the commercial and residential sectors of the future, while emissions from the transportation sector represent a great challenge and opportunity for electric and hydrogen-based transportation. The most important supply problems in Colombia's electricity sector include concentrated market power, rising prices and poorly designed subsidies. There is a regulatory backlog for the adoption of new business models and systemic risk for power production (a concentrated hydroelectric matrix). Also, universal electricity coverage has yet to be achieved (approximately 1.5% of the population lacks service).

The biggest problems of the hydrocarbon sector are Ecopetrol's dominance of all links in the chain, distorted prices of liquid fuels for the end consumer, and low investment in proprietary technology. The main problem relating to natural gas is the fact that its market structure is concentrated in supply and transportation. Price formation rules and incentives to trade various products throughout the chain create distortions that have hindered the market penetration of natural gas. Unconventional

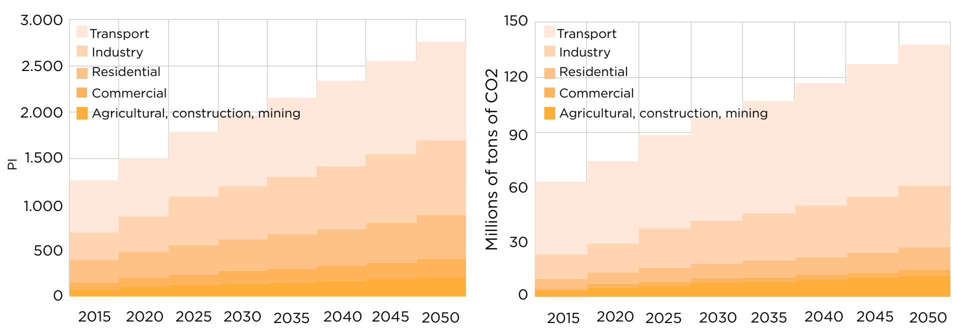

Figure 18. Base scenario COP21 by sector of consumption
Source: UPME, 2019

hydrocarbons are an important source for balancing the energy supply portfolio with positive macroeconomic impact. Like any energy source, unconventional hydrocarbons have impacts that must be studied and mitigated in a responsible and transparent manner.

The main contribution of the NCRE will be to reduce the risks associated with electricity supply, which can continue until the storage capacity of the reservoirs are full. Once this has happened, natural gas and energy carriers (synthetic fuels produced from biomass waste, including green hydrogen), nuclear generation and other supply alternatives that are currently being piloted can be employed to complement the intermittent NCREs.

Colombia in STI for energy

Table 12. summarizes the information gleaned from experts in academia and industry on identifying barriers and opportunities for STI in energy.

Table 12. Summary of barriers and opportunities for STI in energy

	Barriers	Opportunities
Sources of payments and instruments for funding	• There is neither proactive public work towards finding new sources nor the development of innovative instruments to bring in more resources. • Regulated energy companies invest very little in STI	• Public support for basic science, co-financing of applications and entrepreneurship • % taxable corporate income for STI
Organization of the industry	• Oligopolistic sector which is slow to adopt new technologies	• Encourage new businesses to enter and empower prosumers with open and non-discriminatory network access rules.
Regulation	• Energy regulation is complex, sluggish and conservative • High transaction costs for financing, new business development and STI projects	• Innovation-friendly regulatory sandboxes. • Simplification of public processes and ex-post supervision of STI projects
Institutional	• Lack of coordination between energy subsectors • Public funds are dispersed between initiatives that are of interest to researchers	• Portfolio energy policy; integrated resource planning • STI mission funding

	Barriers	Opportunities
Capacities	• Shortage of talent to take advantage of technological change and develop businesses • Inadequate governance that would allow talent to interact with the generation of useful knowledge	• National doctorates • Energy Transition Center to serve as a liaison between universities and industry
Social and cultural	• Lack of knowledge of the fast pace of technological change in the energy sector and its impact • Urban and industrial designs lacking circularity and efficiency	• Social appropriation of STI, recognition of technology leaders • Changes in urban planning norms and standards, with dialogue on and public support of Smart Cities.

Source: Authors

According to this diagnosis, the introduction of STI in the field of energy will require the concurrence of industrial policies and regulation that increase competitive pressure on a concentrated industry structure and facilitate the entry of new businesses and technologies, the creation of incentives and new sources of payment and financing instruments.

Recommendations

Create an Energy Center

We propose that an Energy Center be set up that supports the Productive and Sustainable Colombia Mission. The Center will be independent of universities (but which must be partners) and companies, in its first five years 70% will be co-financed by the State and 30% by industry (with a reversal of these percentages from the sixth year), and governed by private law.

Cutting-edge technologies will be rapidly developed in other countries and their adoption will depend first and foremost on favorable regulations and reduced paperwork, rather than on R&D activity. The Center will focus on issues where there are unexplored opportunities and advantages and will collaborate with other centers that already have mature agendas on complementary issues, such as in the case of hydrocarbons.

The Center may have a decentralized structure in several of the country's cities. The Center would require an initial investment of USD 20 million in prototype laboratories and advanced computing facilities, and would have annual operating expenses of between 5 and 7 million USD, to cover the salary of fifteen full-time senior researchers, their assistants and R&D activities. With this budget, advanced prototypes would be available in four years, which would support the deployment of the proposed industries and the laboratories would become a technical example for the rest of Latin America.

The projects proposed are intended to diversify the economy and support increased total productivity, create cleaner and sustainable habitats, and improve capabilities to anticipate and test business and regulatory alternatives for energy transition: (i) support for the creation of an electronic and digital industry of organic solar panels, instrumentation and control for smart grids and microgrids, and energy efficiency; (ii) support for the creation of a biorefinery industry; (iii) set up an intelligent cities and simulation laboratory to support the implementation of solutions such as electric transport, energy efficiency and buildings, accompanied by a component for cultural change. The Missions section discusses the Center's relationship with other existing centers (e.g., the ICP in hydrocarbons) and justifies and describes these projects.

Policy and regulatory needs

Research and technological surveillance should be commissioned for all technologies that may become candidates to form part of the country's energy supply, including those that are in the pre-marketing stages (such as nuclear fusion and hydrogen) and those that are controversial (such as non-conventional hydrocarbons and nuclear fission energy).

There needs to be a shift towards Integrated Resource Planning to balance supply risks and costs and promote increasingly clean and economical solutions.

Competition should be promoted at the entry point and within the electricity and hydrocarbon markets. Regulatory sandboxes should be used to test new business models and new energy market architectures, following the experiences in California and the United Kingdom. Regulation should facilitate the rapid adoption of decentralized energy resources and their monetization, as well as encouraging the electrification of urban transport.

Financing and Early Financing Ecosystems

The carbon tax must be specifically earmarked to co-fund the Energy Transition Center. Financing of R&D in the sector's companies should be increased with incentives for investment in the missions described above. The Center can become the fulcrum of the energy innovation ecosystem, with startups gaining public support through calls for proposals from the projects originating in the proposed missions and laboratories.

Reflections of the Creative and Cultural Industries pillar and proposals for reform

Context and scope

The term Creative Economy includes all productive activities based on knowledge and creativity, and this includes science (Howkins, 2013). However, the Cultural and Creative Industries have, at their core, forms of knowledge production that have not been traditionally considered as being part of the National System of Science, Technology and Innovation, but are central to the cultural sector, which is a fundamental part of a knowledge-based society.

An important precedent is the National Committee of Arts, Architecture and Design, and its activity between 2013 and 2015. One of the purposes of this committee was to emphasize that the knowledge produced in these academic areas in research + creation (R + C), represents added value for the creation of content which is transferable to the creative and cultural industries, promoting innovative and disruptive forms of connecting with other areas of knowledge.

The creation of the Creative and Cultural Industries pillar within the Mission of Experts 2019 constitutes, above all, a call to connect the SNCTI with the cultural sector, under the understanding that the transition to a society based on knowledge (or multiple knowledge systems) must necessarily give a central role to art and creativity, especially at a time when these industries are emerging as areas in which the country can be competitive globally in the short term.

State of the Creative and Cultural Industries (CCI) in Colombia

In the last thirty years, the country has seen an accelerated development of the CCIs, especially in sectors such as film, publishing and recorded music. Many of these advances are due primarily to the enactment of laws that include specific promotional instruments.

Despite the above, between 2014 and 2018, the contribution of the creative economy to GDP remained between 1.8% and 2% and showed no signs of increasing (DANE, 2019, 15). The National Government has formulated a series of guidelines and additional incentives based on the *Ley Naranja* (Law 1834 of 2017), designed to increase the contribution of the creative economy to 6% of the GDP. Within this framework, we consider it fundamental to understand the creation of cultural content as a form of production of specialized knowledge that fulfills two functions: on the one hand, it enhances the possibilities for the expression of the country's cultural identities, creating a sense of belonging and enhancing our heritage. It also opens up possibilities for improving quality as a result of the economic exploitation of cultural production. The recommendations and proposals discussed in the following section suggest that Colombia may be able to find an engine for development for the next thirty years in the CCIs that combines these two functions in a balanced and sustainable manner.

Proposals

Symbolic value, cultural identity and content generation

a) The STI Ministry must intensify the integration of research + creation (R + C) into research, development and innovation activities, and give it a leading role, both in the mechanisms for promotion of knowledge and in the dissemination and social appropriation of knowledge.

b) The STI Ministry must develop mechanisms specifically intended to promote dialogue between different forms of knowledge production and between different actors, inside and outside the SNCTI.
c) The Mission-Oriented Research approach gives priority to the *knowledge and sustainable use of Colombia's cultural heritage*, through research, development, innovation and creation activities, from all areas of knowledge, with a view to strengthening the country's cultural diversity, and its appropriation and use for the creative and cultural industries. To this end, specific lines have been formulated within the Mission for a diverse Colombia with a bioeconomy and creative economy.
d) The STI Ministry should lead efforts to coordinate all state entities that promote knowledge production in the country. A close relationship of cooperation and policy harmonization should be especially encouraged between the Ministries of Culture, Education and ICT. It must also lead processes that promote the appropriation of knowledge in all its forms, with special emphasis on R&D in the country's scientific, artistic, cultural and educational fields.

Education for the creative and cultural industries

a) Conditions must be guaranteed to ensure that arts education is implemented as a fundamental area of the curriculum and that it becomes compulsory from early childhood and through all levels and modalities of basic and secondary education[23]. It must be based primarily on content from different parts of the country, particularly those where the programs are being implemented[24]. These and other aspects must be framed within a National System of

23 This implies that it be structured as part of the Institutional Education Projects (PEIs) and inserted into the curriculum with defined hourly intensity from preschool to high school.
24 This does not mean that it is exclusively about "folkloric" or "traditional" content, but about the practice of living cultures or cultures that have a special heritage interest in the regions.

Artistic and Cultural Education and Training, which is coordinated, participatory, decentralized and with effective mechanisms for consultation, under the responsibility of the Ministry of Education and the Ministry of Culture[25]. The latter, in conjunction with the STI Ministry and the Ministry of Labor, must implement a National Policy for Artistic and Cultural Education[26], which updates and implements the public policy for artistic education previously proposed by the Ministries of Education and Culture.

b) This policy should contain a specific program to train teachers who are in charge of content related to art, culture and the cultural creative industries in their different areas and modalities. It must also include training programs for trainers intended as on-going programs in academic education, as well as in personal, emotional and pedagogical development. Both programs must be permanent and must address processes that lead to the intertwining and formation of complementary and diverse areas of knowledge. Both programs should include teachers and trainers who work in formal, informal, and non-formal educational settings.

c) According to this framework, at least one educational institution specialized in the arts should be established in each of the 32 departmental capitals. These institutions will be responsible for training exceptional talents in the different artistic areas, offering intensive training from preschool to high school, culminating in a technical degree, and linking its undertaking and guaranteeing

25 Recently, there has been a consistent implementation of joint efforts by the Ministries of Education and Culture, which open up a new and promising scenario in sensitive issues which, due to their complexity, necessarily require this articulation. An example of this is the Artistic Primary School project in the Department of Quindío, which highlights the fundamental role played by the departmental secretariats of both branches and, in general, the promising alliances that work of this type can bring about at departmental, municipal and local levels.

26 This National Policy of Artistic and Cultural Education must contain a policy of teacher training in the arts.

continuity by offering scholarships in university arts programs. In addition, each department capital must structure their higher education offering with technical, technological and professional level programs in different specialties of the artistic areas. These programs should be related to the different roles involved in the CCI's value chains, and establish agreements and extension programs for those department capitals that do not yet have a university level program in the arts.

d) The Ministry of Education must produce guidelines to achieve curricular, pedagogical and evaluative transformations in early, basic and middle education using an aesthetic approach, that is, one that develops perception, sensitivity and receptivity (*esthetics*). These should include: the privilege and incorporation of local knowledge into the curriculum, establishing links between this knowledge and global knowledge; allowing for subjective and intersubjective exploration; implementing classroom methodologies which prioritize creativity as a form of problem solving, in which there are no single, pre-established answers, and where priority is given to innovative solutions to problems or questions that are commonly included in the curriculum; to incorporate teamwork as an educational strategy and methodology, to develop creativity in a collective context and use experimentation and creation as ways to build knowledge and work in the classroom. An emotional education should also be fostered, in which knowledge is permeated by amazement, emotion, and acceptance of diversity, emphasizing curiosity for creation, research, and experimentation.

e) Progress must be made in the implementation of the National Qualifications Framework with much greater participation by universities, businesses and basic and secondary education institutions, in order to guarantee agreements on the scope of each level of training. This will allow the technical and technological training offer to focus on the roles required to develop the CCIs. The methodological skills-building model must be made more flexible and adapted to the particular conditions of cultural phenomena, and not the other way around.

f) Professional training in areas related to CCIs should promote, from a very early stage, permanent spaces for collaborative work between different disciplines, including other links in the value chain and areas of knowledge that are not very similar to the area or scope of study. The Ministry of Education —and especially the Vice-Ministry of Higher Education— must produce guidelines in this regard.

g) Decentralization of training for CCIs should be encouraged. Stimuli should be generated to expand the training offer in all regions, taking care that it does not only address creators, but the entire CCI value chain. Through public-private partnership schemes, a sustainable program of scholarships and incentives for internships, residencies, diplomas and graduate programs in specialized artistic and creative areas should be designed, and in each of the 32 departments these should be connected to training and productive processes in order to democratize training opportunities across the country and promote talent equitably. This will connect the different levels and modalities, ensuring a gradual and complete path to a high level of development that will place the arts and creative practices in a dignified position in the country's social and productive development.

h) Research + Creation (R+C) must be present throughout the entire educational process, especially in higher education. The offer of high-level training (master's and doctoral degrees) in areas related to CCIs should be expanded to emphasize R+C processes.

i) There is a need to develop networks that allow teachers and cultural managers from different parts of the country to meet and exchange knowledge, methodologies and pedagogical strategies.

Circulation of content, connection with industry, integration of value chains

a) The Ministry of Culture must strengthen its role as the central point of the network of cultural centers, guaranteeing an information system that allows the flow of content, human talent and good practices. It is also important to develop articulated and sustainable processes to train the managers of cultural centers. Other specific proposals in relation to the cultural centers are dealt with in the section on infrastructure and technology, and in the Creative Incubators initiative.

b) We must encourage the application of cultural censuses in different regions and sectors as a starting point for the implementation of an information and communication policy for CCIs.

c) Grants and other incentives must be created for roles other than creators. These may be of a fiscal nature or through prioritization in calls for funding, but in any case, they must privilege the circulation of national content. Similarly, incentives can be offered to private companies that support the enhancement of different roles within the chain. Incentives should also be considered for the national circulation of human talent in all roles throughout the value chain.

d) Emerging processes of associativity need to be identified in order to channel relevant information on stimuli and incentives to the resulting collectives and associations. This work should be led by the Ministry of Culture in coordination with the Secretariats of Culture, the Chambers of Commerce and other entities in the sector. In this sense, it is essential to encourage the strengthening of networks and associations at all levels of the sector, including informal networks, at national, departmental and local levels.

e) It is important to prioritize triple and quadruple helix relationships for the creative and cultural industries. In addition to the Creative Incubators project, this type of relationship should be promoted through joint calls for funding from different state entities, as has already been done for other types of projects within the SNCTI framework.

f) As well as training human talent and creating knowledge through research and creation, universities are vital for the circulation of content and cultural dynamism, as part of their outreach function. We propose that the CNA consider this activity within the evaluation criteria for accreditation purposes.

Infrastructure and technology

a) We propose that a relationship model be created as a flagship project that integrates characteristics of creative laboratories, business incubators, and centers offering programs that are open to the public, through a national network of Creative Incubators.
b) A call for funding should be launched to form a bank of investment projects in cultural infrastructure that will allow the application of the existing Public Works Tax Deduction Law incentive. This can be implemented through a joint call for funding from different state entities and can serve to prioritize those investment projects that have a greater cultural impact.
c) Agreements with foreign companies should explicitly include clauses conducive to local capacity building. Platform content quotas or producers' demands of hiring Colombian talent are well-intentioned concerns, but not sufficient in the long run. There must be clear schemes of knowledge and technology transfer that strengthen the local industry.
d) The cultural and creative industries need knowledge and technology—interfaces, methods, materials, etc.—for creation that is currently imported at high cost, but that could just as well be produced in the country. In turn, the sciences can benefit from new forms of representation, communication and expression explored by the arts (not only for the purposes of dissemination and social appropriation, but for scientific production itself). We propose that the Ministry of Science and Technology, together with the Ministry of Culture, open specific calls for funding for this type

of project that encompasses mutual support between science and art through R+C processes.

e) Many properties in the country have been declared to be national heritage, whose use is highly restricted due to the difficulties of working with them. We propose that these properties be prioritized as spaces for the circulation of cultural content, through a specific stimulus that can be of a fiscal nature or regulatory flexibility.

f) Public and private entities must coordinate to set up a policy that sees actors of the CCIs appropriate convergent technologies. This policy must include, at minimum, a wide-reaching training program—both formal and informal—alongside mechanisms to facilitate the movement of experts (creators, managers, intermediaries, technicians) around the country, with a focus on local capacity building.

g) Academic programs must be expanded to include state-of-the-art technologies in high-level education in creative areas (master's degrees, doctorates, lifelong education), either through new programs or new lines of training in existing programs.

Regulation, financing, information

a) The National Copyright Office must continue as an entity separate from the Superintendence of Industry and Commerce. Care must be taken not to create inconsistencies by giving way to interpretations that obey the Copyright rationale rather than that of Colombian legislation on Authors' Rights[27].

b) Efforts should be made to formulate and approve a sponsorship law that defines structural and long-term incentives for investment in cultural activities, based on the experience gained in film laws and others that have had a positive effect on the sector.

27 Authors' Rights legislation in Colombia is different from the Anglo-Saxon *copyright* system for historical, legal and conceptual reasons, connected with the concept of culture established in the Constitution and in Law 397 of 1997.

c) Streamlining processes and reducing the tax burden is essential for the formalization of different types of organizations in the cultural sector, based on long-term mechanisms rather than on a short-term basis.

d) A policy on information and communication for CCIs should be formulated in order to: i) bolster and coordinate existing information systems and create new ones where needed[28]; ii) establish clear benefits for users, such as enabling the two-way flow of information or mediating between supply and demand; iii) communicate educational content to specific users and obtain timely feedback on sector-related problems; iv) achieve full ownership of cultural policies; v) involve different CCI actors in data gathering through clear duties and rights; vi) perform big data analytics, in order to provide decision makers with relevant information about the sector. The formulation and implementation of this policy requires a significant investment of time and resources, and must be carried out under the leadership of the ICT Ministry, the STI Ministry, and the Ministry of Culture.

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28 Although systems such as SIMUS are proposed as intermediaries between supply and demand, users state that they do not perceive any benefit from registering their data, as they do not receive any information and do not gain useful contacts for their activities. The same could happen with the DNDA's *Red Naranja* initiative, unless it is articulated as part of a policy that prioritizes two-way communication.

Reflections of the Oceans and Water Resources pillar and proposals for reform

Context and scope

The focus here is on three components: the ocean and its marine-coastal and island ecosystems; the terrestrial freshwater ecosystems, and the marine and terrestrial water resources[29]. On a global scale, the ocean covers 70.8% of the Earth's surface (~ 510 million km^2) and with sea ice it represents 97.95% of the planet's water. Colombia's terrestrial area covers 1,141,748 km^2 [56%] and the maritime area, 919,376 km^2 [44%], distributed between 540,876 km^2 of the Caribbean Sea (3513 km of coastline) and 378,500 km^2 of the Pacific Ocean (1556 km of coastline) (Ministry of Environment and Territorial Development, 2010).

Many ecosystem services are provided, including oxygen production, creation of biological resources, lines of maritime communication, and renewable and non-renewable energy sources, among others. This leads to the jurisdictional waters, the land mass, and coastal areas being used for different activities such as: tourism, fishing, maritime transport, mining exploration and exploitation, alternative energy production, conservation, recovery of biological diversity, scientific developments, technology, innovation, and maritime culture. It is also where ocean-atmosphere interaction

29 According to national regulations – Decree Law 2811 of 1974. Code for Renewable Natural Resources and Environmental Protection –. Article 270: "*Water resources are understood as the set of animal and vegetable organisms whose life cycle is totally fulfilled within the aquatic environment, and their products*." Excludes fishing resources, Law 13 of 1990, General Statute of Fishing and Aquaculture.

and the physical and chemical dynamics are determining factors for the Earth's climate and environmental dynamics (Ministry of Environment and Territorial Development, 2010).

According to IDEAM (2007), Colombia has 114,049,388 ha in continental ecosystems: among the coastal-marine and island ecosystems are coral reefs with 2844 km^2 of structures in the Caribbean region and 15 km^2 in the Pacific region; mangroves with 294,636.3 ha (Sánchez-Páez *et al.,* 2000; Invemar, 2013); 43,223 ha of sea grasses, exclusive to the region; rocky coasts; the sedimentary bottoms of the Caribbean-Pacific continental shelf, which constitute 99.5% of the marine ecosystems, occupying an estimated area of 889,400 km^2 (Guzmán-Alvis and Solano, 2002); beaches; and the pelagic or oceanic zone.

According to a new census, there are 8.7 million species on the planet and only 1.6 million species have been identified, which means that approximately 86% of terrestrial and 91% of marine species have not yet been described (Mora *et al*. 2011; United Nations, 2015), with inland waters hosting a very high percentage of those not yet described compared to other ecosystems, as they cover less than 1% of the planet's surface, but are home to more than 25% of the described vertebrates, more than 126,000 of the known animal species, and approximately 2,600 aquatic macrophytes. It is estimated that, globally, there are 27,400 species of fish, mollusks, crabs, dragonflies and freshwater plants, of which only 6,000 have been described to date (IUCN, 2008; RAMSAR, 2018).

With respect to marine and oceanic biological diversity, according to the latest available data, each year 1635 new species are described and, at present, there are between 230,000 and 250,000 species, representing 15% of the planet's biodiversity (McIntyre, 2010). These diagnoses make it possible to conclude that Colombia's biodiversity holds close to 30,436 species of plants, 7432 vertebrates, over 300,000 species of invertebrates, 1644 fungi and 1647 lichens, all obviously dependent on water resources. Indeed, Colombia is one of the 14 nations considered megadiverse, and, although it covers only 0.22% of the earth's surface, it is home to about 10% of its known species.

As for the country's marine and estuarine fish wealth, it is estimated at nearly 2000 species of fish (Acero and Polanco, 2006). Likewise, in the Caribbean there are reports of 1498 species of mollusks, 239 echinoderms, and 990 fish; while in the Colombian Pacific, approximately 806 species of fish, 551 crustaceans, 459 polychaetes and 30 marine mammals have been registered. Of the approximately 2000 marine and estuarine species, 449 are considered fish of current or potential commercial importance. Regarding freshwater fishes, Colombia has 1435 species grouped in 14 orders and 47 families; of which, around 21% are endemic and 12% of commercial interest. The orders with the highest number of species are Characiformes (637), Siluriformes (524), Perciformes (124) and Gymnotiformes (74); the remaining orders have between 1 and 35 species (Maldonado-Ocampo *et al.,* 2008). Colombia's fish species represent approximately 5% of all recognized marine and freshwater species globally, and, on the continent, they represent approximately 29% of the freshwater fish that inhabit waters from the southern border of Mexico to Chile and Argentina (Maldonado-Ocampo *et al.,* 2008).

The goal for this pillar is to provide guidelines for the formulation or modification of public policies by designing strategies and flagship missions that promote the adequate knowledge, management, control and sustainable use of natural resources—renewable and non-renewable—so that natural capital can produce future socioeconomic and research opportunities that facilitate its development in the interest of the regions in these areas.

Status of the field in Colombia

Looking 10-15 years into the future, we should, in the first instance, consider which national policies and international commitments that have been signed are most relevant to the ocean and water resources, and to look again at those that can be reconsidered within the framework of the United Nations' program Decade of Ocean Science for Sustainable Development.

An initial approach is to consider the recommendations made by the second Mission of Experts in 1994, which the Colombian government formed under the name Science, Education and Development Mission. This Mission produced a document entitled Colombia: On the Edge of Opportunity (*Colombia: al Filo de la Oportunidad*), which formulated recommendations on institutional, educational, and science and technology related factors. Some of these were implemented and led to the development of public policies, but most remained pending and are now applicable to the themes of this pillar for the current mission.

- *Education for sustainable development*, which should work as a junction between scientific and technical knowledge, while recovering traditional knowledge —regional, local, native, *raizal*, indigenous, and Afro—in order to implement the appropriate and concerted management of natural resources and the environment.
- *More training for scientists,* which needs to consider the priorities in science and technology the country requires for its development, without leaving behind the basic sciences. In the words of that 1994 Mission, an endogenization of science and technology in Colombian culture.
- *A legal framework,* which must be consistent, relevant, up-to-date, forward-looking and provide all guarantees that will allow research on natural resources in any of their forms or modalities, both by nationals and foreigners, whether individuals or legal entities.
- *Inventory, characterization, calculation and valuation* of the country's natural resources, in order to understand their potential development and use and contribution to the economy.
- *To identify and understand* the tasks undertaken by each of the national, regional, local public entities, NGOs, private entities, foreign entities and international organizations regarding biodiversity and environment, in order to formulate an agenda of concrete and concerted actions, to avoid dispersion, repetition of actions and investments.
- *Develop an environmental education program* to raise awareness about the need to properly manage the environment.
- *Strengthen research (research centers, research groups, researchers, national companies)* that can give added value to the use of biodiversity through state-of-the-art biotechnology.

Since the second Mission, the country now has documents and policy developments for science, technology and innovation[30]. To these, we can add the passing of Law 99 of 1993 on the National Environmental System, as mandated by the 1991 Constitution (Articles 79-80), and policies on biodiversity—knowledge, valuation, conservation, recovery and restoration—and water, which in the case of this pillar, became its fundamental axis[31]. Although the regulatory framework is very broad, laws, decrees, policies, strategies and guidelines have also been issued to guide the conservation and responsible use of the country's natural resources, including water resources. These must be taken into account as a fundamental input for defining public policies over the next 25 years[32], given that we depend on the natural capital that in some cases can withstand aspects of crisis.

30 Decade of Ocean Science for Sustainable Development 2021-2030. The Sustainable Development Goals 2018-2030. The Third National Communication on Climate Change. The Science Manifesto. Fresh Water Resources in Colombia. The National Policy for the Integral Management of Water Resources. National Policies, Plans and Strategies for the Oceans and National Water Resources between 1993 and 2018. Development Plan 2018-2022, *Pacto por Colombia*, *Pacto por la Equidad*.

31 Conpes 3886/2017. Policy Guidelines and National Payment for Environmental Services Program for Peacebuilding. National Council of Economic and Social Policy. Republic of Colombia. National Planning Department. Bogotá, D.C. p. 94.

32 National Policy on Biodiversity (1996). Guidelines for the National Policy on the Ocean and Coastal Areas, (LPNOEC; 2002). National Policy on Sustainable Production and Consumption (2010). National Policy for the Comprehensive Management of Water Resources (2010). National Policy for the Comprehensive Management of Biodiversity and its Ecosystem Services (2012). Plan to restore the Magdalena River waterway (2013). Plan for Green Business (2014). National Policy on Oceans and Coastal Areas (2015, 2015, 2016, 2018). Policy for Sustainable Land Management (2016). National Policy on Climate Change (2016). Comprehensive Strategy for the Control of Deforestation and Forest Management – *Bosques Territorio de Vida* (2016). Policy Guidelines and National Payment for Environmental Services Program for Peacebuilding (2017). Strategy for the implementation of sustainable development goals (SDG) in Colombia (2017). National Policy on Science and Innovation for Sustainable Development (Green Book; 2018).

Proposals and calls for funding

Based on the historical information reviewed and the country's current context, the following proposals are made for implementation and development over the next 25 years:

Promote modern and inclusive education in the natural sciences, supported by a scheme for technological and research training in schools and training centers

In this respect, students and their families will be involved in making research proposals, emphasizing the importance of promoting critical and scientific thinking from the beginning of comprehensive education. To this end, the educational process must take into account the country's regional and local cultures, particularities and needs. This purpose will be accompanied by telepresence education systems, ensuring real-time monitoring of processes, studies and research, the appropriation of knowledge, awareness raising concerning the conservation of natural resources, and the entry into a stage of promoting research and teaching in the digital era.

Transforming culture and research for the new generations

This can be achieved through associations between the country's public and private schools, led by the Ministry of Education and the STI Ministry, that encourage science and the correct management of natural resources.

Support for local and regional human resources

Ensure that highly-trained human resources focus on local and regional issues, and that their permanence in these areas is guaranteed. This can be achieved by establishing specific quotas for the financing of research and researchers, geared towards solving problems, based on a National Plan for Science and Technology. The country has a strong doctoral education in certain areas, which, in terms of investment, will reduce costs.

Foreign doctoral researchers

In order to expand research, scientific production and the possibility of knowledge transfer, scholarship programs should include funding for foreign students in areas in which we are lacking. For this, the new STI Ministry can redirect resources through its various support programs.

Expand the knowledge base of terrestrial and marine biodiversity

A special fund of national and international financing should be set up to survey groundwater and aquifers, terrestrial water and deep ocean, as well as promoting the acquisition of oceanographic vessels.

Catalogue, identify, monitor and update the inventory of water resources and their quality

Action to be led by the National Environmental System at the head of the Ministry of Environment and Sustainable Development, the Oceanographic and Hydrographic Research Centers of the National Navy, as well as research groups, universities, and the private sector. Implementing the open data initiative, this task must accurately address land management and the resolution of environmental conflicts such as bioaccumulation and biomagnification of chemical elements and compounds, which make water a poor-quality resource in most of the water network. For this to happen, entities belonging to the National Environmental System (SINA) must rethink their actions.

Implement an open data policy

Any person or entity should have access to all scientific and technical information that allows them to collect the physical, chemical and biological information of the national territory in situ or under remote sensing, when involved in innovative strategies of international scope (e.g., data papers). Data is an important element for generating added social and economic value, and forms part of countries' comprehensive economic development (OECD 2007). The trend towards open data in STI has closed the knowledge gap allowing researchers, students, and non-academics to have access to information worldwide and it is precisely this that underlines the difference between being competitive and creating value-added products. Due to technological advances, research is in a methodological transition phase, moving from an individual modality to one based on the human collective and artificial intelligence, these being the fundamental bases of the concept of open science.

This proposal is based on the initiatives of the Electronic Government, Conpes 3920 of 2018, in Law 1712 of 2014, which in addition to defining the public entities involved, establishes that private universities, research centers and institutes and NGOs should be included. A law and its regulations are needed, establishing the obligation to publish information obtained with public resources in data article format with the raw data freely accessible in one of the digital repositories. The private sector and private and public educational institutions should be given incentives in terms of quality indicators for their management or for the dissemination of their students' theses and research information. In addition, a robust platform of global reach is needed where, for example, the National Academic Network of Advanced Technology (RENATA), is the basic tool for this task.

Improve the installed infrastructure for monitoring the atmosphere, hydrosphere, and geosphere

Employing the usage mechanisms implies the definition of: i) the fundamental aspects of the creation of the National Policy on the Use of White Vessels, based on the strategy of research vessels being managed by a special civil society body or consortium; ii) renew and enhance the *National System of Environmental Observation and Monitoring* for rivers, lagoons, lakes, wetlands, and seas, bearing in mind the importance of ocean-atmosphere, continent-atmosphere interaction, a fundamental tool through which to understand, predict, and model national climate change scenarios; and iii) strengthen the system of museums and biological collections, as safeguards for biodiversity, with open access to society. The Colombian Navy, IDEAM, the Ministry of Environment and Sustainable Development, the STI Ministry, and SINA, ASCUN and the Colombian Academy of Exact, Physical and Natural Sciences, are the fundamental actors for the creation of this consortium. However, the STI Ministry needs to have an Agency for the appropriation of the knowledge base, where the resources for the operation of environmental monitoring systems and their modernization are ensured in the long term.

Relationship with the other pillars

The four hierarchical proposals described above interact dynamically with at least four of the Mision's thematic pillars: i) Social Sciences, Human Development and Equity; ii) Biotechnology, Bioeconomics and Environment; iii) Basic and Space Sciences; and iv) Convergent Technologies, Nano, Info, Cogno, Industry 4.0.

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Reflections of the Convergent Technologies and Industry 4.0 pillar and proposals for reform

Context and scope

As a result of large-scale technological convergence that has provoked new scientific discoveries and, above all, highlighted the need to think about where we want to go as a society, we are currently facing one of the most demanding challenges of recent history. Its intensity, speed and capacity for social, cultural and economic transformation are on a revolutionary scale. The wonders of human ingenuity are ushering in the creation of services and business models that will enable social wellbeing like never before; productivity and efficiency will grow, and the dynamics of work will be transformed, producing one of our greatest challenges as a society: the new definitions of productive roles. It is possible that the jobs we have in 2020 will not be the same in 2050, hence the importance of improving training for Colombians; providing them with the tools to deal with these uncertainties. At the same time, quality of life and longevity will increase, hand-in-hand with new and powerful tools for medical diagnosis and treatment of diseases; the convergence of *Nano-Bio-Info-Cogno* (NBIC) technologies even leads us to think about improving "human performance." The possibilities of interpersonal communication and social interaction are magnified with a possible impact on social structures and group behavior. Aspects such as ultrapersonalization; disintermediation; the decentralization of business models; and social, economic, and political interaction through the mass usage of data and its analysis, will bring new and major ethical challenges, related (but not limited) to privacy and security rights that must be managed by society as a whole to ensure the guarantee of these inalienable rights, which are more critical than ever in our modern society.

Many of the developments happening now are a product of the joint action of numerous disciplines brought together by a common goal. Four areas of knowledge combine under the expression Convergent Technologies in hierarchical systems from the nano to the macro scale: Nanotechnology, Biotechnology, Information Technologies and Cognitive Sciences (NBIC). The systemic approach is another foundational field that has implications for the integration of convergent NBIC technologies. Could this convergence lead to more significant results than any of them individually? The answer is that convergence exponentially potentiates results (Bainbridge, 2013).

The dynamics of this phenomenon are easy to imagine, but understanding its impact on Colombia is not. Therefore, a diagnosis of national capacities is required in order to embrace the fourth industrial revolution for the State's development strategies. The nations that understand the above and significantly improve strategic digital infrastructure environments, education, research, and innovation, coupled with modern and intelligent regulation, will be those that can turn this moment of change into an opportunity for development.

The Convergent Technologies Group—Nano, Bio, Info and Cogno—and Industry 4.0 has set itself the goal of proposing actions that will ensure a role for Colombia in the national and international context of this new industrial revolution. Colombians of today and future generations must always be taken into account, and a set of proposals has been constructed as a framework for the creation and implementation of a solid public policy in education, science, technology and innovation.

Status of the field in Colombia

Our preparedness to maximize the benefits of technological convergence and digitalization is based on the following elements: the quality of basic education, the relevance of higher education, the robustness of our research system and its levels of internationalization, and the profile of the productive system.

Internet coverage and access for basic education in Colombia

Basic and secondary education are the fundamental basis of the quality of the STI system; the coverage and quality indicators published by the Ministry of National Education (MEN, 2019) show that Colombia has much work to do. The training of human capital to assimilate the new challenges imposed by nano and bio technologies, automation, digitalization, Big Data, artificial intelligence and in general, dizzying technological development, begins at the basic level. At this stage of schooling, basic sciences, language, computational thinking and soft skills would be the main pillars of education. Otherwise, Colombia is still trying to deal with problems of coverage and minimum quality. Minimum requirements such as access to computer resources and internet connection are unacceptable. Only 33% of rural students have a computer and 25% have internet access; in the urban area the values are 63% and 65% respectively (Icfes, 2018). Our backwardness puts at risk the quality of higher education, companies' capacity to start using new technologies and the possibility of reaching a high-level critical mass that will strengthen the national STI system.

The challenge of basic preparation for integrating automation and artificial intelligence applies globally. We must reach a national agreement that redefines the role of teaching according to the need to take advantage of the great technological convergence in contexts such as artificial intelligence, from inclusive content with a great capacity for personalization for students at all stages, inside and outside the classroom.

Programs in higher education, graduates, and their level of training

In this case, only the number of students per area and per educational level is evaluated, in order to define the critical mass required for this great transformation. According to the statistics published by the National System of Information on Higher Education in Colombia (SNIES), the population that completed their studies in higher education—at all levels, from technical to doctorate—in these areas, almost tripled between 2001 and 2017. However, the observation of the number of enrolled students shows a stable trend of around seventy thousand students over the last three years, with a very small reduction in 2019 (SNIES, 2019).

Data on the distribution of students, according to educational level, for the second half of 2017 show a prevalence of vocational training, followed by technical and technological training. In the distribution of graduates in Colombia between 2001 and 2017, there is a considerable reduction in technological training and an increase in the participation of postgraduate students. Although the natural or life sciences, basic sciences, human sciences, agricultural sciences, and engineering sciences continue to dominate our universities and schools, the interdisciplinary and multidisciplinary dynamics that researchers and companies have begun to develop in recent years is undeniable. A factor not mentioned in these statistics, but which is of great relevance globally, is the need to design programs to attract more women to train in the areas of Science, Technology, Engineering, and Mathematics through Art and Design (STEAMD). This is an opportunity that must be pursued by making the right interventions that create the incentives for more active participation.

The relationship between these dynamics and the needs of the production sector is a matter of great concern, as there is no evidence to indicate that the programs offered and their curricular content include any kind of feedback mechanism. We also highlight the value of the SENA's experience, catalogued as "training for work," and whose relevance and articulation with the production sector is a major strength of the country's training system. Some 68% of those enrolled in the SENA are pursuing technological programs related to the pillar's areas (SNIES, 2019). The SENA also offers operational and technical training. Global trends point to high quality and specialized programs with a shorter duration (less than two years) and much more in line with the clear demands of the local and global market (e.g., coders, virtual reality and applied artificial intelligence specialists, etc.).

Research groups in the areas of NBIC and Industry 4.0: number, academic production and impact

The critical mass of research in the country is initially measured by classifying the registered research groups, using the eight thematic pillars of the Mission (Colciencias, 2019) as categories. This has identified that only 13% of the research groups in the country—a total of 1153 researchers—work on topics related to convergent technologies and Industry 4.0. However, a subsequent analysis based on the thematic lines of the groups shows that another 120 groups assigned to areas of basic sciences, biotechnology or health are directly related to NBIC or Industry 4.0 themes. This is explained by the undeniable transversal nature of convergent technologies.

Productivity can be described through the number of academic publications; if we add our academic production to that of Chile, Mexico and Brazil, Colombia published 9% of total publications in applied technologies and 6% of the total in basic sciences. The relationship between these two items is fundamental and shows the important support that basic sciences provide for technological developments. The number of publications in both areas, identified for the Latin American countries mentioned and the United States, China and Germany, shows a very constant and approximate ratio of 33 to 1; that is, for the countries mentioned, for every 33 articles on the basic sciences, one is published on technological applications. In this same line, we found that the four Latin American countries listed contribute 6% of the articles in convergent applications and 7% in basic sciences.

The impact of our scientific system as measured through patents and patent citations is minimal. According to data published by Lens.org, out of the total of world patents in areas associated with NBIC and Industry 4.0, Colombia has logged 0.0008 % of the registered patents; the impact of publications on world innovation is a little higher: Colombian academic works constitute 0.0256 % of the theoretical support cited in these innovation processes.

Depth of knowledge in topics related to the pillar in the productive sector

Taking into account the DANE manufacturing and services surveys, the participation of the sub-sectors most closely related to the pillar is analyzed in relation to total sales or income, value added and employment. In the manufacturing sector, the following sub-sectors were considered: computer, electronic and optical products, electrical appliances and equipment, machinery and equipment n.e.c., motor vehicles, trailers and part-trailers. In the case of the services sector, the following were included: development of computer systems, data processing and professional, scientific and technical activities. Table 13 contains information that describes the participation of the most knowledge-intensive subsectors in the large manufacturing-services sectors by income, employment and value added. It is clarified that in both cases there may be errors of overestimation, since not all activities within these large production subgroups are directly related to the themes of the pillar.

Table 13. Percentage participation in the large manufacturing/service sectors of the most knowledge-intensive subsectors by income, employment and value added.

Sector	Income (%)	Jobs (%)	Total Added Value(%)
Services	9	3	13
Manufacturing	6	8	5

Source: Authors.

Conditions for retaining and attracting human talent - work opportunities

Highly educated human capital finds few opportunities in Colombia for labor market insertion outside of the university environment. The data on the number of PhDs in Colombia is quite imprecise, since there is no effective mechanism for monitoring the number of PhDs trained abroad.

However, the DANE manufacturing and services survey (2016-2017) identifies 15,000 PhDs in the labor market, including the university sector. This same survey establishes that only 10% of the people with doctoral training work in the industrial or service sector; the rest are linked to higher education institutions. Those that attended the regional forums held by the Mission of Experts, consider that companies do not have a work environment conducive to research, nor are there any salary incentives that invite academic qualification within the work environment. Figure 19 shows the low insertion of highly qualified personnel in government or industry, all of whom are concentrated in the academic environment. The flagship missions proposed by this Mission of Experts represent a great commitment to training, recruitment, development and retention (repatriation) of PhDs and, in turn, a break with the past in terms of attracting international talent to help advance the country's great project.

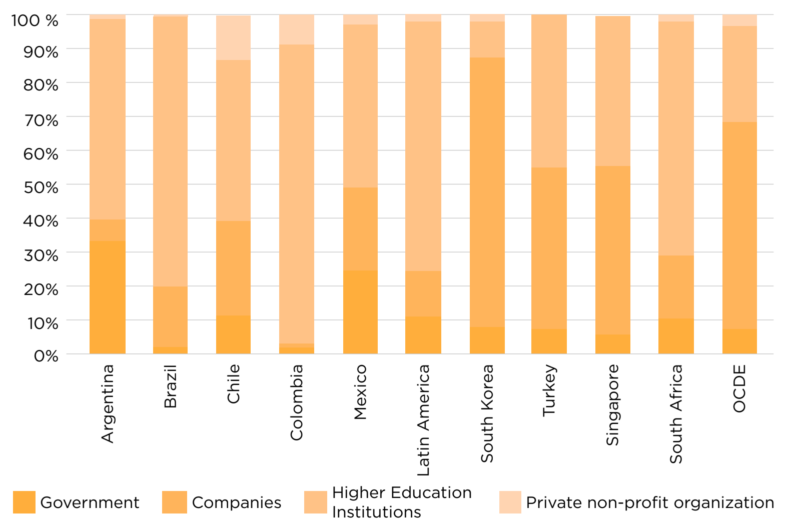

Figure 19. Insertion of researchers in the public and private sectors.
Source: National Competitiveness Report Colombia 2018-2019

Critical Architecture for Innovation and Global Opportunity

This pillar of the Mission of Experts proposes the implementation of what has been called *Critical Architecture for Innovation and Global Opportunity* that brings together the necessary elements to position Colombia as a knowledge-based society, based on intelligent, organized and focused investment; this proposal also includes a taxonomy that could help make critical projects viable at scale, as well as national strategic commitments with transformational potential for the benefit of society as a whole. The architecture is presented in Figure 20, which identifies five horizontal layers and seven pillars that cross each layer vertically. The pillars illustrate the critical dependencies that describe where to direct our efforts and resources to position the nation for a better future. The horizontal layers represent the physical elements, technologies and capacities that support the National System of Science, Technology and Innovation (SNCTI) as well as a layer including beneficiaries who will be included economically and socially as a result of a successful implementation of the proposed Critical Architecture for Innovation and Global Opportunity.

Proposals

The proposals put forward in this pillar arise from the description of the *Critical Architecture for Innovation and Global Opportunity*. The intention of these vertical pillars is to highlight the critical dependencies that define where we should direct our efforts and resources in order to translate them into sustained actions of great transformational significance. Based on this scheme, we illustrate three major proposals of the pillar and two major challenges addressed by it.

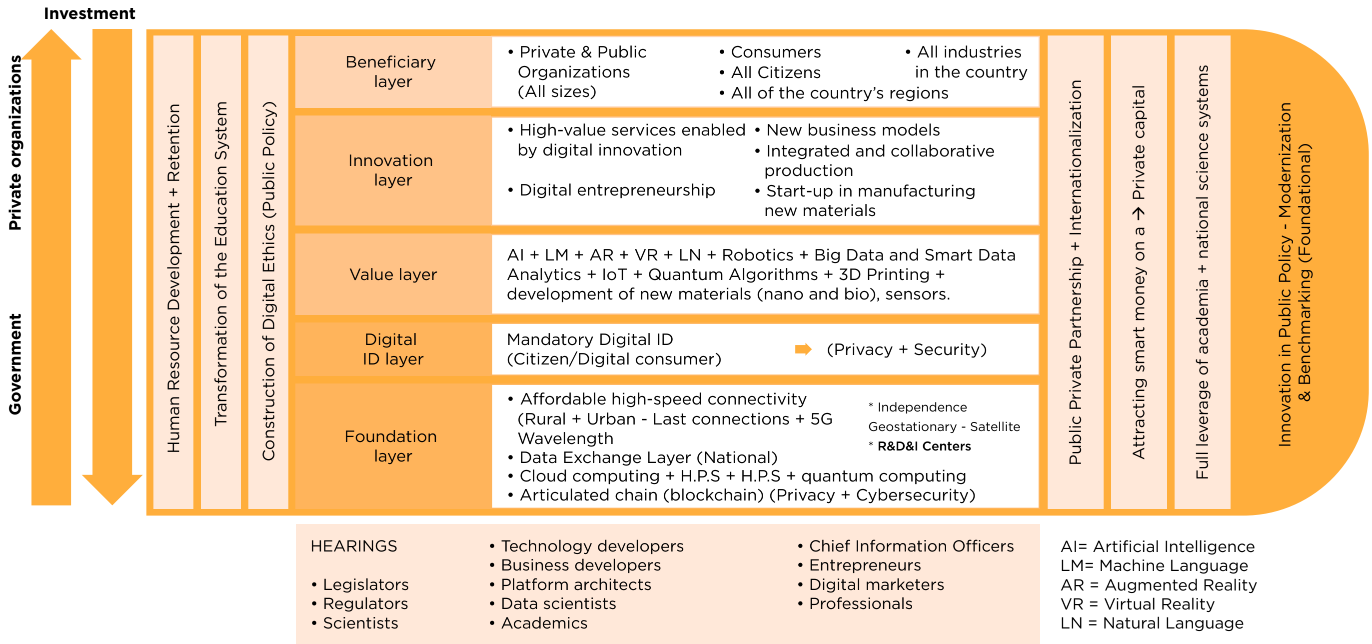

Figure 20. Critical architecture for innovation and global opportunity, with the five layers and the vertical pillars required to build a knowledge-based society.

Transformation of the educational system

a) Computational thinking and bilingualism should become a comprehensive part of basic education in Colombia by integrating the former as a basic area and dedicating more weekly hours to the latter, especially English. Finally, strategies for training based on a STEAMD approach should also be adopted, in particular, in terms of data analysis, robotics, and artificial intelligence and their respective algorithms, which are areas of very high demand globally and of immense priority for the leading countries in the transformation of their educational systems in convergent technologies. It is very important to mention the urgent educational need to drive ethical values, which above all include transparency and inclusion in the development and use of new technologies. This will require a transformation of the curriculum, relevant teacher training, and the provision of computers or tablets and Internet connection in all of Colombia's educational institutions.

b) The number of engineers in the country is not enough to ensure high levels of research and technological appropriation. All engineering curricula must enhance the teaching of basic sciences, and promote the development of AI, IoT, and advanced mathematics skills. This will inevitably require major country projects to ensure their retention.

c) Higher education institutions of all levels and profiles must ensure their programs are adapted to the "Ethical education throughout life" scheme and the social appropriation of knowledge, targeting employees in the production sector in particular, since 63% of this population lacks any form of higher education. This is a condition that must be corrected, as the country's technological development requires both researchers to create and innovate, and a broad foundation of technicians and technologists to implement the new developments.

Digital transformation of the State, digital identity, and national infrastructure for digital connectivity

a) The State is, by definition, the basic platform of national administration, its efficiency results in the good performance of all other sectors of society. In today's world it is impossible to speak of efficiency without digitalization. The State' s digital transformation must be consolidated beyond the goals of the current PND and must include the digital identity of citizens as a tool to improve the distribution of public and private services due to the dispersed nature of the Colombian population. The establishment of a data exchange layer for the State is essential for this purpose, since it would provide transparency in the use of the public funds, and would be instrumental in creating the conditions for innovation for the State itself and its relationship with the production sector.

b) The instruments of territorial management, environmental monitoring systems, and disaster prevention, as well as urban mobility control, have enormous potential for improvement through new technologies. In this sense, big data, IoT, blockchain or artificial intelligence, among others, become basic instruments of transformation. Public-private partnerships with high-tech companies will be essential in reaching the scale needed to provide solutions that really provide effective responses to these challenges and opportunities.
c) All this transformation also requires a basic infrastructure for connectivity and high-speed data transmission with coverage throughout the national territory. The State must consolidate infrastructure that ensures total regional connectivity as an instrument of social welfare and educational inclusion, as well as control and local development. Connectivity in today's isolated regions must be a national priority, again, beyond the goals of the PND.
d) The State as a regulatory entity must also modernize, meeting the demands of new business and information management models, including the pressing need for innovation in public policies that help create the conditions necessary to accelerate innovation in all its dimensions.

Innovation Ecosystem

a) Modernize research funding systems and the promotion of risk capital to convert ideas into consolidated products and enable the creation of new technology-based companies – public-private partnerships –.
b) Redefine the role of technicians, technologists, professionals, academics and researchers, leveraging the interactions between all levels through institutes that articulate scientific research, production sector, and public sector – National Centers, Institutes and Laboratories –.

c) Integrate SMEs into the dynamics of the fourth industrial revolution; their lag in terms of technological appropriation and their importance in the national economy make them the focus of any program that seeks to involve Colombia in the global dynamic. This is a great opportunity for public-private alliances with companies that today are highly focused on this sector and whose productivity is enabled by state-of-the-art technological tools.

Challenges for the country addressed by the themes of this pillar

1. Productive and Sustainable Colombia.
2. Biodiverse Colombia: in nature and culture

Flagship Missions

Mission-oriented research (MOR). General policy

Origin and definition

Mission-oriented research (MOR) recognizes that the State should be proactive in guiding scientific development and innovation. The State should take on the role of an entrepreneur (Mazzucato, 2014). MOR consists of a set of systemic public policies informed by the latest scientific knowledge in order to achieve specific purposes, or "big science deployed to meet big problems" (Mazzucato, 2018).

In the current context of major social and environmental challenges, governments seek to promote smart, inclusive, and sustainable social and economic growth. Adopting the political strategy of "Mission-oriented research" (MOR) facilitates the way challenges are addressed by identifying and articulating concrete problems (missions). This way, MOR fosters the link between scientific expertise and society's interests and requirements, as well as supporting relationships between the public and private sectors in joint ventures. Missions provide solutions, opportunities and a different way of approaching every-day challenges that face both communities and nations.

Knowledge created by STI should be harnessed to guide social, policy, and sustainability goals while promoting equitable and inclusive development. Missions are a powerful tool for guiding political and development agendas and for increasing the impact that scientific knowledge can have on society. This strategy provides the means to focus research and innovation on solving critical problems, while also spurring growth, employment and effecting positive spillovers across many sectors (Mazzucato, 2018). Orienting public investment of STI in new strategic areas, collectively defined by different actors (public, private, and third sector), promotes collaboration among these sectors. On the other hand, investment interest may be awoken in the normally cautious and risk-averse private sector by the clearer picture that missions provide of future growth opportunities.

MOR has evolved over time. The first examples of MOR, dealing with defense concerns such as the Apollo Mission (aerospace) or what is known as the Manhattan Project (nuclear weapons), were under centralized control by the government, had tightly controlled public relations, low participation by private companies and were highly confidential. This has since changed with the creation of large-scale national or international missions that solve social problems of common interest in a political framework that promotes scientific knowledge and the use and development of new technologies. Currently, especially at an international level, MOR is mainly being used to try to achieve environmental, social and economic sustainability in the face of problems like climate change and to fulfill the Sustainable Development Goals. Countries that have adopted mission-oriented research philosophy also encourage and fund curiosity-driven research which, as explained above, complements and supports MOR.

Once a mission has established its concrete goals and a course of action to address a social problem, it starts recruiting various sectors to its cause. In this modern approach to MOR, the various actors involved (public sector, businesses, researchers, consumers) guide the project's scientific and technical direction, the dissemination of results is actively encouraged, and, given the large number of actors involved, control is decentralized. Pioneering and innovative work is encouraged, as is full participation from various sectors. Support for the venture from public policy is essential, and so the MOR approach must provide capacity building to public institutions in order to introduce the learning processes, development of new indicators and tools for decision making and impact evaluation. The missions selected require the participatory involvement of the various actors in order for them to have democratic legitimacy, stability and motivate other sectors in society (Mazzucato, 2016).

MOR overcomes the alleged conflict between science and production sectors. It combines basic research tasks, pre-competitive research tasks and competitive research tasks. Companies, academia, the State and, in some cases, social organizations, converge on a common purpose of high national interest. Where the science, technology and innovation systems are mature, MOR coexists in harmony with fundamental research that is the seed of new and future MORs.

Missions provide different actors with research goals which can only be achieved by designing a set of research programs and innovations, and with policies, deployment actions and citizen participation. The missions must be specific and flexible. In some areas, a mission should trigger the development of new basic and applicable theoretical knowledge and technologies to increase its social impact. In other areas, missions should guide systemic transformative change in social and productive processes. Missions need a combination of both approaches – technological development and systemic change – to have far-reaching social impact. Missions must be challenging, inspiring, relevant and ambitious, but at the same time supported by realistic research and innovation actions; they must have a clear direction, measurable objectives and be achievable within a certain time limit; they must develop interdisciplinary, intersectoral and interactive innovation and be grounded in communities (bottom-up solutions) (Montenegro, 2019).

Mission-oriented research combines advanced science, such as deciphering the human genome, recent advances in physics, or the math behind AI and robotics, with market-oriented industrial endeavors. The knowledge developed as part of MOR must also be oriented to improve society's wellbeing. Those who create knowledge are not expected to apply it to find solutions, but they are part of a work chain that serves the purposes of the mission they are assigned to. Various types of research converge in an MOR, and so workload must be evenly distributed, especially when budgets are limited.

These initiatives are inter, multi and transdisciplinary, and generally with long time horizons, although specific stages and goals should be defined within shorter periods and should be permanently monitored (European Commission, 2018). For this reason, initiatives must consider financing on a longer timescale than conventional projects.

There have been some difficulties in adopting STIs as a priority for public policy and recognizing them as beneficial for sustainable productive development. There is still a lack of coordination among key actors in the system and between public and private sectors. One way to avoid the fragmentation of knowledge in scientific activities is to define specific problems through the MOR and join together efforts from different fields of knowledge which could be related and complement each other. MOR integrates different levels, objects of analysis and disciplines. Mission-oriented policies are based on recent and major technological advances and offer a transformative approach which is required today.

In sum, the main characteristics of the MOR are as follows:

- A country decides to establish policy relating to structural changes, in order to find a solution to an important problem for society, with a specific goal for a country or region, and within a limited time period.
- MOR connects an issue with one or more sectors of society.
- It requires all sectors of society to participate and interact actively and cooperatively, this includes business investment.
- It fulfills a social, environmental and economic function.
- A mission requires the full and active participation of a variety of actors from different fields of expertise.
- Efficient, proactive governance is needed to implement new models of cooperation and sustainable management alongside technological and social innovation.

Examples of MOR at the international level

Most countries are looking towards a more knowledge-intensive development model to take advantage of technological advances and agree that a key instrument for promoting sustainable growth includes new approaches for addressing problems. The greatest challenge for a country is to define and prioritize its missions, whether these have social or environmental relevance, or both. Questions related to production systems, sustainability, energy, quality of life, or issues of regional interest must be addressed. Big questions that promote the scientific development of the region must be collectively defined.

One of the main examples of joint international effort is the European Union's support of the Sustainable Development Agenda 2030 with a focus on research and innovation (Mazzucato, 2018). Each of the 17 SDG can be divided into several themes or missions, according to the specificities of the complex problems affecting a country or region. Achieving these mission's objectives requires interdisciplinary development and innovation, and these are contained in a portfolio of strategic programs and projects. These have been formulated with the direct participation of diverse actors – including local level initiatives – and openness to experimentation and modeling is important (Montenegro, 2019).

Another major global mission that is developing high quantities of crucial knowledge is the Earth BioGenome Project (EBP), a ten-year initiative in which an international consortium of scientists seeks to sequence, catalogue and analyze the genomes of all known eukaryotic species on Earth (plants, animals and single-cell organisms) to learn about them and promote their conservation and use. This mission is studying the impact of climate change, the conservation of threatened species and ecosystems, and the promotion of ecosystem services. Its objective is to preserve the planet's biodiversity and involves leading universities and research centers who share this goal, including the Smithsonian (USA), the Beijing Genomic Institute (BGI) in China, the Wellcome Trust Sanger Institute of Genomics and the Royal Botanical Gardens in the United Kingdom, the Fapsep Research Foundation in São Paulo, Brazil, and the

United States Department of Agriculture. They work closely with the Global Biodiversity Genome Network, the World Bank and numerous biotechnology and Fourth Industrial Revolution ventures. Their results will be free to consult and presented to the public on a digital platform. It is important to emphasize that this project, through the mapping of genes, will reveal the deepest and most intimate characteristics of each species, whereas previous projects have only mapped the morphological characteristics.

Project execution requires complementary and convergent public policies, both in terms of supply and demand, along the value chain, for which effective flexible governance of a strategic nature is indispensable. A capable public sector should exercise leadership, implement and experiment with innovative public-private partnerships and should not limit itself to simply overcoming market failures (Montenegro, 2019). Figure 21 shows the logical structure of a mission.

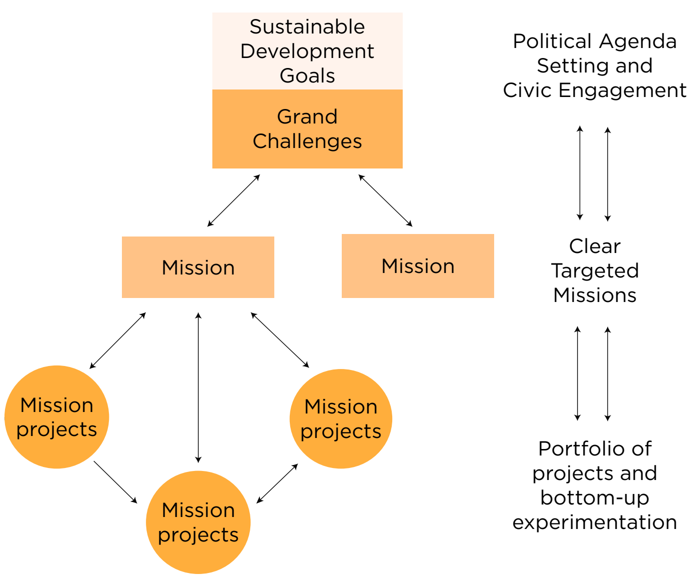

Figure 21. Logical structure of a mission
Source: Mazzucato, 2018.

Specific role of missions in the context of Colombia

In addition to the general functions set out in the preceding paragraphs, the use of missions in Colombia can correct the way scarce funds have been atomized and dispersed, and focus them on solving the country's critical problems. Missions bypass an unhealthy competition for resources by pinpointing common interests and goals where diverse actors from all sectors can participate. Public support for STI can be strengthened by disseminating the impacts of this approach.

Proposals for Colombia

For a country whose greatest potential is its biological assets, the issues of environment, cultural diversity and sustainable development are of crucial importance and should be approached using principles of the bioeconomy and the creative economy. Addressing these issues requires the participation and interaction of different actors at different levels; a scenario perfect for mission-oriented research and innovation. The country requires knowledge and new technologies for the understanding and management of natural and cultural resources to respond appropriately to the challenges of social, environmental and economic sustainability for 2030.

In the context of a knowledge-intensive society, the Fourth Industrial Revolution becomes a fundamental component of the MOR approach, since it constitutes accelerated transformative change in STI in today's production systems, combining digital, physical and biological fields (Big Data, AI, IoT, robotics, nanotechnology, biotechnology, molecular revolution or genomics). For example, in the case of sustainability and compliance with the SDG (Agenda 2030), MOR would articulate and reorientate innovations in life sciences and materials, making scientific research and industries more efficient, facilitating the use of biomaterials, resulting in a reduction of polluting waste.

The plurality of possible initiatives (national and regional), as well as the different scales of mission orientation and their directionality and intentionality are fundamental points to take into account when formulating policies in MOR. There are initiatives aimed at rapid STI advances (accelerators), and others aimed at social change (transformers), and those with variable components of both. For MOR to be successful, an adequate political and institutional environment and cultural acceptance are required. In addition, the project must have the capacity and knowledge to support and be supported by all actors (European Commission, 2018). It is a joint effort that involves a comprehensive chain of articulated functions with the participation of all members of society, each with a specific role, and generally involves a combination of diverse projects because they address a variety of issues. Many of the initiatives dealing with sustainability, the circular economy, climate change and energy have a broad approach and topics such as transportation, safety, health and food have a narrower focus. An additional advantage of MOR is that, as it is directed towards a major common interest goal, specific components relevant to the local or regional situation can be defined that can contribute to that goal.

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Challenges and Missions

In a world and an era in which reason and knowledge face great challenges, many countries have mobilized a good part of their research and technological development efforts towards major flagship Missions. The classic example was the decision by the United States to put a man on the moon in a time frame that seemed unlikely at the time. The decision mobilized the government, business and academia in a coordinated and highly motivated effort, which not only achieved the ultimate goal, but also gave a general boost to all science and technology in that nation, triggering a true revolution in electronics, computing, materials science, communications and many other areas that previously seemed unconnected.

The Mission of Experts 2019 advises that the country address three major challenges using the Mission's strategy. The first challenge is that of a Biodiverse Colombia that proposes that the cultural and natural diversity of the country be identified, understood, documented and taken advantage of to promote the bioeconomy and the creative economy, and to generate awareness in Colombians of the value of their heritage and inspire them to protect and preserve it. The value obtained will allow the country to stop depending on the exploitation of non-renewable resources and primary agricultural products and to turn towards an economy based on knowledge, conservation and the use of biodiversity with high added value and the creation of new products. The second challenge, Productive and Sustainable Colombia, seeks to modify the productive structure of the country towards technologically-advanced industries and services and the creation of environmentally sustainable companies with circular economies that make maximum use of waste, through technological diversification, increased productivity, use of convergent technologies and industries, and the supply of sophisticated and export-oriented products and services. The third major challenge, Equitable Colombia, seeks to ensure that wide access to education, health, basic services and decent employment become the basis for development.

These initiatives are inter- and transdisciplinary and involve fundamental and applied scientific developments. They have long-term time horizons but specific stages and goals have been set throughout which will be permanently monitored. They contain bold and inspiring ideas with a clear direction that points to the heart of great national problems. They are ambitious but achievable. They offer multiple solutions to problems and propose that all interested populations participate in their construction.

Some general government mechanisms will have to be implemented, most of which depend on the Ministry of Science, Technology and Innovation, but it is important to define who will be in charge of connecting the policies with their implementation. This chapter presents a "command control" list that suggests, for each activity, which ministries should participate, those responsible, the terms of execution, and the indicators of compliance. It also defines some preconditions that will be necessary for the success of the various undertakings.

The three major challenges are interdependent initiatives, which overlap in many of their actions and feed off each other. They require the

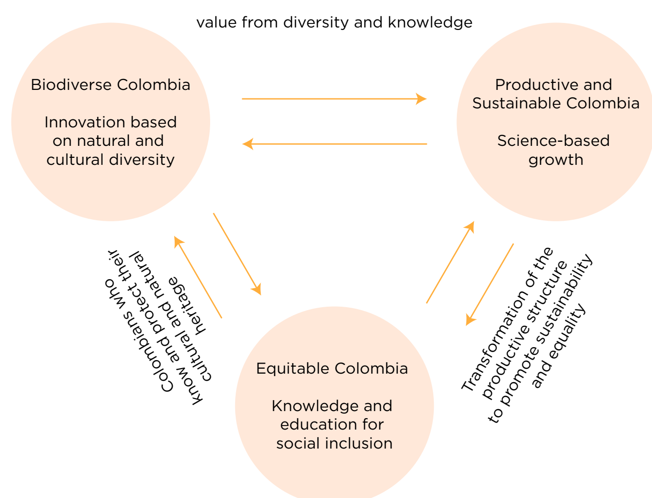

Figure 22. Relationship between the Mission's challenges.
Source: Authors

support of several ministries, universities, centers, institutes, companies and various social organizations. The following figure explains the inter-relationships that will largely define their chances of success.

It is necessary to define adequate financing strategies. The Missions should be seen as an additional effort, which should not displace the main goal to promote the general scientific activity of the country. The strategy must have short, medium and long-term components. In the short term, it is important that the calls for funding financed by royalties and the regional priorities are framed by the proposed challenges and Missions, but this alone is not enough to ensure the necessary resources. In the medium term, 25% of revenue from royalties should be assigned to the Mission's challenges as an additional resource. This requires constitutional reform. Part of this revenue would be destined, in accordance with regional priorities, to funding education with comprehensive attention for the under-5s and also to consolidate and build new regional innovation and research centers and institutes that play an intermediary role between those creating knowledge and the companies that use it. It is also necessary to explore the possibility of multilateral credit that has been awarded here in the past and in other countries of the region, and has had positive impacts on the growth of scientific activity. Without a doubt, private sector participation will also increase, driven by state investment and the success of new ventures.

The Challenge of a Biodiverse Colombia: a model of sustainable economy based on natural and cultural diversity

The Biodiverse Colombia Challenge proposes a sustainable economic model based on natural and cultural diversity, and is supported by two Missions, namely, (1) the Mission for a biodiverse Colombia with a bio-economy and creative economy, which projects that by 2030, the bio-economy must represent 10% of the GDP, and the creative economy 8%, by doubling the value of exports and creating 100,000 new jobs through a strong public-private partnership. This will allow Colombia to discover and value the extent of its natural and cultural megadiversity, and thereby preserve, protect and understand its importance. Economic activities related to the agricultural and food, cosmetic, chemical, textile, pharmaceutical, cultural, forest, artistic, energy, and health sectors among others will have to be transformed. The second (2) Water and Climate Change Mission has the main goal of guaranteeing Colombians access to drinking water, the quality of their bodies of water, the optimal management of water resources, and protection from extreme events. Colombia must reduce the socio-environmental risks of climate change in the period 2030-2050 by 50%, guaranteeing the sustainable development and socio-environmental resilience of the country.

Diverse Colombia, Bioeconomy and Creative Economy flagship mission: knowledge, conservation, appropriation and sustainable use of our cultural and natural heritage for a sustainable economy

The Challenge of a Biodiverse Colombia
A sustainable economic model based on natural and cultural diversity

Mission
Biodiverse Colombia, Bioeconomy and Creative Economy

Programs

- Bio Colombia 2.0 and Cultural Colombia Cultural
  - Cultural and Natural Heritage Repository
- Research program for the conservation of biodiversity
  - Sustainable agriculture and product generation for the industry
- Improving responsible fishing and aquaculture
  - New industrial revolution and manufacturing
- Training and retaining the human talent needed for the regional bioeconomy model based on biodiversity and cultural heritage
  - Content creation based on of cultural heritage

Mission
Water and Climate Change

Programs

- National program for integrated water management in Colombia
  - Ensuring Colombia's water flow
- Water connectivity and maintenance and improvement of the water system
  - Quality and coverage of water resources
- Ensuring the resilience of aquatic ecosystems and biodiversity
  - Threats and risks to water resources
- Towards economic development, competitiveness and improvement of the quality of life of the communities that use water resources
  - National research program on extreme weather events
- National research program on the combined impacts of climate change and global environmental change (CC+CAG)
  - Update of adaptation and mitigation programs for impacts of CC+CGA

Figure 23. Sustainable Development Biodiverse Colombia
Source: Authors.

Mission Statement

In 2030, the bio-economy will represent 10% of the GDP and the creative economy 8%, by doubling the value of exports and creating 100,000 new jobs through a strong public-private partnership. This will allow Colombia to discover and value the extent of its natural and cultural megadiversity, and thereby preserve, protect and understand its importance. Economic activities related to the agricultural and food, cosmetic, chemical, textile, pharmaceutical, cultural, forest, artistic, energy, and health sectors among others will have to be transformed.

Objectives

- A total of 10% of the new jobs will be based on the bioeconomy.
- Colombian society will create comprehensive knowledge of its biodiversity and will use this knowledge to lead international programs for the protection, conservation and restoration of ecosystems.
- Colombian universities and research centers will position themselves as international benchmarks on the knowledge of their natural and cultural diversity and will create a world-class postgraduate offer in this area.
- Measures will be taken to conserve biodiversity, with emphasis on threatened species and ecosystems.
- Cultural and natural diversity will be set out in the national curriculum as programs of study throughout every stage of the national educational system, involving children, young people and teachers in processes of creation and citizen research.
- Regional wellbeing and productivity will be improved by expanding opportunities for the sustainable productive use of terrestrial, coastal, insular and continental biodiversity as part of an open innovation model.
- Regional wellbeing and productivity will be improved through the energetic valorization of the agricultural sector's residual biomass as part of an open innovation model.

- Our natural capital will allow us to build the world's most valuable bank of bioproducts and our cultural capital will allow us to feel closer to our heritage and put it to good use.
- Cultural expressions and practices in all of the country's regions must be mapped and charted, including an understanding of their changing dynamics with a view to protecting and promoting cultural diversity.
- National identity and sovereignty will be fortified by emphasizing, promoting and developing the value and importance of natural and cultural heritage, especially as a tool for social cohesion through diversity and as a source of cultural, identity and economic development in regions.
- The country will be an international reference point for research and participatory action, where society is involved in every step, from beginning to end, of every research project or creative endeavor concerning the recognition of natural and cultural mega-diversity.

Programs and indicators

Colombian society will benefit from efficient and sustainable production systems, goods and services with added value and job creation possibilities in areas such as cultural and scientific tourism; gastronomy; handicrafts; design; cultural industries; production of antifungal, antiviral, and anti-cancer drugs; agrochemicals; analgesics; pesticides; industrial products; textiles; cosmetic products; and products for environmental benefit.

Strategic planning processes must be developed for priority sectors in the various different regions of the country, in accordance with national strategies for the bioeconomy and the creative economy, the green growth policy and the green business program, among others.

Program 1. Bio Colombia 2.0 and Cultural Colombia

Products, goods and services of cultural and natural heritage.

Premises:

- All regulations concerning the collection and access to genetic resources, collections and exports must be modified to favor the expansion of our knowledge on biodiversity.
- By 2025, the complete map of the zones which are off-limits for deep sea research will be available. With this, civil society will be able to apply for international exploration funds without entering into conflict with these sensitive regions.
- By 2025, the practices and assets that have been declared cultural heritage but cannot generate economic and social benefits for their communities due to technical and regulatory barriers will be identified.
- Comprehensive strategies must be developed to forge complementary links and recognize diverse areas of knowledge in a cosmological and universal context.

Tools:

- By 2030, 100% of the knowledge contained in current biological records will be digitized and the number of accessions will increase by 50%.
- From 2020, open innovation calls for bioprospecting must be opened for each sector, for example, calls for proposals in the health and pharmaceutical sector, in the food and nutrition sector, in the agricultural sector, in the environmental benefit sector, in the industrial sector, etc.
- By 2030, there will be extensive documentation of Colombia's cultural heritage. To this end, calls should be opened for proposals concerning mapping, cartography and content development for the appropriation of cultural practices by their communities, with emphasis on those that have not been so far subject to commercial exploitation.
- A portfolio or bank of bioproducts will be available to be used for the second stage of species bioprospecting (scaling up of breeding

methods, patenting or similar processes of intellectual property, commercialization and sales) financed by the interested sector.

- A virtual repository of biodiversity and cultural heritage must be built by boosting citizen science and art projects with participatory action-research models.
- In 2020, calls for proposals will be opened for joint projects of knowledge transfer with a biotechnological approach between universities, institutes and centers and small, medium and large companies. The calls will be directed at different sectors that can benefit such as agriculture, aquaculture, industry, and the healthcare sector.
- By 2030, solutions will have been developed for the technical and normative adaptation of identified patrimonial assets and practices, with a view to their economic and social use.

Program 2. Cultural and Natural Heritage Repository

Premise:
By 2020, the institutes comprising the National Environmental System (SINA) must be subject to increased funding and administrative restructuring to create a research department for them. Their budget will be doubled and partnerships will be forged with universities and research centers.

Tools:

- By 2021, the feasibility study for the National Museum of Natural and Cultural History will be carried out, for the creation of a museum of inclusive and interrelated knowledge. This museum will integrate all areas of knowledge, with content articulated in inter- and transdisciplinary models and scalable to various versions that fit the context of the country's different regions. Cultural content should include areas such as the history of computer science, technology, computing, engineering, video games, among others.

- By 2023, the first phase of the National Museum of Natural and Cultural History will be completed.
- By 2023, the National Museum will have expanded the country's network of museums and aquariums.
- By 2023, there will be a network of cultural heritage documentation centers complying with an open data model.
- By 2023, calls for proposals to produce content for the dissemination and social appropriation of natural and cultural heritage will be opened.

Program 3. Research program for the conservation of biodiversity

Premise:
Colombia's biodiversity is increasingly under threat as a result of habitat transformation, over-exploitation of species, pollution, climate change and invasive species, all of which affect people's quality of life.

Tools:
- The Humboldt Institute will maintain a register of threatened species and a research program to support their management and recovery will be established.
- IDEAM will periodically publish a map of Colombia's ecosystems for their sustainable management, which will evaluate changes and the impact of policies.
- A program will be established to support conservation efforts of threatened species in botanical gardens, zoos and *ex situ* conservation centers.
- Support will be offered so that postgraduate programs in conservation biology and sustainable development can be created.

Program 4. Implementing agriculture which is both sustainable and creates products for industry

- From 2020, innovation and technology will be brought to agriculture with programs of different calls for proposals aimed at universities and research centers for them to provide spaces for co-creation, research and innovation with agro-industrial companies and farmers.
- From 2020, citizen science programs will have been started to expand germplasm collections. Farmers will contribute to collections of wild species that are related to cultivated species.
- From 2020, calls for innovative proposals will go out to farmers for the identification of promising crops in certain regions.
- Regional public-private partnerships will be improved and co-funded for the training of agricultural extension officers in technical subjects, entrepreneurship, marketing or other areas of interest.
- Regional public-private partnerships will be improved and co-funded to reconstruct the social fabric in rural areas using a participatory action-research methodology.
- From 2020, calls for innovative proposals to address the challenges of sustainable agriculture and regenerative agriculture will be opened (applying cascading technologies for the recovery of waste biomass).

Program 5. Improving responsible fishing and aquaculture

Premise:
By 2023, institutes such as MADs, Aunap, Ministry of Agriculture, Sinchi, Invima and the CARs, among others, will be offered the minimum of support needed to comply with current sector standards to ensure health and safety and decent working conditions in the water resources sector.

Tools:

- From 2020, there will be calls for funding for co-management or participatory management projects, in which communities actively contribute to the sector's adoption of sustainable practices, using their ancestral knowledge and in a relationship of mutual respect with the authorities. Communities must participate in the decision-making process which will be carried out in an atmosphere of collaboration and trust.

- From 2020, calls will open for proposals to bolster ongoing projects and create new processes to improve biological and commercial monitoring.
- Aquaculture and ornamental fish: call for proposals that develop or conclude the native species technology packages.

Program 6. New Industrial and Manufacturing Revolution

- From 2020, calls for innovative proposals will be opened for addressing the challenges associated with improving bioproduct procurement for industry and manufacturing.

Program 7. Training and retaining the human talent needed for the regional bio-economy model based on biodiversity and cultural heritage

Premise:

- Cultural and natural diversity will be set out in the national curriculum as programs of study throughout every stage of the national educational system, involving children, young people and teachers in processes of creation and citizen research.

Tools:

- By 2020, strategic and ambitious calls for applications will be opened for the posts of technicians, technologists, and young researchers (from undergraduate level), and for master's degrees, doctorates and postdoctoral stays to support the construction of the bioeconomic model in the regions.

- By 2020, calls for applications will be opened for the posts of technicians, technologists, and young researchers (from undergraduate level), and for master's degrees, doctorates and postdoctoral stays in private organizations and the public sector for work on bioeconomic processes.
- By 2022, a series of incentives and strategic calls for applications will be opened to attract Colombian talent abroad that can contribute to the construction of the bioeconomy.
- By 2022, a series of incentives and strategic calls for applications will be opened to attract the Colombian diaspora to work on research and development processes in their regions of origin.
- By 2022, national curriculum guidelines will be developed by the Ministry of Education in cooperation with the Ministry of Culture and the Ministry of Science, Innovation and Technology, which will emphasize the importance of studying cultural and natural diversity in early childhood, basic education and high school programs.
- By 2022, national initiatives will be developed for the social appropriation of knowledge concerned with natural and cultural diversity.

Program 8. Cultural heritage content creation

Premise:

- By 2020, the National Copyright Office's Orange Network (Red Naranja) platform should be fully operational.
- By 2021, guidelines will be published to facilitate the transition between the identification of goods and practices of cultural interest and the creation of content based on these, protected by copyright and other intellectual property mechanisms, with a view to its circulation, distribution and commercialization.

Tools:

- By 2021, calls will be opened for the production of original content deriving from cultural heritage through research + creation (R+C) processes, with the participation of the communities that own this heritage.
- By 2022, calls will be opened to communities, in conjunction with research groups, companies and other SNCTI actors, for the construction of value chains from cultural expressions protected by copyright and other forms of intellectual property.

Impact of the Flagship Mission on the STI system and Colombian society

In order to guarantee the success of the programs and indicators set forth in this Mission, it is necessary to strategically bolster the national infrastructure in education, research and technological development, as well as the digital infrastructure (connectivity) in order to guarantee the storage and transfer of data across the country, as part of an open data scheme that will play a key role in the country's development.

Impact and value to society

This Mission proposes large-scale scientific, cultural, educational, social and industrial transformation through the incorporation of knowledge of terrestrial and marine biodiversity and cultural heritage into the country's educational and productive systems. The study of Colombia's natural and cultural diversity and its preservation is not the end goal in the knowledge value chain, rather, this is the starting point for the creation of efficient and sustainable value chains involved in the production of value-added products and services. Scientific and cultural tourism; science-based cuisine; production of antifungal, antiviral, and anti-cancer drugs; agrochemicals; painkillers; pesticides; industrial products; cosmetic products; products for environmental benefit; handicrafts; and design are just some examples of products that this Mission will benefit and promote.

a) The collection, analysis and disclosure of scientific information will:

- Guide the formulation of public policies for the conservation of diversity, sustainable development, and climate change adaptation and mitigation. The scientific research available, which is still incomplete, indicates that putting a stop to deforestation and the fragmentation and contamination of Colombia's ecosystems is a priority that cannot be postponed.
- It is equally important to identify and conserve the natural wealth found in underground water sources and in the deep ocean of the Colombian Caribbean and Pacific.

b) Cultural information that is recovered will:
- Render the symbolic, historical and identity value of our cultural heritage visible whilst also protecting it, as well as highlighting its economic value in the framework of the country's growing cultural and creative industries.
- Allow a network of cultural heritage documentation centers to be established, which will enhance efforts already being made for discovering and appropriating cultural heritage.
- Allow for the non-centralized and homogenized development of cultural content. People throughout the country will start to recognize Colombia's diverse cultural expressions and this will facilitate the expansion and enhancement of that diversity, which in turn will enable a globally competitive creative economy to be built.

c) The National Museum of Natural and Cultural History will serve:
- As a repository for the information created and collected.
- As the central point of a network of museums and biological aquariums.
- As a space for gathering information that connects the scientific and business sectors, promoting proposals and projects for sustainable development based on biodiversity. Additionally, it will be a space for cultural and scientific training, where citizens can participate in research and creation, appropriating and contributing to the country's scientific and cultural knowledge.

d) Networks of botanical gardens, zoos and aquariums must be bolstered, initiating dynamics or systems where understanding of the natural environment can enrich society's knowledge and emphasize the importance of biodiversity in Colombia. Colombia is one of the few countries that has a Botanical Garden Law – which was approved 20 years ago – and a very active network of gardens that suffer, like many STI institutions in Colombia, from insufficient funding. In addition to botanical gardens, we must include zoos and aquariums, which fulfill similar Missions.

e) A network of documentation centers must be set up, bringing together information related to cultural heritage and putting these resources at the service of the country's researchers and creators, under clear open data policies. Much of the information which is relevant for constructing a comprehensive view of Colombian cultural heritage lies in documentation centers promoted by state, educational or private entities, on topics such as music, fine and visual arts, performing arts, architectural heritage and literature. These entities, however, have not been linked to the SNCTI and in many cases their assets have not been the subject of detailed and rigorous research by academics in these areas. The national network of heritage documentation centers will make it possible to share good practices, facilitate the circulation of content and serve to inspire the expansion of cultural heritage.

f) In the context of the creative economy, strategies will be developed to appropriate and recognize local cultural practices, to appropriate, respect and protect the environment, and value local knowledge, techniques and technologies with diverse applications including creative practices in the arts. This in turn will see content appropriated, resignified and transformed, and economic and commercial innovations promoted and advanced, culminating in the expansion of emotion-based practices that will permeate education at various levels and be absorbed into population's thought processes. The complexity and diversity of the natural environment must be communicated, different sectors and knowledge systems must be linked together, and these elements reflected in the creative and cultural practices and applications.

g) For the agricultural sector, we propose the application of a sustainable model of improved production for the country's main crops, using convergent technologies, and transforming the value and supply chains. A digital platform will be built that will contain knowledge of sustainable bio and nanotechnological systems for soil management and crop health, as well as real-time marketing for growers. The model can be replicated for other crops by creating highly differentiated value-added chains, conserving while using natural resources, reducing environmental, social and economic sustainability, and encouraging social and environmental responsibility. Harnessing technological convergence to modernize agriculture will have a positive impact on the Colombian economy and society and, in addition, would contribute to job and business creation and the reduction of poverty in the medium and long term.

h) The development of products for healthcare should be encouraged, taking advantage of Colombia's biodiversity as an opportunity to advance national health sovereignty and, more importantly, to create value in the communities that produce plant material, which will translate into economic opportunities and improvements in their living conditions by being incorporated into circular production chains.

Academia: research and innovation

Knowledge of the cultural and natural diversity of Colombia gained through scientific and cultural study will guide processes of identification, valuation, conservation and sustainable use in order to create even more knowledge, boost the productivity of various sectors, and develop bioprocesses and bioproducts in different production and industrial sectors (sustainable aquaculture and fisheries, gastronomy, scientific and cultural tourism, pharmaceuticals, agro-ecology, cosmetics, etc.).

a) Research on agri-food systems is important as it can increase the productivity of this sector, improve food security and gastronomy, encourage scientific and cultural tourism and kick-start other sectors that offer income alternatives with added value to the Colombian population, such as freshwater and marine aquaculture.
b) Holistic knowledge (distribution, descriptions, genomes) will be created of the country's terrestrial and marine biodiversity, the results of the genomic Bio-sequencing expeditions will be improved to feed into the inventory of genetic diversity: Colombia Earth Biogenome project (www.earthbiogenome.org).
c) National institutions should work together to create a map of "no-go areas" for deep sea research (e.g., the border with Nicaragua, vicinity of the San José galleon), so that civil society can apply for international exploration funds, without coming into conflict with these sensitive regions.
d) Improving the research + creation (R+C) model: Colombia still lags behind other comparable countries in its knowledge of its cultural heritage. This is due in part to the fact that the country has only had a clear cultural policy for the last twenty years and in this period not enough resources have been allocated for a task of this size. A decisive and prioritized commitment to the production of knowledge about cultural heritage implies not only research activity, but also support for the creation of knowledge through creation and research + creation.
e) Adapting the technical and normative elements of cultural heritage is important to be able to put it to use. A commitment must be made to research, R+C and innovation projects that will support cooperation between norms, regulations and practices applying to heritage. Through the development of materials, techniques and processes, sustainable production processes will be enhanced and cultural content will be of a quality for it to circulate globally,

reinforce the social fabric and enhance cultural identities and communities' sense of belonging[33].

f) Information to guide processes of conservation of cultural heritage and natural resources must be analyzed. For example, with data on the heterozygosity of a species, decisions can be made as to which organisms should be reintroduced in certain regions to avoid problems of inbreeding depression.

g) To more effectively guide conservation programs, the relationship between cultural and natural diversity should be understood better. Similarly, practices need to be developed at various levels that establish in practice the relationship between the cultural and natural, the artistic and scientific.

h) Knowledge must be applied to contribute to SDG compliance. Nanotechnologies, biotechnologies, and information and communication technologies will be developed and applied to identify and characterize potential properties in our biodiversity and by-products of agro-industrial processing and green industry that could be used to develop high value-added bioproducts.

33 A large number of practices and assets declared to be national heritage no longer occupy a place in the daily life of communities because they do not meet the standards and norms required by the authorities. For example, stilt houses have many advantages due to their sustainability and suitability for the local context but they are prohibited because they do not comply with seismic-resistance standards. Banana leaves cannot be used as a food wrapping material due to health regulations and wooden spoons cannot be used in restaurants for the same reasons. The Ministry of Culture has identified about eighty similar cases, but inter-institutional collaboration is not enough to find solutions that will allow this heritage to be used daily; scientific knowledge is needed to address this problem.

Education

a) It is important that a critical mass be formed to address the new challenges that the country faces. We propose that a series of ambitious calls for applications be opened for training at all levels.

b) On the other hand, environmental and cultural education should be the fundamental goal of institutions such as museums (the Museum of Natural and Cultural History), libraries, concert halls, exhibition halls, botanical gardens, and zoos and aquariums among others. Similarly, it is essential to increase and promote exchange processes and agreements that connect these spaces to the country's educational system. Similarly, the national educational system must emphasize the importance of issues such as the preservation, protection, dissemination and appropriation of the environment and culture, through various strategies such as the incorporation of these issues into lines in the curriculum, guided by the particularities of each region. In addition, it should ensure content on natural and cultural heritage be circulated and exchanged nationally and inter-regionally, and so allow and enable the social appropriation of diversity.

c) Education and public awareness are two of the central functions of museums, botanical gardens, zoos, aquariums, etc. For example, the Explora park in Medellin is the most visited museum in Colombia (with 700,000 visitors) and its most visited exhibit is the aquarium.

d) The country's diversity will only be a social reality to the extent that it is appropriated by Colombia's different communities and the best tool for this is education. In addition to formal educational processes, content on cultural and natural heritage must be circulated and exchanged nationally and inter-regionally to ensure an energetic appropriation of this wealth. Although a large part of this appropriation should occur in basic and secondary education, it is necessary that the STI Ministry and the Ministry of Culture develop strategies for the knowledge and dissemination of cultural heritage and biodiversity as a scenario for knowledge generation. Likewise, it is fundamental to develop strategies of cultural appropriation in all its dimensions, to implement processes in which the cultural and natural wealth of Colombia is valued, emphasizing the importance of incorporating it into the daily life of our society. By integrating it into the educational context and making it part of the common language of Colombians, it will be possible to establish a daily dynamic in which scientists and artists, and the various manifestations of that heritage, are fundamental points of reference for society, thus cementing an essential and indispensable model of citizen culture. Therefore, the various dissemination centers such as museums, concert halls, cultural organizations and new non-conventional spaces, should be connected to the country's education system, offering experiences that can be integrated into training programs.

Cooperation and Collaborations

For this mission to be completed, the academia-business-State-society/NGO partnership must be made a reality. Academia, universities, research groups, communities in the territories and society in general must participate in the study of natural and cultural diversity with the support of investment by the State. This knowledge must then be transferred to the production sector with the support of the private sector. Regional and international cooperation, especially South-South, must also be intensified to promote knowledge of our biodiversity so that it may be valued in the international arena.

Broad-based national and international public-private partnerships will be established and improved, involving, in part or in full, universities, research institutes or technology development centers and technology transfer units, business, the State and regional stakeholders. State-university-center-business-society collaborations will allow the country to expand training and its STI offer, which will be of social and economic interest to companies as well as society.

Thus, for example, the country requires a negotiated strategy for the deep-sea exploration of biodiversity inside hydrocarbon blocks, with all actors gaining from the information acquired. In addition, a fast-track procedure must be created so that international research vessels may enter our waters (e.g., Okeanos Explorer, Nautilus, Atlantis, Falkor, Alucia, etc.) for exploration outside of the no-go areas. It will be fundamental that the STI Ministry draw up agreements with NSF and NGOs such as the Schmidt Ocean Institute, Ocean Exploration Trust and Ocean Exploration and Research, as well as with entities from other countries such as NIWA (New Zealand), SCIRO (Australia), AtlantOS, and Ifremer, to have access to binational expeditions days (Colombia-USA, Colombia-European Union). This will be advantageous for deep sea exploration and will allow civil society researchers to be awarded spaces through a merit-based process, much like *Colciencia*'s calls for funding on contingent recovery. This type of agreement should be devised with other countries, and even to explore other areas of interest such as Antarctica or other aspects of oceanography.

This mission is especially interested in intervention and collaboration on sustainable scientific and cultural tourism. One of Colombia's biggest tourist attractions is its cultural and natural heritage: its landscapes, ecosystems, native species, festivals, architecture, music, handicraft techniques and a myriad of knowledge and practices attract travelers from all over the world. However, it is clear that the relationship between tourism and heritage is not without risk and tension. Tourist activity must be sustainable both in terms of the environment and in terms of respecting the integrity of the cultural practices that represent added value to tourism. To this end, it is necessary to prioritize research, creation and innovation processes, from within multiple disciplines and in conjunction with the State and companies in the sector who should contribute to finding the right balance between conservation, promotion and exploitation of diversity in the field of tourism. Additionally, it is important to prioritize strategies that involve the commercial and business sector in initiatives that emphasize the role of knowledge in developing tourist experiences in the environmental, natural and cultural sectors.

Long term

The mission is planned for 2030 when all countries will have to report back on the sustainable development goals. However, as can be seen in the goals and indicators, results are planned for the short, medium and long term.

Regionalization

Colombia's richness in cultural expressions and natural resources responds to its territorial diversity, so the social appropriation of this wealth must also be regional. The bioeconomy and the creative economy are models of regional development.

a) The social appropriation of natural and cultural diversity must take place in each region. Regional universities or institutes should be involved in bioprospecting and R&D projects.

b) The mission is based on the concept of good practice. This must be recognized in the regions and used to build a minimum set of conditions needed to implement a bioeconomy model in each, where each region is a bioeconomy cluster.

c) The flagship mission is relevant to the different regions of the country because it can be adjusted depending on their infrastructure, natural resources, economy, capacities and opportunities. The mission proposes that parallel pilots be carried out in the various regions and in different production sectors.

d) Regions such as Valle del Cauca and the coffee region can be used as examples to follow for applying projects of freshwater and marine aquaculture in other regions which are less advanced in terms of technology and education.

Internationalization

It is important that Colombia start conversations with countries that have adopted the bioeconomic model as the basis for their development.

Knowledge has no borders and Colombia should be part of global research initiatives, such as the Global Biodiversity Information Facility (GBIF).

It is expected that countries such as the United Kingdom and Germany will continue to support projects within the Bio Colombia program. However, researching Colombia's megadiversity will continue to require the support of different actors, for the promotion of science and technology in the country.

a) It is possible that we will procure the involvement of research and development institutes from other countries, those that are knowledgeable about Colombia and specializing in applied research in convergent technologies and Industry 4.0 in the agricultural and bio-economic sectors.
b) It is important to strengthen bilateral and multilateral scientific and technical cooperation and participation in international, global, research and development programs to seek solutions to global environmental problems, such as the major conventions on biodiversity (CBD) and climate change (WCRP. IPCC). It would be excellent to have the opportunity to sign agreements and arrangements with foreign institutions of scientific excellence to be able to improve internally with the support of the best in the world.

Bottom-up solutions

a) Our goals must be achieved through a series of solutions, such as calls for proposals that will allow us to create knowledge and technologies for different sectors such as agriculture, healthcare, and the cultural industries among others. It must be emphasized that a single call for proposals or a single technology will not allow the construction of the knowledge base needed by the country to advance towards its development of the bioeconomy and the creative economy. Therefore, as well as calls for proposals we will need to improve the training and retention of human talent; support SINA institutes; bolster the network of botanical gardens, as well as the network of museums using existing infrastructure alongside the creation of museums of natural and cultural history; create the network of documentation centers of heritage, platforms for academia-industry interaction, and fiscal tools so that companies can participate in R&D and R+C projects. All of this to promote science and citizen culture programs, to encourage the development of proposals such as creative incubators, which are fed by the creation of knowledge from processes that are born from community and society initiatives. Likewise, strategies must be established for the country's education and training programs, in which models of student participation at various levels must be designed, and include experimentation, and research and creation projects which act as incubators for the development of future creators and researchers and which create new knowledge at different levels and stages, contributing, moreover, to processes of appropriation.

b) A fundamental aspect that should be promoted as part of this initiative is the "dialogue of knowledge" that allows for the identification, appropriation and enhancement of regional cultural knowledge. This dialogue must take place on figurative neutral ground, and value its participants and recognize their potential, creating a process of integration and construction.

c) The mission should promote mechanisms of participatory construction that emerge from society's grassroots, involving regional actors and communities, based on problems specific to the territories. The training programs should include practices and experiences that can be scaled up. The way these approach problems and find solutions will allow them to become processes that create links between community and the State, companies and the academic community.

Convergences

This mission addresses scientific issues (knowledge of biodiversity), cultural issues (recognition and preservation of cultural heritage), technological areas (bio, nano, info and cognitive) for transference to society, economic issues (bioeconomic model), social sciences and education (appropriation of knowledge and its transfer). Likewise, the interaction between academia-business-State-community should be made possible, as explained above.

Several ministries should be involved in addressing the challenge: (1) Health and Social Protection, (2) Mines and Energy, (3) Trade, Industry and Tourism, (4) Agriculture and Rural Development, (5) Environment and Sustainable Development, (6) Education, (7) Labor and (8) Culture.

a) The mission will allow innovators and social entrepreneurs to take advantage of the benefits of sustainably discovering more about biodiversity and cultural heritage. In order for our use of diversity to become more efficient and lead to economic development and the wellbeing of society, it is necessary to bolster the actor's connectivity, as well as management, privacy, and integrity of the data. To achieve this, it is important to foster dialogue between academia, society, the State and business.

b) In a transformative world, in which areas of knowledge evolve at a dizzying and unsuspected pace, it is essential to bring diverse areas of knowledge together, especially those that tend to be kept apart due to their disciplinary context. Historical searches for knowledge, such as the Renaissance, have demonstrated the importance of finding solutions based on methodologies, techniques, models and approaches deriving from seemingly unrelated areas of knowledge.

Governance

By mandate of the Vice-Presidency, this challenge will be coordinated by the Science and Technology Ministry. The other ministries involved in this mission are (1) Health and Social Protection, (2) Mines and Energy, (3) Trade, Industry and Tourism, (4) Agriculture and Rural Development, (5) Environment and Sustainable Development, (6) Education, (7) Labor and (8) Culture. Consequently, the coordination will be inter-ministerial, based on the premise that the combined efforts of the ministries will benefit the country. Since the mission has a territorial approach, the ministries must coordinate their efforts in liaison with regional entities, secretariats of science and technology, regional competitiveness councils and other bodies.

Financing

As mentioned in the mission, this implies having a strong public-private partnership. The open calls for innovative proposals will involve the sum of public and private resources.

a) The Bio Colombia 2.0 calls for proposals have a budget of 2000 million pesos. To be ambitious and meet this mission's goals, the open calls for innovative proposals must have at least 10 billion pesos per region, deriving from both public and private resources.
b) The National Museum of Natural and Cultural History must have a strong initial investment from the State, but also must conduct a dynamic campaign to raise funds through donations and private contributions.
c) In general, for open calls for innovative proposals in specific sectors: aquaculture and fisheries, agri-food systems, industry and manufacturing, at least 10 billion must be available per sector.
d) For the training and retention of human talent, a public-private commitment must be made where not only do we have sufficient resources for the training and hiring of the aforementioned personnel, but the government must also commit to a tax reform to favor the sectors that support the development of the bioeconomy and the creative economy.

Water and Climate Change flagship mission: conservation and sustainable use of water, minimizing risks and maximizing biodiversity, ecosystems and society's resilience in light of climate change

Mission Statement

By 2030, Colombia will guarantee its inhabitants access to drinking water, the quality of its water bodies, the optimal management of the resource and the protection of society from extreme events, appropriating the concept of the value of water. This will demand knowledge of the spatial and temporal variability of the quantity and quality of the country's water. Under normal conditions, this information will allow us to assess the resource, and under extreme conditions, this will be to measure the level of threat. Additionally, the country will reduce the socio-environmental risks of climate change in the period 2030-2050 to 50% of the current value, by updating adaptation and mitigation plans. This will allow us to maximize the socio-environmental resilience of the country, based on scientific knowledge of the current and future risks of climate change on our ecosystems, society, and different systems and sectors.

Main Goals

a) To guarantee, in the short, medium, and long term, the knowledge, conservation, sustainable use, and optimal management of water as a resource, both under normal conditions and extreme conditions, for the wellbeing of society, biodiversity, and ecosystems, with the participation of the different social actors and considering the cultural, ecological, environmental, and economic dimensions, as well as sectoral policies.

b) Quantify the risk, vulnerability and exposure of biodiversity, ecosystems, society and different sectors to current and future climate threats, by projecting future impacts of climate change in Colombia, and, by creating and updating adaptation and mitigation plans, reduce those risks to half of the current value.

Specific Goals

- To quantify the natural supply of water, taking into consideration how ecosystems are connected in average long-term conditions and in extreme conditions and the spatial and temporal fluctuation of all variables that are part of the hydrological cycle in Colombia.
- To guarantee the availability of quality water to society, biodiversity and ecosystems, taking into account the spatial and temporal variability of water bodies in Colombia (rivers, lakes, lagoons, wetlands, reservoirs, groundwater, aquifers, flood plains, coastal areas and atmosphere), to allow it to be used in an efficient and sustainable manner.
- To ensure access to clean water for human consumption and other uses, guarantee non-toxic discharge, and develop appropriate technologies and tools for the sustainable management of urban and rural water supply and basic sanitation, and to respond to the challenges posed by climate change, population growth, and deforestation.
- To develop future projections for the rest of the 21st century on the natural supply and demand of water for different uses, including palaeo-environmental reconstructions of preanthropocene conditions, which will serve as inputs for the Program for Integrated Water Management in Colombia.
- To carry out the National Program for Integrated Water Management considering the supply and demand of water for different uses, focused on sustainable economic development, risk reduction in light of extreme events and the improvement of the quality of life of the communities, using ancestral knowledge and means for cultural transformation.
- To provide the Territorial Ordering Plans with the necessary information, which involve interactions between the natural supply and the demands for water, and different land and soil use.
- To include the concept of Global Environmental Change (depletion and contamination of life support systems) in the evaluation and

projections of the impacts of Climate Change (CC) in Colombia (CC+CAG).

- To quantify the risks that Colombia's present and future climates (2020-2050) present to society, ecosystems and different sectors, considering climate threats and exposure, vulnerability factors and CC+CAG.
- To construct various projected scenarios of socio-economic development for Colombia for the period 2020-2050, including variables such as population growth, changes in land use, land use plans, adaptation and mitigation policies, with the purpose of evaluating the future hydrological impacts of CC+CAG.
- Devise or update plans, strategies and measures for adaptation and mitigation of CC+CAG to reduce by half the current risks and the vulnerability of ecosystems, social systems and various priority sectors in light of the future climate (2030-2050).

In relation to the impacts of climate change and global environmental change (CC+CAG), we propose the following priority sectors: (1) water (assessed as a resource and level of threat), (2) biodiversity and environmental services, (3) human health, (4) agriculture and food security, (5) terrestrial ecosystems and freshwater bodies, (6) floodplains and watershed/coastal transition zones, (7) oceans and coastal areas, (8) clean and renewable energy, (9) disaster risk management, (10) human settlements and infrastructure, and (11) industries. The main goal of this mission is to reduce by half the current risks associated with CC+CAG, through three strategies: (1) study of past, present and future climate and hydrology, (2) construction of scenarios for socio-economic development, population growth and land use and occupation, and (3) construction of adaptation and mitigation plans, which will lead to Colombia having reduced its climate change risks to at least 50% of their current value in the period 2030-2050 (Figure 24).

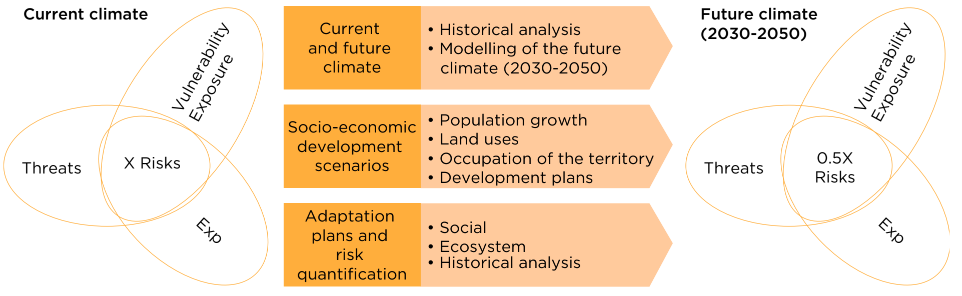

Figure 24. Overall goal obtained by fulfilling the specific goals associated with Global Environmental and Climate Change.
Source: Authors.

Programs

Program 1. Integrated water management in Colombia

By 2030, Colombia will have carried out planning and management processes that lead to the sustainable use of water resources. Limitations, restrictions and problems will have been considered, with their solution depending on creating knowledge on a combination of issues: the natural supply of water and its spatial-temporal variability with demands for different uses and their impact on quantity and quality. There will need to be emphasis placed on:

- Knowledge of the context and baseline assessments of the water resources (in terms of quantity and quality).
- Effects of natural climate variability on the hydrological cycle on a wide range of time scales (from inter-decadal to daytime cycle).
- Impacts of climate change and deforestation on water supply and demand.
- Water supply and basic sanitation in small towns and in rural areas.
- Water and its relationship with biodiversity conservation and the sustainability of terrestrial and aquatic ecosystems.
- Groundwater and its use along with surface water.
- Hydraulics, river geomorphology and sediment transport.
- National water quality study to consider comprehensive strategies based on the dynamics of water in river basins.

- Efficient and sustainable use of water for different uses (e.g., human health, agriculture, aquaculture, ecosystems and biodiversity) and decontamination of water bodies.
- Land use and water. Aspects of institutions and governance that may aid optimal integrated water management.
- A comprehensive valuation of the ecosystem and environmental services of water.

Program 2. Guaranteeing the flow of water in Colombia

By 2030, Colombia should have the capacity to guarantee and recover the good condition of freshwater ecosystems with respect to water deposits and flows and ecosystem services, and ensure the environmental flows of its biotic communities through the following lines of action:

- To understand the spatio-temporal dynamics of the variables of the inland hydrological cycle in each of Colombia's five major regions, both in average and extreme conditions, and how they will be affected by climate change and deforestation.
- Estimate the environmental flow for all hydrographic subzones with extensive water resources.
- Incorporate the environmental flow compliance criterion into the process of granting and monitoring environmental licenses and water concessions in hydrographic subzones with extensive water resources.
- Incorporate the analysis of the change in the regulation coefficient in the process of granting and monitoring environmental licenses and water concessions of heavy water users in hydrographic zones with high biodiversity.
- Assess the state of hydrological connectivity of the continuous system of water basins, rivers with flood plains and coastal areas, as terminal zones of transfer for water, sediment and all associated substances.

Program 3. Water connectivity and maintenance and improvement of the water system

In 2030, Colombia will be able to guarantee the ecological and aquatic relationship of its lotic and lentic and terrestrial ecosystems (riparian forest, flooded forest, meandering rivers and swamps). The actions will be oriented towards guaranteeing the active and passive movement and transfer of energy, nutrients and sediments, by means of (1) detailed inventories of the infrastructure that affects the water resource and the connectivity of the aquatic ecosystems in the hydrographic sub zones with extensive water resources, (2) update of the permits for occupation of watercourses in the subzones with extensive water resources and (3) the recovery of watercourses.

Program 4. Water resource quality and coverage

Environmental authorities across the country must complete, by December 2020, the inventory of the sources and quantities of liquid and solid waste disposal, in order to define in 2021 a 20% reduction in the polluting sources undertaken by January 2022. In 2030, the country should improve/establish and maintain water quality conditions by seeking the adequate disposal, treatment and final disposal of liquid and solid waste into aquatic and coastal marine ecosystems from one or more sources that could put the subsistence of aquatic species at risk. This requires:

- That the National Study of Water Quality be completed, considering comprehensive strategies based on the water dynamics of drainage basins.
- Monitoring water quality in stretches and bodies of water with medium and high species richness indices.
- The use of sustainable technologies of potabilization and treatment and management of wastewater.
- Establishing quality criteria for the conservation of aquatic flora and fauna in stretches and bodies of water with medium and high rates of aquatic species richness.
- Establishing decontamination goals and charging discharge fees for specific discharges in watercourses and stretches and bodies of

water and their tributaries with medium and high aquatic species richness indexes.

- Incorporating criteria and quality standards for the conservation of flora and fauna into the processes that license and grant dumping permits.
- Implementing strategies to reduce nonpoint pollution in areas close to stretches and bodies of water with high and medium rates of aquatic species richness.
- Reducing or eliminating toxic and bioaccumulative discharges by wielding environmental authority.

Program 5. Ensuring the resilience of aquatic ecosystems and their biodiversity

In 2030, Colombia should advance programs leading to the improvement of the ecological processes, populations and communities of organisms in aquatic ecosystems. This program should include the following lines of action:

- Establish new national and regional protected areas that cover under-represented inland freshwater and coastal-marine ecosystems.
- Identify, delimit, restore and rehabilitate the areas of freshwater ecosystems that were transformed during the period 1990-2020.
- Define and geographically delimit freshwater ecosystems at a scale of 1:25000 for inland water subzones prioritized for ordinance and watershed management plans (POMCA) and seascapes prioritized for POMCA.
- By 2025, the country will have a clear inventory of the threats and risks to surface and groundwater resources in order to take management and prevention measures to protect the resource.
- Carry out an inventory of the populations of invasive species that have been introduced and transplanted into water resources.

Program 6. Towards economic development, competitiveness and improvement of the quality of life of the communities that use water resources

By 2030, Colombia will have developed a comprehensive program for the improvement of the quality of life of communities that rely on water resources, focusing on wellbeing with intergenerational equity, socio-cultural prosperity and sustainability. This program will be developed through the following lines of action:

- Consolidate the inventory of marine, coastal, insular and continental hydrobiological resources (RHMCIC).
- Establish management programs for the populations of water-based resources that are to be exploited.
- Establish the limit and reference points for the water-based resources that can be used in different ways, such as agriculture, human health, hydropower, aquaculture, navigation.
- Develop schemes and instruments for the comprehensive valuation (economic and non-economic) of water-based resources and their ecosystem services.
- Promote and enhance *ex situ* conservation tools (gene banks, research stations, zoos, aquariums).

Program 7. Research on extreme hydrometeorological events

By 2030, Colombia should have adequately evaluated and quantified the present and future threats (CC+CAG) emanating from extreme hydrometeorological events (intense storms, hurricanes in the Caribbean Sea, frosts, rising rivers, avalanches, floods, landslides, as well as droughts –hydrological, meteorological and agricultural –), as well as the exposure and vulnerability factors and risks to ecosystems and society.

Program 8. National research program on the combined impacts of climate change and global environmental change (CC+CAG)

By 2030, Colombia should have a complete understanding of the current and future causes and impacts of CC+CAG during the 21st century, with particular emphasis on:

- The water, energy and carbon balances of its ecosystems and watersheds, flood zones and transition zones between the land mass and the ocean (deltas, estuaries, etc.).
- The quantity (supply and demand) and quality of water for different uses (domestic, industrial, agricultural, etc.) and surface and groundwater resources.
- The spatio-temporal dynamics of the frequency and duration of intense storms.
- The main mechanisms determining the weather and climate of the country.
- The spatio-temporal dynamics of rising rivers, floods and landslides.
- The processes that give rise to droughts of different duration and their prediction and the processes of soil-atmosphere, ocean-atmosphere and land-ocean interaction on different time scales.
- Oceanographic and geological processes associated with warming, acidification and sea level rise (including land rising or sinking) and their consequences on marine and coastal ecosystems.
- Human health.
- The country's biodiversity, ecosystems (terrestrial and aquatic) and life zones, with emphasis on deforestation and changes in land use. The role of ecosystems as "buffers" for CC+CAG.
- Human health due to air pollution in Colombian cities.
- Agricultural productivity and Colombians' food and nutritional security.
- Ecosystem and environmental services.
- Clean and renewable energies.
- Urban centers, industries and infrastructure.

- Interactions between ecosystems and social systems and risks in the face of CC+CAG, involving climate hazards, and exposure and vulnerability factors.

Program 9. Update of programs for the adaptation and mitigation of the impacts of climate change and global environmental change

By 2030, Colombia will have updated plans for the adaptation and mitigation of the risks of climate change and global environmental change, considering diverse future scenarios of socio-economic development, population growth trends, changes in land use, land use plans, trends and projections of socio-economic variables and conditions, national, regional and municipal public policies, etc. In relation to adaptation and mitigation plans, it will be necessary to develop research on (1) opportunities, restrictions and limits, (2) needs and gaps in knowledge, (3) practical experiences of autonomous and planned adaptation, including lessons learned, (4) observed and expected barriers to adaptation, (5) interactions and co-benefits between adaptation and mitigation strategies and programs, (6) environmental economics to value ecosystem services and the environmental and ecosystem costs of deforestation, pollution, and natural resource depletion.

Program 10. Climate change and ecosystems program

By 2030, Colombia will have updated plans for adaptation to CC+CAG including ecosystem-based adaptation. To do so, it is necessary to create knowledge on (1) the effect of climate extremes on the functioning of its ecosystems, (2) the impact of current socio-economic changes (including the Post-Peace Agreement context) on rates of ecosystem change, (3) the effects of rapid transformations in land use and deforestation on the resilience of ecosystems to CC+CAG, (3) the improvement of production systems to make them more resilient to CC+CAG, (4) the current and future impacts of CC+CAG on agricultural production, (5) the development of resilient agricultural systems, (6) the impact of CC on the biodiversity of CC+CAG; (7) the role of ecosystems as mechanisms for adaptation to CC; (8) support to build the resilience of socio-ecological systems to CC;

(9) the impact of land use changes on biomass burning and its mitigation, (10) the formation of a (possibly virtual) national synthesis center to make use of existing databases and information, (11) the establishment of an environmental observation network to collect new databases and synchronize different *in situ* measurements, relevant for monitoring the interaction of ecosystems with the hydrosphere, the atmosphere and the geosphere, (12) the implementation of new platforms for dialogue between science and policy.

Impact of the Flagship Mission on the STI system and Colombian society

Water is the most valuable resource for society, biodiversity and ecosystems; all three need it for their subsistence and survival. Quantity and quality are the main paths to a truly healthy and sustainable social-ecological system over time. Climate change adaptation plans in all sectors must be built, updated and implemented based on the best information and state-of-the-art scientific knowledge in order to minimize risks, vulnerability and exposure and to maximize the resilience of society, biodiversity and ecosystems.

Carrying out this Flagship Mission will allow us to:

- Create knowledge about the natural water supply and demand for it in Colombia, considering both its quantity and quality.
- Guarantee access to water in both quantity and quality for different uses and to reduce the risks that communities face when up against extreme events.
- Conserve and ensure the sustainable use of water (as a resource and as a threat) as a requirement for a full understanding of its biological, social and economic importance, for its management involving all stakeholders.
- Improve the quality of life of the population, through the conservation of water, biodiversity and ecosystem services.
- Identify the anthropic or exogenous causes that are or could put at risk the quantity and quality of water resources and their relationship with society and biodiversity.

- Reduce the risks, vulnerability and exposure of society to the occurrence of extreme hydrometeorological events (intense storms, floods and droughts) for the construction of climate change adaptation and disaster risk management plans.
- Create knowledge to face challenges and to build public policies and plans for adaptation to and the mitigation of climate change, which causes serious economic, environmental, ecological and social impacts in all sectors, exacerbating poverty and inequity.
- Learn about the functioning and natural dynamics of the five major regions of Colombia and their ecosystems, on a wide range of spatial and temporal scales.
- Quantify the current and future impacts of CC+CAG on Colombian ecosystems' water, energy and carbon cycles.
- Quantify the risks of current and future climates (2030-2050) on social systems, ecosystems and priority sectors.
- Update plans to help society and ecosystems adapt to the impacts of CC+CAG (including ecosystem-based adaptation) to reduce risks, vulnerability and exposure to half of the current values.
- Maximize ecosystems' socio-environmental resilience to the impacts of CC+CAG.
- Update Colombia's commitments to the Paris Agreement and the Conference of the Parties of the United Nations Framework Convention on Climate Change

Academia: research and innovation

We only value, care for and responsibly use resources that we understand and know about, and, therefore, it is essential to understand with scientific rigor the quantity and quality of our water resources, both in average and extreme conditions, and their interrelationships with societies and with the biodiversity of aquatic and terrestrial ecosystems in rivers, lakes, wetlands, groundwater, flood plains, estuaries, the ocean's surface and depths.

It is necessary to carry out scientific research on the functioning of the spatio-temporal dynamics of the water, energy and carbon cycles and their interactions with social systems in different regions and ecosystems.

Some hydrological processes are not well understood, so the study of their palaeo-environmental and present conditions is required, which in turn would support the development of predictive models for the analysis of CC+CAG scenarios (including scenarios of the country's socioeconomic development). These studies will serve as a basis for developing and implementing adaptation plans that reduce risk, vulnerability and exposure and maximize socio-environmental resilience.

It is necessary to define a sufficiently broad research agenda in the short, medium and long term to guarantee that the appropriation of natural resources is carried out in line with sustainable development and the wellbeing of society, as well as on the effects of climate change in Colombia. This agenda should include the topics described in Program 1, related to integrated water management, and others such as (1) spatial disaggregation (downscaling) of the results of global climate models at regional and local scale, using statistical techniques and dynamic models with high spatial resolution, (2) analysis of the consistency between the results of climate models for the 21st century, with respect to the observed long-term trends in the records and time series of the main hydrological, climatic and ecological variables, (3) attribution of extreme hydrometeorological events to CC+CAG.

Education

Environmental education should be the tool by which Colombians understand the interdependent relationships between life support systems and the vital resources provided by nature. We live in a megadiverse and water-rich country, and its conservation and sustainable use is the duty of all Colombian society. The solution to the current climate crisis is based on education in climate and environmental issues from primary to doctoral and postdoctoral levels.

Likewise, it is fundamental to include the environmental knowledge of indigenous people, peasant farmers and Afro-descendants in the educational curricula of primary and secondary education.

The educational and dissemination processes concerned with environmental subject matter must be dynamic and must seek to build spaces for collaborative work between the different institutions and actors in the regions in order to include all perspectives and needs for basic and applied knowledge, which will allow natural and social conditions to improve. Two strategies are proposed to improve science's capacity to harness knowledge and research on RHMCIC, climate change and global environmental change:

Strategy 1. Participation: the development of participative mechanisms should be encouraged, as spaces that urge the recognition and importance of these resources and the environment in which they occur.

Strategy 2. Training, research and information management: this strategy is oriented to promote and develop research and information management actions related to RHMCIC and CC+CAG, by public or private entities and persons, in such a way that they contribute to the State's understanding and the evolution of the country's water resources, to achieve the proper management of the resource and to disseminate the most relevant information on climate change and its effects in Colombia.

Cooperation and Collaborations

The challenges posed by water and its interconnections with biodiversity, ecosystems, and society, as well as the impacts and risks arising from climate change and global environmental change, demand a dynamic and innovative interaction between the State, academia, civil society, and the private sector.

This mission is a comprehensive one and should involve the contributions of the eight thematic pillars of the Mission of Experts, as well as multiple public entities at national, departmental, municipal and local levels, as well as Academia, NGOs, the private sector and civil society, to respond to the need for "water security," understanding water as a resource and as a threat. The mission requires the creation of knowledge to contribute to the fulfillment of the SDG, as well as to the formulation of public policies, climate change adaptation plans, and risk management and territorial management plans. These challenges will demand research in all environmental sciences, physics, chemistry, mathematics, probability theory and stochastic processes, statistical and information thermodynamics, non-linear dynamic systems, differential equations, chaos theory, fractals and multifractals, complex network theory, machine learning, etc., as well as implementation of Big/Smart Data and cloud computing platforms, among others.

Cooperation on financing research and activities related to water resources and their biodiversity will also be essential. Learning from the concept of "sustainability," current and future financial resources will need to be optimized. For example, the Inland, Coastal/Marine and Island Aquatic Resources Plan becomes an appropriate strategy to quantify and prioritize investments, and to finance proposed actions. Likewise, it can be accompanied by water use taxes, which will be used to cover the costs of protection and renewal of water resources, for the purposes established by law. The obligatory investment of 1% of the value of the investment in projects using water and subject to an Environmental License (Law 99 of 1993) must be oriented towards activities of conservation, recovery and monitoring of the watershed. In relation to climate change and global environmental change (CC+CAG), it is necessary to improve the National Environmental System (SINA) research institutes, as well as research in universities and research centers on relevant issues. Adaptation and mitigation plans should be formulated based on scientific research results on the future impacts (2030-2050) of CC+CAG on the various climatic, hydrological and environmental variables, in order to quantify the threats, exposure and vulnerability factors of the social systems and the ecosystems. In addition, interaction between the State, research centers and units, civil society, and the private sector is required to build Colombia's socio-economic development scenarios (at the national and regional levels), so that the expected impacts of CC+CAG on ecosystems, society, and the various priority sectors can be estimated.

Long term

The challenges posed by water (as a resource and a threat, its quantity and quality) and by climate change require short, medium and long-term measures and strategies. In the short term, immediate prevention, control, and management measures and actions are needed to meet sustainable development goals, as well as to ensure the wellbeing of society, the conservation and sustainability of life support systems, guaranteeing health, food security, and the conservation of biodiversity. In the medium and long term, the formulation, updating and implementation of plans and strategies for adaptation to climate change should reduce risks, vulnerability and exposure and maximize socio-environmental resilience.

Throughout the document, especially with regard to Programs, clear goals have been defined for the next decade of necessary fulfillment.

Regionalization

The only way to value and make sustainable use of water and its biodiversity is to understand the cultural and geographical heterogeneity of the country, of public and private actors, as well as the historical and present needs of local communities to use water resources everything else they bring. The impacts of climate change and environmental change are eminently regional and local and, therefore, must be understood, modeled and projected at these scales. This requires scientific research involving universities and regional research centers. At the same time, adaptation and mitigation plans require contributions from regional and municipal governments, as well as local and regional civil society and private entrepreneurs.

Water planning and management efforts, as well as RHMCIC, should bolster the scientific roles and capacities of regional, municipal, or community public and private institutions. The political-institutional fragility and the precarious implementation of management and control instruments for ecosystems and natural resources have various causes: (1) lack of human, technical and financial resources to exercise environmental control functions, (2) little political will on the part of some of the entities responsible for implementing actions on the ground (fishing, irrigation, public use goods, basic and environmental sanitation), (3) precarious scientific training of environmental authorities, (4) lack of articulation between the national, departmental and municipal levels, (5) insufficient knowledge and information about environmental problems and their solution, (6) lack of public awareness about the importance of biodiversity and its RHMCIC and about the mechanisms of citizen participation. There are also investments that lack focus on effective problem solving, or partial or isolated investments that are not guided by co-financing or inter-institutional collaboration. There are four strategies for strengthening public and private institutional actors' capacity to fulfill their functions and implement programs and projects related to water and climate change in the regions:

Strategy 1. Improvement of the capacity to publicly manage marine/coastal, insular, and inland water resources: this strategy seeks to enhance the actions of regional environmental authorities in planning, administration, monitoring, and control of the impacts of RHMCIC.

Strategy 2. Normative review and articulation with other policies: develop regulations and synchronize them with environmental and sectoral policies that affect the integrated management of RHMCICs.

Strategy 3. Creation of knowledge for integrated water management at the regional and local levels: For this strategy, it is necessary to define medium and long-term regional research agendas to ensure that the use of natural resources is in line with the SDG.

Strategy 4. Creation of knowledge on the regional and local impacts of climate and environmental change and construction of socio-economic development scenarios and regional and local adaptation and mitigation plans. Climate models at high spatial and temporal resolution will allow the quantification of the impacts of CC+CAG on the most important climatic, hydrological and environmental variables, at a regional and local level.

Internationalization

Watercourses and water resources know no geopolitical boundaries and respond to the natural and anthropogenic dynamics in watersheds. Therefore, knowledge on them and their management and use must respond to joint policies and efforts from different countries. Funding for this research should have a very important international component. The impacts of climate change and global environmental change demand scientific research with international support for environmental instrumentation and monitoring (satellites, radars, lidars, drones, scientifically instrumented airplanes, field research on land, atmosphere and oceans), and for experimentation (laboratories) with biogeochemical, physical, hydrological and climate processes. In addition, climate simulations require the use of supercomputers. All this must be bolstered with international support from agencies, research centers and universities abroad.

Governance is one of Colombia's greatest challenges in adjusting to international standards in water management. Inter-institutional and inter-sectoral coordination in water management is necessary to maximize its impact on poverty reduction in Latin America (Akmouch, 2012). In turn, Colombia has awakened the interest of countries that have a long experience in water management issues, such as the Netherlands (Ministry of Foreign Affairs, 2018), in relation to the basins surrounding Bogotá, Medellín, Cartagena and Barranquilla. Even with the existing gaps in the information, there has also been international interest in groundwater and aquifers in Colombia, such as the Global Environment Facility (GEF) since the Rio Convention meeting in 1992.

Bottom-up solutions

In order to fulfill the proposed goals, various strategies and lines of action must be pushed forward, many of which are focused on convening national, departmental, and local scientific research projects to generate knowledge about the current state of water resources and their biodiversity, the impacts of climate change, and the real capacity of the country's different regions and municipalities to face challenges, minimize risks, and maximize social and environmental resilience, including scientific, economic, social, and cultural aspects. In order to devise plans for adapting to and mitigating climate change, we propose that a series of regional workshops be held with the participation of academia (natural and social scientists), the State (governments and municipalities), industry, civil society, and communities, including peasant farmers, indigenous people, and communities of African descent.

- It is necessary to identify, value, appropriate and understand ancestral and regional knowledge about using and caring for water, as well as the customs rooted in the communities that are strategies of adaption to the climate and other natural dynamics. This should consolidate a library of local knowledge that enhances scientific knowledge about water and global environmental change.
- Mechanisms for calls for grassroots participation, in which regional actors and communities are involved, based on problems specific to the territories, as well as regional workshops, should be encouraged.
- Complementary to this, these calls should integrate the State, business, academia and civil society to achieve viable solutions with regional identity.

Convergences

Water is the fundamental vital resource that should bring together ancestral knowledge, scientific and technological developments, productive processes, socioeconomic developments and the wellbeing of the population and, as such, its vision should be transdisciplinary and intersectoral. Access to clean water is a right of all society and its guarantee has profound implications in terms of social equity. Climate change and poverty feed off each other, and therefore the solution to the climate crisis will have very important implications for Colombia's search for social equity.

There is a clear connection of this Flagship Mission with the eight pillars of the Mission of Experts. All are able to contribute to the goals of the Flagship Mission proposed here. In particular, the present mission attempts to contribute directly to the Equitable Colombia challenge and has implications for the Productive and Sustainable Colombia challenge as it works to defend the right to access adequate quantities and quality of water, as well as to reduce the risks of the most vulnerable populations in the face of extreme hydro-meteorological events, which has profound implications in terms of social equity. The same is true of the implementation of climate change adaptation and mitigation plans, since these break the vicious circle between climate change and poverty and aim to minimize vulnerability and maximize social and environmental resilience, improving the quality of life and the wellbeing of populations and ecosystems.

Governance

The mission will be governed by a scientific steering committee made up of researchers recognized by *Colciencias* in the areas of water, its biodiversity, environment and climate change, with appropriate regional representation, as well as representatives from the following ministries: (1)

Science, technology and innovation, (2) Health and Social Protection, (3) Mines and Energy; (4) Agriculture and Rural Development, (5) Environment and Sustainable Development, (6) Transportation, (7) Education, (8) Culture and (9) Industry and Trade Civil. Civil society and industry should also be involved. Since the mission has a territorial approach, the ministries should coordinate their efforts in liaison with regional entities, secretariats of science and technology, regional competitiveness councils and other bodies.

Financing

It will be necessary to create a specific fund in the Science, Technology and Innovation Ministry to finance the Flagship Missions proposed by the Mission of Experts. It should also be supported by obtaining resources from royalties to support scientific research at the departmental and local levels. The open calls for innovative proposals will be fundamental for the construction of the proposed research programs, whose financing should come from different national and international sources, where the public-private partnership should directly participate. We also propose that a fund be created to finance this research by taking a percentage of the cost of projects that demand environmental licenses, to be paid by the applicant entities. In addition, other possible sources of funding include the Latin American Alliance of Water Funds[34] or the Cooperation Fund

34 See FCAS; http://www.aecid.es/ES/FCAS

for Water and Sanitation[35], an instrument of Spanish Cooperation that develops programs for institutional improvement, community development and promotion of water and sanitation services in 19 countries in Latin America and the Caribbean. Also included are the Nature Conservancy's Water Funds[36], the German Government's Water Funds for the implementation of ecosystem-based adaptation measures to climate change[37], the Adaptation Fund established under the Kyoto Protocol of the United Nations Framework Convention on Climate Change[38]. Finally, it will be necessary to establish cooperation agreements in scientific research between universities and research centers in Colombia and developed countries to take advantage of scientific and laboratory capacities, and monitoring capacities in environmental, ecological, climatic, hydrological, hydraulic, forestry, ecosystemic, oceanic and atmospheric issues.

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35 See https://www.fondosdeagua.org/en/
36 See FCAS https://waterfundstoolbox.org/
37 See FCAS https://www.adaptationcommunity.net/ download/ ecosystembased_adaptation/WaterFunds-EbA.pdf
38 See FCAS https://www.adaptation-fund.org/

The *Productive and Sustainable Colombia* Challenge

Colombia towards a New Productive, Sustainable and Competitive Model flagship mission

Colombia's productive structure is not very diversified, not very technical and very vulnerable to external shocks. In 2017, the manufacturing industry was positioned as the economy's third most relevant production activity with a 12% share of the total gross domestic product (GDP), corresponding to USD 34068.9 million, half of the percentage it had in the eighties. The country has a high dependence on basic goods as a source of economic and fiscal income. Eighty percent of exports come from mining.

The most worrisome deficiency of the Colombian economy is that total factor productivity (TFP) made zero contribution to economic growth between 2000 and 2016, a phenomenon associated with low investment in Science, Technology and Innovation. The National Association of Financial Institutions (Anif) estimates that the contribution of capital to economic growth has been 55.5% and that labor 40.8%, while productivity has only contributed 3.7%.

Export growth is a necessary condition for the country's economic growth. Colombia exploits only one third of its arable land. If agricultural production were to double, about one percentage point per year could be added to GDP growth (Hommes, 2019).

The Colombia towards a new productive, sustainable and competitive model mission is designed to meet the Sustainable Development Goals (SDG), particularly goals 2 (Zero hunger), 3 (Good health and wellbeing), 5 (Gender equality), 6 (Clean water and sanitation), 7 (Affordable and clean energy), 9 (Industry, innovation and infrastructure), 11 (Sustainable cities and communities) and 12 (Responsible production and consumption).

This mission has three characteristics: (1) it applies and develops state-of-the-art, cross-cutting general-purpose technologies (GPT), (2) takes advantage of comparative advantages in natural resource reserves, and of the capabilities and international relations with leading universities and research centers and (3) can ensure competitive advantages for the country in the export of high value goods and services. The aim is to incorporate knowledge into productive activities in integrated, sustainable, and profitable value chains, and to create new technology-based industries with an export projection that will benefit communities at the regional and national levels.

Green industry, intelligent and sustainable materials, renewable energies, medical supplies, instrumentation and control equipment for tropical environments and connectivity platforms are promising axes for the new industrial revolution in the context of integrated production, whether customized, personalized or large-scale, making use of the convergence of technologies and disciplines, for example, engineering, chemistry, biology, and information and communication technologies. It would contribute on different fronts across the country; to the more environmentally-friendly energy transition, to the diversification of the productive apparatus, the creation of (start-up or spin-off) enterprises and also of large companies depending on the markets and consumers. Strategic associations (clusters) and regional developments would also be enhanced according to their capacities.

Main goal

The mission will work towards the goal of doubling, by 2030, the production of manufacturing industry and scientific and technical professional activities, increasing the share of digital industries to 3 % of total GDP and doubling production of agriculture and its professional, scientific and technical services, through the use of convergent technology and Industry 4.0, the supply of more complex, high quality products and services that incur less environmental impact, and the resulting increases in productivity and diversification of the economy.

Sectors with great potential and high impact

The Colombia towards a new productive, sustainable and competitive model mission seeks cross-cutting impacts in all sectors through the dynamic application of general-purpose technologies (especially digitalization). Without this general leveling, which has abundant positive spillovers and externalities in the economy, overall factor productivity will not increase. In all of Colombia's production sectors, the comparative advantages and potential of the bioeconomy stand out. In this context, agro-biodiversity and the application of biotechnologies to the sustainable use of biodiversity and resource conservation must be promoted at the national, regional and local levels. Adding value within the production chain allows for local development and provides greater economic and social wellbeing, which will promote the development of new uses for materials, processes, services, products and knowledge in the context of an industry with a new production model, the development of new businesses and the strengthening of social appropriation processes.

The bioeconomy comprises activities such as the primary production of biomass for food and animal nutrition, fiber and cellulose; research on genomes and cellular processes (genomics, proteomics and metabolomics); discovery of nutraceuticals and pharmaceuticals; new therapies and diagnostic systems for health; medical supplies; fine chemicals and metabolites of high added value; bioenergy; instrumentation and control equipment for tropical environments; bioplastics and industrial enzymes; all carried out from a perspective of sustainability, with the concept of cascading or circular processes. The development of reserves of biological resources will require the application of convergent technologies (nanotechnology, biotechnology, information technologies and cognitive sciences), in hierarchical systems from the nano to the macro scale, whose characteristics and role are discussed extensively in another chapter of this document. Biotechnology is a dynamic element for generating central platforms that promote the development of the bioeconomy (ECLAC, FAO, IICA, 2017) and is the gateway to a new world of sustainable business that presents many management and organizational challenges.

Mission goals, horizon 2030

Manufacturing Industry

a) Double the production of the country's manufacturing industry, and go from 0.57% to 3% of GDP in digital industries, between 2020 and 2030.
b) Push manufacturing, agriculture, agro-industry and convergent technologies towards carbon neutrality.

Agriculture and Agribusiness

a) Double Colombia's agricultural production between 2020 and 2030
b) Harness solid and liquid biomass to increase its share of energy production from 9% to 15% and develop at least four industrial sectors based on green chemistry, each with at least one new technology-based company.

Convergent technologies and industries 4.0

a) Increase high-speed data coverage to 90% of the population.
b) Co-invest in satellite capabilities for land observation for the benefit of agriculture, aquaculture, environment, mining, security and land management.

Energy

a) Create five technology-based companies producing instruments, controllers and equipment for energy transition with a view to export.
b) Create five biorefinery companies with a view to export.
c) Support the transfer and adoption of technologies for five smart and sustainable cities in Colombia.

Health

a) Double the number of essential medicines produced in the country
b) By 2030, there will be at least ten medicines, phytotherapeutics or biological products developed in the country for the treatment of the main public health diseases in Colombia.
c) Triple the number of advanced therapy companies in Colombia.

d) Develop a medical instrumentation industry adapted to Colombian conditions.

Goals and programs based on R+D+I

Programs can start in 2020 and the results will be achieved gradually until the goals are reached in 2030. Intermediate checks will be made as necessary.

Program 1. The creation of centers that provide indispensable services for the creation of new companies, financing, initially, exploration and scaling activities and legal and mercantile advice.

Program 2. Training of human talent, from undergraduate to postgraduate, in areas related to the challenge of technological support for businesses and the retention of that talent.

Program 3. Promotion of the creation of venture capital funds and strategies to boost and generate private demand for innovation.

Program 4. Carrying out of national calls for research and development in advanced and promising topics co-financed by the different ministries related to the mission (Science, Technology and Innovation Ministry; Ministry of Trade, Industry and Tourism; Ministry of Education; Ministry of Environment and Sustainable Development; Ministry of Agriculture and Rural Development; Ministry of Information Technology and Communications; Ministry of Mines and Energy; and Ministry of Health and Social Protection).

Energy

Three energy programs with their projects are outlined below. They are an input which could feasibly achieve commercial results in the medium term, and should be developed in the relevant government areas. One of the first tasks of the STI Ministry should be the development of skills to be able to quickly apply “proof of concept” and validations from experts with different perspectives.

E1 program. Create an industry producing instrumentation and control equipment for energy transition with a view to export.
Numerous technologies in renewable energy and electronic products associated with global energy transition are not adapted to demanding tropical conditions (humidity, high temperatures, biological pollution, altitude, etc.). Colombia has several outstanding and consolidated research groups, in various universities and institutes, working on the instrumentation, control, and design of digital devices and organic solar panels, among others, and there is a gap in technological solutions for Latin America that Colombia could fill.

The E1 program proposes 3 prototyping and design development projects in: (1) organic solar panels and energy storage, (2) devices and components for microgrids, smart meters, smart grids (with 5G technology), instrumentation and control devices for energy and control devices for energy efficiency in industry, buildings, and electric transportation; and (3) equipment and processes for solar thermal (cooling). It will take advantage of the connections of the Colombian diaspora with universities and institutes at the global cutting edge (Max Planck, Fraunhofer, FAU, MIT, among others).

E2 Program. Supporting the creation of biorefineries a view to export.
Colombia has abundant biomass residues deriving from agriculture, forestry, livestock and waste that have different characteristics from corresponding residues of the countries of the northern hemisphere, where most of the technologies associated with energy vectors originate.

Colombia has several consolidated research groups in organic chemistry, development and optimization of thermal processes, crop biology and others. From Guatemala to Peru, and in the Caribbean, biomass waste is also abundant and unused. Colombia has the capacity and the right location to take on a regional leadership role in the development of biorefineries.

The E2 program proposes 2 prototype developments and designs of (1) biorefineries focused on energy carrier production and (2) biorefineries focused on high value-added chemical production (green chemistry). We will take advantage of connections with Colombian researchers at cutting-edge institutes and of the interest industrialists have taken in development, with the intention of exporting small-scale modular plants that can be used in a decentralized manner with heterogeneous organic inputs.

E3 Program. Support the transfer and adoption of technologies for smart and sustainable cities

The transfer and adoption of new energy technologies depends largely on the capacities of the actors and on regulatory flexibility. To develop these capacities, the E3 program proposes that two laboratories be established: (1) an advanced computing laboratory to simulate energy systems, transactional architectures and regulation models, inspired by the working style of the US National Renewable Energy Laboratory (NREL) and (2) a decentralized laboratory to support the development of smart and sustainable cities, promoting the use of large data, the Internet of Things and the design of competitions to promote technological solutions in energy efficiency (especially in industry) and in hybrid and electric transport, among other issues. It will also be a center for social innovation and social appropriation of efficiency and the circular economy. We propose that it start in the country's five largest cities and reach agreements on agenda and co-financing with the municipal administrations.

Agriculture and Agribusiness

The modernization of Colombian agriculture and agroindustry requires mechanisms that facilitate development and innovation and the improvement of capabilities in the creation, transfer and adoption of knowledge for the inclusive advancement of its production systems in the territories. By 2030, this mission will include the development and appropriation of compatible (nano, bio, info and cogno) and bioeconomic technologies for greater efficiency in agricultural production and processing.

A1 Program. Incorporate advances in STI for the sustainable technological modernization of the agro-industrial sector

The incorporation of STI advances for the sustainable technological modernization of the agro-industrial sector (agriculture, aquaculture, forestry) is aimed at improving productivity and efficiency (competitiveness) throughout the value creation chain, contributing to food and nutritional security. It includes new technologies for selection and improvement, seed quality, agro-bioprospecting to take advantage of regional biodiversity, nutritional improvement of food (biofortification), greater efficiency in the use of inputs to produce more with less (precision agriculture), use of bioinputs (biofertilizers and biopesticides), digitization, robotics, connectivity, technologies for value addition and *in situ* transformation of products to favor territorial and community development with cascading or circular processes that reduce the production of residual biomass, since any by-product or co-product is used as raw material for another process in a circular fashion.

A2 Program. Bolster the scientific and technical infrastructure of the regions in instances of R+D+I

The regions must identify which critical scientific and technical infrastructure they require to bolster research, development, and innovation activities to facilitate the knowledge creation and transfer, interconnectivity, communications, technical assistance, and ease of delivery of products, byproducts, or co-products and services developed. To do this, it is necessary to facilitate the dissemination and transfer of available technologies, promote associative work and strategic interactions.

Some goals for the regions in 2030 are (1) that the productivity of the crops be increased by 10-15 %, (2) that the costs of production be reduced by 10-20 %, (3) that the creation of (more qualified) employment be increased by 20-30 %, (4) that, for different factors, the CO2 emissions be reduced by 20-40 %, depending on the region and agro-industry and (5) the volume of waste and effluents from the different agro-industries be reduced by 30-40 %, and half of this volume is creating additional value in new products.

A3 Program. Contributing to the slowdown or even reversal of the negative effects of climate change

It is possible to contribute to the slowing down or even reversal of the negative effects of climate change by improving energy efficiency, reducing CO2 emissions and using convergent technologies and Industry 4.0 in agricultural, agro-industrial and industrial operations, providing new technological tools and information networks with good quality data for better use of land, water, energy, fertilizers, and biocides among others. Satellite capabilities are needed to generate images for the benefit of agriculture and the environment. This will result in the conservation of non-renewable resources, in the protection of crops from infestations, and in the reduction of greenhouse gas emissions by balancing fertilization, land management and irrigation.

Industries 4.0

I1 Program. Incorporating progress in technological convergence for the development of the regions

Incorporate advances in technological convergence (nano, bio, info and cogno), such as connectivity, biotechnologies, precision agriculture, Internet of Things (IoT), green chemistry, and nanotechnologies among others, to increase the efficiency of the productive systems and their services. It will also aid their incorporation into comprehensive value chains or networks as part of cascading processes that maintain the value of the components in a cyclical manner during the different processes involved. This a felt and clear need for territorial development and facilitates the country's positioning and global opportunity.

I2 Program. Enhancing the articulation of the information and data management in the country.

The improvement of the high-speed data connectivity infrastructure will facilitate the development of new products, services and business models through the convergence of technologies (nano, bio, info and cogno) that will support the country's new productive, sustainable and competitive model. It will be possible to bring new technology to the field and also deploy this infrastructure on demand in remote areas.

The primary production sector and its related services require, without delay, the articulation and increased efficiency of its electrical and data connectivity, its supply and value chains, and its norms and regulations, to increase its productivity and profitability, to use inputs more efficiently and to improve the quality of its products, thus achieving significant increases in its income.

Co-investment in satellite capabilities for earth observation is required for the benefit of agriculture, aquaculture, environment, mining, security and land management.

I3 Program. Developing industrial sectors based on green chemistry through agro-industry and the convergence of technologies

The agro-industrial sector and its related services can evolve and contribute to the economic growth of the country with the production of intelligent and sustainable materials of with national and international demand, such as active pharmaceutical and nutritional ingredients, cosmetics, polymers, and lubricants among others. These developments can take place in biorefineries, for example.

Health

By 2030, this mission will have designed, developed and be producing healthcare technologies in search of health security, productivity and sustainability of the national industry.

S1 Program. To finance and consolidate capacity building for the production of essential medicines for public health.

- Finance capacity building for the production of essential medicines that are out of stock, at risk of shortage and for diseases that are designated priority by the Ministry of Health and Social Protection and Invima's sources.
- Promote the drawing up of binational agreements for technology transfer for the local production of medicines.

- Consolidate the national production of strategic active ingredients for national public health and that are at risk of being out of supply.

S2 Program. Reforming the Health Research Fund (FIS) to strengthen innovation in health

- Reform the Health Research Fund (FIS) to strengthen innovation in health and expand the fund's sources of financing with 5% of the taxes collected from the sale of alcohol and tobacco and 10% of the resources collected from the authorization of pharmaceutical advertising to fund innovations in the area of health.
- Develop calls for the clinical evaluation of new products and the creation and expansion of production plants.
- Hold an annual health innovation macro-conference to establish cooperation between the companies, universities and the State, in which resources are available to finance the projects positioned during the macro-conference.
- Design and implement the biotechnology production program in Colombia.
- Formulate and implement an industrial policy in health that promotes the development of products and services of interest to public health.

Impact of the mission on the STI system and Colombian industry

Impact

This mission represents a large-scale industrial transformation through the incorporation of knowledge and technological innovation into production systems, their related services and value chains or networks based on the sustainable use of biodiversity, environmental and health management, renewable energy and convergent technologies.

The impact of this mission will be the economic growth of Colombia to affect improvements in the standard of living of the population by doubling the production of the country's manufacturing industry by 2030.

The modernization of the production and public sectors, as well as their technological convergence services, will have a positive impact on the Colombian economy and society and, additionally, will contribute to the creation of employment, technology-based companies and the reduction of poverty in the medium and long term.

Technological convergence applied throughout all dimensions of biodiversity, including marine/coastal, insular and inland water resources, supports the industrial, cultural, regional and local economy at all levels in an important way. It is also key for food and nutritional security. Rules and regulations must be fit for purpose and promote the operation of convergent technologies, and their sustainable handling and application, facilitating agricultural and industrial activities, as well as value chains and services within regions and local communities.

In the health sector, local production and the development of technologies from biodiversity is the way to overcome the country's technological dependence and explore new growth opportunities. In this case, the development of phytomedicines, biological products and nutraceuticals, in addition to medical devices, is the way to cover the health needs of Colombians at lower costs and contribute to the wellbeing of the Colombian population.

Academia

Basic research will be promoted to support technological innovations and their transfer to the production sector. We will apply knowledge and technology to contribute to the fulfillment of the SDG. Nanotechnologies, biotechnologies and information and communication technologies will be developed and applied to identify and characterize potential properties in biodiversity and by-products of agro-industrial processing and green industry to develop high value-added bioproducts. Big/Smart Data platforms will be implemented, and the use of cloud computing will be expanded.

Research will be strengthened in Internet of Things (IoT) scenarios, drones, Blockchain traceability, and artificial intelligence, among others.

Cooperation

Far-reaching national and international public-private partnerships will be established and strengthened, involving, partially or totally, universities, research institutes or technology development centers and technology transfer units, business, the State and regional actors. The State-university-center-business-society collaborations will make it possible to expand STI training and offerings in the country, which will be of social and economic interest to companies and society. Intersectoral and interdisciplinary collaborations will be promoted. The modernization of public entities can be accelerated with technological convergence and the Fourth Industrial Revolution for the benefit of industry and society. Trade associations will be considered in these collaborations.

Bottom-up solutions

An important bottom-up mechanism will be the definition of specific problems or challenges that will be disclosed through calls for funding, chambers of commerce, associations, incubators, accelerators, planning secretariats, universities, institutes or centers, institutions that make public purchases and other entities related to STI. Workshops will be held to consult the community in order to detect problems and define priorities.

A fundamental aspect that should be promoted as part of this initiative is the "dialogue of knowledge" that allows for the identification and appropriation of different systems of knowledge, including communities' ancestral and indigenous knowledge and knowledge of those in industry. In addition, this mission can be a propitious scenario in which innovators and entrepreneurs to have the possibility to explore, scale up and implement processes, products and services that respond to specific needs and problems of their communities by using knowledge.

In order for the use of biodiversity and agricultural biomass to be more efficient and conducive to economic development and the wellbeing of society, it is necessary to begin by strengthening the connectivity of the actors and the technological culture, as well as the management, privacy and integrity of the data.

Regionalization

The mission Colombia towards a new productive, sustainable and competitive model is relevant for the country's different regions because it can be adjusted to serve a demand-based infrastructure, natural resources, economy, capacities and opportunities and promotes their competitiveness in particular niches. This mission proposes to advance parallel pilots in the various regions and in different agricultural, aquaculture, agro-industrial, industrial, energy and health sectors, among others.

Internationalization

There are ample opportunities for international cooperation, as well as integration with research and development institutes in other countries, such as Germany (Fraunhofer Institutes, Leibniz Institutes and others), France (Cirad and others) that are knowledgeable about Colombia and specialize in applied research of convergent technologies and Industry 4.0 in the agricultural, aquaculture, agro-industrial, industrial, energy, health and bio-economic sectors. Likewise, there will be collaboration with the land-grant universities of the United States. This can also be a "platform project" for convergence in research, establishing close partnerships with major technology players in the global arena, who have excellent proposals for platforms and solutions of "precision agriculture," using a wide range of technologies in the technological convergence.

Convergences

Transversality: this mission is echoed in the eight thematic pillars of the Mission of Experts: Convergent Technologies and Industry 4.0, Bioeconomy, Biotechnology and Environment, Oceans and Water Resources, Sustainable Energy, Life and Health Sciences, Basic and Space Sciences, Social Sciences, Human Development and Equity (Education) and Creative and Cultural Industries.

Long term

The mission proposes the adoption of public policies to maintain the updating and transfer of technology to the production sector in order to obtain greater benefit from all the advances in knowledge. The application of knowledge to the various production sectors of society at the regional level is the best tool for them to maintain their relevance, efficiency, and competitiveness for the benefit of the entire community and the promotion of territorial development with environmental, social, and economic sustainability.

Governance of the mission

Under the coordination of the Vice-Presidency of the Republic of Colombia, this mission should be jointly addressed by the Ministries of Trade, Industry and Tourism, the Science, Technology and Innovation Ministry, the Ministry of National Education, the Ministry of Information and Communication Technologies, the Ministry of Agriculture and Rural Development, the Ministry of Environment and Sustainable Development, the Ministry of Mines and Energy, and the Ministry of Health and Social Protection, as well as the National Administrative Department of Planning (DNP), an entity that designs, guides and evaluates Colombian public policies.

Financing

This mission requires public-private partnerships. The regional and national calls for research and development in advanced and promising areas require both public and private resources, the latter being covered by a legal security scheme.

For national calls for proposals in specific programs, at least USD 6000 per program and an additional USD 4000 must be available to fund the training of high-level human talent.

For the regional calls for proposals in specific programs, at least USD 6000 per pilot in the five main regions of Colombia must be available to strengthen the scientific and technical infrastructure of these regions in research, development and innovation instances.

A fund of at least USD 80 million must be created to establish promotional instruments for the exploration, scaling up and creation of new technology-based companies with a view to export, as well as centers to close the gaps in technology and economic growth. This fund will have long-term tax incentives.

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The *Equitable Colombia* Challenge

Despite the achievements of the last decades, Colombia continues to have great inequalities. The concentration of income, measured by the Gini coefficient, reached 0.517 by 2018, one of the highest on the continent. Multidimensional poverty remains at 19.6% for the entire country and 39.9% for rural areas, but in five departments this figure exceeds 45%. The Human Development Index places Colombia comes in 90th among 189 countries with an indicator of 0.747 (DANE, 2018).

Persistent disparities in education, health and other basic services in the same regions and population groups over decades have led some authors to use the concept of social exclusion to point to the existence of a "self-perpetuating" process (Garay, 2003, p. 55), based on structures whose historical trajectories go back hundreds of years. As early as 1993, the Green Paper for European Social Policy noted that discussions on social exclusion place "particular emphasis on the structural nature of a process that excludes part of the population from economic and social opportunities." Later on, the same text pointed out that "by highlighting the shortcomings of the social structure, social exclusion reveals more than just social inequality and therefore entails the risk of a dual or fragmented society" (Commission of the European Communities, 1993, p. 24).

The risk of social fragmentation, today evident in different societies in this and other continents, and the gradual deterioration of climatic and environmental conditions indicate that economic growth is only sustainable if it is accompanied by equity, inclusion, democratic participation and respect for the environment. In particular, Colombia must seriously face the challenges of creating opportunities for all and generating and promoting autonomous local and regional processes in conjunction with populations that have historically been subject to exclusion.

Because of their structural, multidimensional and complex nature, the problems of exclusion and social inequality cannot be addressed through a one-off policy or a marginal set of mechanisms. To solve them, they need to be addressed as a national challenge, which will lead to a reorientation of the foundations for growth, prioritizing decision-making, the allocation of resources and the production of knowledge.

Colombia needs to grow and become more equitable. These are not contradictory goals. On the contrary, the United States, Korea and Finland show a close relationship between broad access to education and growth. For these two goals to be compatible, we must shift from a model of economic growth based on income —especially from the exploitation of natural resources— to one in which human capital and knowledge provide this basis for growth and where environmentally and socially sustainable development is the priority. This is where the central role of education as an instrument of change arises. In order to build a different possible future, we must promote knowledge and education. Knowledge, which includes science, the humanities, the arts and ancestral knowledge, is fundamental for the development of new and creative alternatives. Education is the means to develop capacities that allow the creation, sharing and dissemination of this knowledge and that allow Colombians to use this knowledge to develop as people and contribute to the entire country's sustainable development.

As part of this, the Mission of Experts proposes the following as one of the great long-term challenges for the country:

> *To reach a stage in which all of Colombia's people and communities are actors of their own destiny, where they develop their knowledge, their creativity and their capacities, enjoy equal opportunities and exercise their rights of participation, to become the base of the national development.*

To take up this challenge, we propose two missions: the Knowledge and Innovation for Equity Mission and the Quality Education for Growth, Equity and Human Development Mission.

These are described below.

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Knowledge and Innovation for Equity flagship mission

Context and Justification

Over the last few decades, Colombia has been gradually reducing monetary poverty figures, both in the headwaters and in rural areas, although with a slowdown in the last five years, especially in urban areas (DANE, 2018a). However, according to the Sustainable Development Goals (SDG), poverty must be understood as something beyond monetary income. In the description of the first SDG, it is estimated that,

> Poverty goes beyond a lack of income and resources to ensure sustainable livelihoods; it is a human rights issue. Among the various manifestations of poverty are hunger, malnutrition, lack of decent housing and limited access to other basic services such as education or health. There is also discrimination and social exclusion, which includes the absence of participation by the poor in decision-making, especially those that affect them.

These complex characteristics of poverty led the United Nations Development Program (UNDP) to begin, in 1990, to produce reports on the Multidimensional Poverty Index (MPI), which assesses deficiencies in health, education, and standard of living, including aspects such as access to clean water, electricity and housing. These same parameters form the core of the Human Development Index (HDI), which measures life expectancy, years of schooling, and per capita income. According to DANE, multidimensional poverty in Colombia did not decrease, but rather grew between 2016 and 2018, reversing a downward trend that had existed at least since 2010 (DANE, 2018b). However, multidimensional poverty in populated centers and dispersed rural areas doubles the national total, indicating a much wider gap than monetary poverty.

As mentioned above the HDI for Colombia in 2018 was 0.747, placing the country as 90th among 189 countries, and the country continues to show one of the highest indicators of inequality according to the Gini coefficient, which measures the concentration of wealth and income, and which by 2018 was 0.517 showing an increase over the previous year (DANE, 2018b). Although UNDP reports have found that there is no clear correlation between multidimensional poverty and inequality measured by the Gini coefficient, it is clear that inequality in access to basic services in the country can delay poverty reduction. According to the description of the tenth SDG, despite progress in poverty reduction in different parts of the world, "inequalities and wide disparities in access to health and education services and other productive assets remain." In the same vein, this text adds: "there is a growing consensus that economic growth is not sufficient to reduce poverty if it is not inclusive and does not take into account the three dimensions of sustainable development: economic, social and environmental." The SDG targets therefore state that, in addition to achieving income growth for the poorest 40% of the population, we must promote social, economic and political inclusion, and guarantee equal opportunities. Although there is a consensus that science, technology, and innovation have a positive impact on development and economic growth, specific efforts are required to ensure that the production of knowledge and its application directly addresses the needs of the less advantaged sectors of the Colombian population, especially with regard to barriers to access to basic services (even more importantly if one considers that an efficient incorporation of technology can raise the Gini coefficient at the outset, rather than lower it). As Esther Duflo, winner of the 2019 Nobel Prize in Economics, has stated, "the goal is to ensure that the fight against poverty is based on scientific evidence." In this respect, the National System of Science, Technology and Innovation (SNCTI) must assume the production of knowledge and innovation to overcome multidimensional poverty and reduce inequality in Colombia as a top priority.

General Objective of the Flagship Mission

Reducing social inequality and multidimensional poverty in Colombia based on scientific knowledge and social innovation.

Specific Objectives

- To build and implement a Social Innovation Policy, in a participatory manner and based on research and empirical evidence, to guide the production, transfer and application of knowledge with a view to eradicating multidimensional poverty and reducing inequality.
- To produce knowledge that contributes to universal access to basic services, accelerates social inclusion, and strengthens the autonomous development of less favored populations.
- To define criteria and instruments for the promotion and consolidation of a dialogue of knowledge, within a framework of respect for local communities, their different forms of knowledge production and their conceptions of development and sustainability.
- To consolidate the institutions required to create equal opportunities throughout the national territory.

The Missions Goals for 2030

- Implement a minimum of five regional projects per program, through the prioritization and concentration of scientific and financial efforts, that show specific contributions to closing the multidimensional poverty gap between rural and urban areas.
- Execute a minimum of forty social innovation projects as part of each of the Mission's programs (320 in total).
- To have a bank of at least ten nationally replicable projects in each of the Mission's programs.

- To ensure that all State and SNCTI actors appropriate the Social Innovation Policy.

Through these goals, and assuming continuity of the six programs, by 2045 the Mission is expected to be able to demonstrate concrete contributions to the following country objectives.

- Ensure widespread access to education, health, justice, water and food, infrastructure and technology, and arts and culture.
- Steadily reduce unemployment, increase formal employment, and strengthen the productive structure, especially in the departments with the highest incidence of multidimensional poverty.
- Reduce multidimensional poverty in populated and dispersed rural centers, as a priority.
- Increase the country's Human Development Index.
- Reduce the Gini Coefficient nationally, especially in the departments with the highest incidence of multidimensional poverty (Guainía, Vichada, Vaupés, Guajira and Chocó).

Strategic approach: Social innovation as a driver of equity

Including the least favored population in the country's social, economic, and cultural development is a moral imperative and a historical debt. This requires an in-depth study of the causes and dynamics of inequality and the creation of knowledge-based solutions to promote capacity building and opportunities throughout the country, and to guarantee access for all Colombians to basic services such as health, education, justice, water and food, infrastructure and technology, culture, productive processes and a healthy environment.

In accordance with the Mission's first goal, in order to put knowledge at the service of equity, we must build and implement a policy of social innovation, which is not restricted to the National System of Science, Technology and Innovation, but rather that poses concrete responsibilities and duties for the State and society as a whole, recognizes existing policies and programs in relation to poverty and inequality, and contemplates concrete mechanisms and instruments to improve the living conditions of the entire population. To this end, taking into account the "bottom-up" nature that should characterize any social innovation process, such a policy should be built on the basis of a research effort that makes it possible to establish bridges between science and other forms of knowledge, to gain detailed knowledge of the dynamics of poverty and inequality in local contexts, and to identify opportunities for the joint deployment of social innovation initiatives and projects with local communities.

In accordance with the above, the Mission Knowledge and innovation for equity sets out the following roadmap:

a) By 2020, the Ministry of Science, Technology and Innovation, must launch specific calls to produce knowledge in each of the programs for this Mission. These calls must prioritize the participation of local communities in project design and implementation, the confluence of different disciplines, the dialogue of knowledge and the participation of the public sector (universities, local authorities) at local and regional levels. Research should also be prioritized in the five departments with the highest incidence of multidimensional poverty (Guainía, Vaupés, Vichada, La Guajira and Chocó). Within the framework of these calls for proposals, a minimum of five projects per year must be financed for each of the programs for this Mission. The calls for proposals must be opened on an annual basis.
b) In 2021, the Ministry of Science, Technology and Innovation must build mechanisms for the systematization of the results of the research calls referred to in the previous point with a view to building social innovation policy.
c) By 2022, the Ministry of Science, Technology and Innovation must produce a social innovation policy document for discussion and appropriation by different State and civil society bodies.
d) By 2022, the Ministry of Science, Technology and Innovation must create specific calls for social innovation that contemplate concrete inclusion goals in each of the Mission's programs. Within the framework of these calls, a minimum of five projects per year should be financed for each program, which should contemplate: 1) the building of knowledge and solutions together with the affected

communities, 2) interdisciplinarity and dialogue of knowledge, 3) participation of the public sector at the local and regional level, 4) participation of the private sector in the financing and execution of the projects, 5) mechanisms for evaluation and systematization of results with a view to their replicability.

e) By 2023, the social innovation policy must be enacted. Beginning that same year, a strategy must be implemented to: 1) foster social ownership of the social innovation policy, 2) ensure that all SNCTI stakeholders incorporate the promotion of social innovation in their policies with a view to equity.

f) By 2024, ministries, administrative departments, territorial entities and other State entities must formulate goals and build specific tools for the implementation of the social innovation policy.

Flagship Mission Programs

Program 1. Understanding Inequality: Production of Knowledge on Historical, Economic, Legal, Social and Cultural Aspects of Poverty and Inequality in Colombia

Addressing a problem as complex as social inequality requires a permanent endeavor to understand phenomena that cannot be reduced to a single disciplinary or epistemic framework. The particularity of each context, of its social disputes and tensions, of its cultural differences and economic dynamics, demands a permanent exercise of empirical and theoretical research that allows the construction of specific explanatory frameworks and the identification of opportunities for the design of social innovation initiatives that can be built together with the communities.

In this respect, it is essential to convene all SNCTI actors to produce knowledge and social innovation around the following themes:

- Historical trajectories of social asymmetries and structural violence in Colombia.
- Cultures and subjectivities in contexts of multidimensional poverty and social inequality.

- Economic and social factors of inequality and exclusion: jobs and wages, social mobility, tax systems, income distribution and land distribution.
- Access to justice, jurisprudence and legal care protocols for victims and communities that are vulnerable or have a high incidence of multidimensional poverty.
- Development of models and methodologies for conflict resolution and education for peace.
- Development of materials and content for the social appropriation of knowledge related to inequality, multidimensional poverty and social innovation.

Program Goals

- By 2022, this program should have produced the conceptual and technical foundations for the formulation of a social innovation policy.
- By 2030, Colombia should be a world reference in the production of knowledge about inequality, multidimensional poverty and social exclusion. This implies having achieved an annual increase of 10% in publications (and citations) on these topics, as well as having increased projects in international collaboration with institutions and individuals recognized in these issues (such as the Abdul Latif Jameel Poverty Action Lab at MIT, the Oxford Poverty and Human Development Initiative and others).

Program 2. Health Equity for Colombia

Health inequity refers to the modifiable and unfair differences between people according to their socioeconomic levels, which affect their health status. According to a Ministry of Health study on health equity, 3.5 million people do not have access to safe drinking water and 10 million lack health services and systems, such as latrines, water disposal, and sewage, which lead to health inequity and poor health and wellbeing (Ministry of Health and Social Protection, 2015). According to reports from the National Health Institute, the highest rate of deaths per live birth in 2018 was recorded in the departments of Vichada, Atlántico, Chocó, Amazonas, and San Andrés. These departments have a high rate of multidimensional poverty, their basic needs are largely unmet, and people have low access to health services. These circumstances prevent access to prenatal care, childbirth, and newborn care (National Institute of Health, 2019). Effective and decentralized interventions are needed to address local needs.

In Colombia, the degree of national inequity in health has been studied through variables indicative of the health of the adult population, children, women and pregnant women, as well as access, quality and utilization of health services. However, the country lacks tools and data to measure health equity conditions among population and social groups against social determinants. This knowledge must be developed in order to tackle the link between poverty and health and provide effective health solutions according to local conditions and for each population group. Thus, the great health challenge is to achieve health equity throughout the Colombian territory. To meet this challenge, the following four lines of work are proposed to create the necessary knowledge and innovation in relation to health objectives: 1) low weight in children, 2) late perinatal and neonatal mortality, 3) life without disease, and 4) depression and anxiety in areas affected by the conflict. The following are the actions and goals associated with these lines of work:

- Research on social determinants of health.
- Research on the nutritional factors that children in Colombia require in terms of regional diets and production capacities to meet local demands.
- Regional feeding programs aimed at early childhood (see also the program “Equitable access to water, energy and food”).
- Strengthening the web-based maternal mortality epidemiological surveillance system to understand the immediate and underlying causes of these deaths.
- Research and intervention to address obstetric transition throughout Colombia.

- Consolidation of promotion and prevention programs in rural areas focused on maternal health by improving coverage and care of pregnant, neonatal and pediatric women.
- Implementation of the Integrated Territorial Action Model (Maite) in vulnerable regions or populations with poor health indicators, through coordinated actions among health system agents (e.g., implementation of the community medicine chair, rural internship).
- Strategies to consolidate collaboration in multi-professional health teams and guarantee adequate resolution capacity with access to health information and telehealth services (including telemedicine), prioritizing the regions with the greatest health vulnerabilities.
- Program and strategies for training caregivers of people with dependencies or disabilities.
- Mental health support for people from populations most affected by the armed conflict, domestic violence and illegal economies.

Program Goals

- Reach a stage in which less than 1% of Colombian children will be underweight in both rural and urban areas by 2030.
- Ensure coverage of over 90% of growth and development programs throughout the country.
- Reduce perinatal and late neonatal mortality by less than 12 deaths per 1000 live births in all of the country's departments.
- By 2030, all municipalities identified as having a vulnerable population should have developed and implemented health prevention plans based on their particular social determinants of health.
- Increase disease-free life years in both men and women by five years.
- Decrease depression and anxiety to less than 10% in the civilian population living in areas historically affected by the conflict.

Program 3. Equitable access to water and food

- Universal access to drinking water services at home, as well as access to a balanced diet, requires innovative and sustainable solutions that can benefit a much larger population, at lower costs, in difficult social, geographical, and economic conditions.

- Although water and food production issues are addressed in other Mission's in general terms, a differentiated approach is required to solve the barriers of access to drinking water and a balanced diet for the country's most vulnerable populations. The following lines of work are proposed in this respect:
- Development of the Integrated Water Management Program in Colombia.
- Water flow and environmental flow.
- Water connectivity and maintenance and improvement of the hydraulic system.
- Water resource quality and coverage.
- Threats and risks that can affect aquatic resources.
- Development and implementation of food and nutritional security policies at regional and local levels.
- Food programs to improve access to healthy food for vulnerable populations (rural and urban). This line includes the design of solutions for school feeding that include not only the production of healthy food at low cost, but also its storage and distribution with technologies such as blockchain, to ensure that it reaches those who need it.
- Urban and peri-urban agriculture.
- Local markets.

Program Goals

- By 2030, child malnutrition should be reduced by 50% in rural areas, among indigenous populations, and departments with a high incidence of multidimensional poverty.
- By 2030, the incidence of obesity in people aged 18 to 64, and especially in urban areas, should be reduced to less than 15% nationally.
- By December 2020, environmental authorities throughout the country must establish a list of sources and quantities of dumping

and disposal of liquid and solid waste, to define an 80% reduction of these sources of pollution by January 2022.

- By 2030, the country should improve, restore and maintain water quality conditions by eliminating, treating and adequately disposing of liquid and solid waste in freshwater and marine-coastal ecosystems from distribution point sources that could endanger the subsistence of aquatic species.
- By 2030, Colombia must have the capacity to guarantee, improve and recover the good condition of a freshwater ecosystem with respect to water hydrology (flow) and the functions it performs (ecosystem services), and the assurance of an environmental flow that allows the development of the biotic communities in the area.

Program 4. Connectivity and appropriation of technologies

According to a 2014 Regional Digital Divide Report, there is significant correlation between the Digital Divide Index (DDI) and the Unsatisfied Basic Needs Index (UBN). Digital connectivity has direct impacts on building equity by ensuring that information flows are as far-reaching as possible. This is an opportunity that can be seized in terms of the quality and coverage of education, management of administrative and productive processes, control and surveillance capacity, and even the dissemination of science and technology. Connectivity is also an effective pedagogical tool, which allows communities, including those traditionally marginalized, to be brought closer to the full range of opportunities that arise from information and communication networks.

But for these goals to be met, connectivity cannot be reduced to an increase in the number of broadband connections. While it is essential to solve basic infrastructure problems, digital connectivity must be accompanied by strategies for technological appropriation that allow its full use by the entire Colombian population. It is therefore necessary for each law initiative that contemplates technological developments to include a report on how such an initiative will contribute to closing gaps, especially considering possible impacts on employment generation.

Although universal access to digital connectivity is on the current government's agenda, and is contemplated in the ICT modernization law (Law 1978 of 2019), the digital inclusion of the most vulnerable populations presents specific challenges that must be addressed with knowledge production and innovation. In accordance with the above, the following lines of action are formulated:

- Development of infrastructure solutions for total regional connectivity, especially for the most remote and difficult to access areas.
- Development of policies for the critical appropriation of ICTs in departments with a high incidence of multidimensional poverty.
- Massive training programs for the appropriation of convergent technologies (nano, bio, info and cogno).
- Development of contents and technological solutions for the strengthening and massification of the ICT Ministry's Digital Citizenship Strategy that certifies digital competences and skills from the age of 13.
- Digital transformation of the State.
- Application of *Big data*, IoT, blockchain, and AI to land management, urban mobility control and environmental monitoring and disaster prevention systems.

Program Goals

- By 2030, the departments with the highest incidence of multidimensional poverty should have achieved an increase of at least 20% in the following indicators measured by DANE in the Technical Bulletin on ICT tenure and use indicators: 1) cell phone use, 2) computer use, 3) internet use.
- By 2030, create a State data exchange platform for the promotion of innovation with transparency.
- By 2030, public-private partnerships with high-tech companies are needed to reach the necessary scale that can generate solutions that truly provide effective responses to the challenges and opportunities that the Fourth Industrial Revolution will bring.

Program 5. Art, culture and creativity for equity

Both the 1991 Political Constitution and Law 397 of 1997 consider culture as a right. However, the infrastructure for the creation, production and circulation of cultural content shows enormous concentration in major cities. At the same time, cultural consumption in small cities and rural areas focuses on content offered by the mass media. These two conditions can lead to a deterioration of local identities and to a weakening of the country's cultural diversity, which is not only one of its main resources; it constitutes a cornerstone for the formation of identities, the construction of social fabric, respect for difference, and the cultivation of democratic values. In this respect, the National System of Science, Technology and Innovation must create the knowledge to guarantee the right to culture, protect cultural diversity, raise people's sense of belonging, and promote the appropriation of cultural heritage. This requires work along the following lines:

- Research and documentation on Colombian cultural practices and manifestations, their history, the human groups that produce them and their role in the formation of identities, focusing on historically excluded populations. This line is complemented by the lines of research on cultural heritage proposed in the Biodiverse Colombia challenge.
- Development of methods, contents and didactic materials for non-formal education in expressive techniques and languages, together with populations in vulnerable situations, through a dialogue of knowledge. This is aligned with the provisions of the Mission "Quality education for growth, equity and human development"
- Creation and research + creation (R+C) together with the communities to strengthen local cultural production and the communities' sense of belonging.
- Development and adaptation of physical infrastructure for the interregional circulation of cultural content.
- Design of low-cost solutions for the production, distribution, and availability of cultural content to the public in all regions.

- Provision of materials and content for the appropriation of technologies related to the creation, production and distribution of cultural content.
- Art and science for social innovation.
- Implementation of the Creative Nurseries initiative in areas with a high incidence of multidimensional poverty.

Program Goals

- By 2030, locally produced content should occupy no less than 20% of the cultural offerings of each municipality and department.
- By 2030, the contents produced in other parts of the country should occupy no less than 10% of the cultural offerings of each municipality and department.
- By 2030, a sustained increase in cultural consumption must have been achieved in the ten departments with the highest incidence of multidimensional poverty, in the variables measured by the DANE Cultural Consumption Survey: Attendance at cultural presentations and shows, cultural spaces, and movies; printed and digital reading of books, magazines and newspapers; reading of blogs, forums, websites and emails; consumption of audiovisuals such as videos, television, radio and recorded music; cultural practices and attendance at workshops in artistic and cultural areas.
- By 2030, at least two creative nurseries must be in operation in each of the country's departments. These nurseries must be producing economic value from original content based on the local culture.

Program 6. Local economies and productive processes

Foreign capital investments in large productive projects are important sources of employment in several parts of Colombia. However, the emphasis on extractive economies around non-renewable resources means that this investment does not always result in capacities and infrastructure for the strengthening of local economies in the long term. Knowledge is required for the development of sustainable productive processes that allow communities to build economic capacities that do not depend on the short-term abundance of a given resource. The following topics can be prioritized as part of this line:

- Identification, adaptation and use of infrastructure, resources and local capacities for the creation of productive projects.
- Entrepreneurship for problem-solving in contexts of social exclusion.
- Alternative economies, local development and sustainability.
- Research and technological development for the strengthening and competitiveness of local productive processes.
- Research and development for the improvement of rural employment
- Development of local markets.

Program Goals

- By 2030, the program must have led to the identification, implementation and evaluation of at least ten sustainable productive projects in each of the five departments with the highest incidence of multidimensional poverty.
- By 2030, the program should have contributed to reducing the rate of rural employment informality to levels comparable to the current national total (in 2018 this rate was 82%, while the national total reached 48.2%).

Repercussions of the Flagship Mission in the STI system and in Colombian society

As a result of the different negotiation processes with armed groups, it has been said on several occasions that peace does not depend on the signing of an agreement, but on the construction of equitable conditions that allow all Colombians to lead a dignified life. The social and human sciences have not been oblivious to this call and have turned their efforts in recent years to the production of knowledge to overcome the conflict. However, these efforts have been made on many occasions outside the SNCTI and with the support mainly of foreign governments, multilateral entities and other national government agencies.

The definition of a priority agenda around the reduction of inequality and the eradication of multidimensional poverty will make it possible to concentrate the country's efforts on overcoming the inequitable conditions that have historically been the source of conflicts of different natures. At the same time, the necessarily interdisciplinary nature of this agenda will allow for greater participation and visibility of the social sciences in SNCTI. This effort will make it possible to set the necessary bases for the development of an egalitarian society with values and principles, a necessary action if the country is to be capable of valuing science as a tool for development.

By bringing together a wide range of actors around a country agenda, framed in two of the SDGs, this Mission will lead to profound progress in the country's social, cultural, political, and economic transformation and provide greater possibilities for its population's health and wellbeing.

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Quality Education for Growth, Equity and Human Development flagship mission

Mission Statement

The Mission of Experts 2019 must think in terms of the next generation. The question we are asking ourselves is what we need to do in order to ensure that by 2045 all young people who turn 18 will have received comprehensive education from 0 to 5 years of age, and will have at least had access to diversified secondary education or a double degree (classical + technical).

This implies having achieved universal education with comprehensive care for children aged 0 to 5 years by 2026 at the end of the next administration (2022-2026) and having achieved universal access to diversified secondary education or double bachelor's degrees (academic and technical) by 2030.

In order for these coverage extensions at both levels to be viable, major changes need to be made in terms of promoting advanced research in education and training, learning processes and teacher training at all levels. National and regional priorities should be discussed in order to define research and training priorities, new technologies should be used, and strong incentives provided to reduce the great regional disparities.

The Mission's central goal

To create the conditions for the emergence of a generation of Colombians with quality education and skills that will enable them to contribute to human development, the promotion of and respect for diversity, the valuation of knowledge, cultural practices of the regions and identities, so as to enhance sustainable and equitable economic development.

The Mission's Programs

- Universal access to education with high quality comprehensive care for all children under 5 years of age.

- Universal access to secondary education, along with disciplinary, professional and cultural diversification to ensure that adolescents have access to a wide range of opportunities and can take advantage of and contribute to developing the potential of the local economy and their communities.
- Reform of the country's teacher training system to meet the new needs of educators, strengthening and expanding the number of teacher training colleges, opening education programs in all accredited universities, and placing the Higher Institute for Research in Education and Advanced Teacher Training (ISIE) at the head of the system to guide national research programs and, through research, train "teachers of teachers" throughout the system.
- Establish a set of regional and sub-regional networks of Centers of Innovation in Education, which will provide meeting and mutual learning spaces for practicing teachers in which, through research, cultural activities and interaction with the community, they can improve the quality of their teaching work and involve the community in educational processes, with the support of local universities.
- Develop programs to promote socio-emotional skills and citizenship competencies taking into account local contexts, community participation and education in historical memory to promote personal wellbeing, democracy and peacebuilding, especially in communities that have experienced various forms of violence.
- To permeate the entire educational system in the development of creative and artistic capacities.
- Ensure a close connection between scientific research and education. To prepare all students, whether they go to university, technical education or work, with a scientific basis that will enable them to fulfil themselves and adapt to new activities later on. In an education aimed at developing creativity and a critical spirit that is both broad and tolerant, scientific research plays a central role. The way in which new knowledge is arrived at is similar to the psychological mechanisms that human beings use to appropriate

it. The role of research should be different at each educational level, but at all levels (including early childhood) it will contribute to the development of creativity and ensure the acquisition of knowledge.

Goals for the first stage (2020- 2022) and subsequent stages

a) Early childhood education:

- Make progress during the three-year period to reach 40% coverage of all children aged 0 to 5 years by the end of 2022 in education with comprehensive care, whether in public or private institutions.
- By the end of 2022, to have trained 30% of the people who are in charge of children aged 0 to 5 years, so that they can be considered suitable to be in charge of the education and comprehensive care of children.
- In the long term, the goal is to achieve universal early childhood coverage in public and private education by 2026.

b) High school education:

- With the support of territorial governments, to provide diversified secondary education programs to 60% of the 15-17 year-old population by the end of 2022.
- In the long term, the goal is to achieve universal coverage for the population eligible for diversified secondary education by 2032.

c) By 2026, to have decreased the dropout rates in primary, secondary, and middle school (urban and rural) in all of the country's municipalities by 20% with respect to current rates.

d) The Higher Institute for Research in Education and Advanced Teacher Training (ISIE) will be operational in 2022, working with resources from the national budget and from private contributions, and will be able to grant master's and doctoral degrees, alone or in partnership with universities.

e) By 2021, an outstanding program of national and international teachers will be in place to promote vocations in the training college system and in the country's faculties of education.

f) By the end of 2022, to have strengthened 40% of the training colleges throughout the country through the outstanding travelling teachers program, the revision of training strategies, and an outreach program with scholarships for high-performing students.

g) To have developed pilot programs of subregional networks of education innovation centers in two departments with high poverty rates, one with medium poverty rates and one where the educational system has made outstanding progress. These networks will be supported by local universities and guided in their research processes by the Higher Institute for Research in Education and Advanced Teacher Training (ISIE).

h) To have initiated the Cosmology(*Cosmología*) project in 10 schools in different regions, as a pilot stage in pedagogical innovation and education, based on the concept of "*universales*" proposed in the Science, Education and Development Mission.

i) To have implemented a comprehensive training program in national and international doctorates and post-doctoral degrees by 2022, along with a program for the employment of doctors that ensures their link to academic or business activities for a minimum term of four years.

j) The ISIE will have designed and guided the implementation, in partnership with accredited universities for this purpose, of continuing education programs for teacher updating and retraining.

k) The country's accredited universities, in partnership with other universities, the SENA and large companies, will be offering continuing education programs that train, update and retrain entrepreneurs, businessmen and technicians in all branches, in all departmental capitals.

l) By the end of 2022, to have developed pilot programs for the development of socioemotional and citizenship skills in six sub-regions that have been especially affected by violence, with a view to taking them to the whole country, after evaluation.

m) By 2022, to have implemented a one-time program of excellence, which selects by competition highly skilled young who wish to develop important areas which are not very prominent in the country. This group of young people will receive scholarships for doctoral studies and post-doctoral internships at world-renowned universities. At the end of the postdoctoral program, they should have guaranteed their link to a Colombian university with good research capabilities and the basic funding to build a laboratory or working group. The estimated duration of the program will be ten years.

n) By 2021, a national network system should be in place, linking various parts of the country, knowledge exchange, the creation of new methodologies and the development of pedagogical strategies.

o) By 2022 there will be a specific program for training teachers in artistic and cultural training methodologies, which will be implemented through the ISIE, the training college, the offer of continuing education from different universities and other channels. With this, the number of teachers with basic knowledge and skills for artistic and cultural training is expected to triple by 2025.

p) By the year 2020, the Ministry of Education must produce guidelines to achieve curricular, pedagogical and evaluative transformations in early childhood, basic and middle schools from an aesthetic approach; that is, one that develops perception, sensitivity, and receptivity.

Program Development

Education with comprehensive early childhood care

During the first five years of life, the brain creates more than 90% of its neural connections, making this period a critical stage. Multiple researches have corroborated the economic, social and public policy advantages of the interventions in that moment of life, which is why it has been established as a priority in the agendas of most governments in this century. Colombia is no exception: its State policy for Integrated Early Childhood Development From Naught to Forever (*Desarrollo Integral de la Primera Infancia De Cero a Siempre*)(Law 1804 of 2016) establishes the goals for this population and harmonizes policies, plans, programs and actions in a concerted manner among the different actors to provide comprehensive attention to the early childhood population.

Despite the laudable progress made in having a State policy to attend to this population, additional efforts are required to achieve its comprehensive implementation throughout the territory. The outlook for this population continues to be worrisome, considering that more than 11.5% live in extreme poverty, 25% do not receive medical attention to monitor their growth and development, and nearly 65% still lack formal early childhood education. Their mothers, with their preponderant role in the care and attention provided to these children, continue to be victims of inequity, abuse and mistreatment. Thus, in order to strengthen the implementation of the policy, the Mission proposes a short-term plan to bring to the most vulnerable population the minimum components of education with comprehensive attention in all the territories where they can be implemented with the already existing institutions, and also to the entire early childhood population in the two departments with the highest poverty indexes. This includes qualified educational agents to support children's development at this early age, and investments in infrastructure in the two selected departments.

As a complementary strategy for gradual development, the Mission proposes to create local centers for research, education, and family and community development that articulate the management of local government with actors from the community, the production sector, academia, and the regional system of science and technology, while serving as networks of Centers of Innovation in Education, where teachers share their knowledge and break the isolation that persists in many of the country's municipalities in terms of culture and community.

These centers will promote the production of socially relevant knowledge through research carried out by educators, supported by regional networks of these centers. They will promote innovative intervention that transforms the care, attention and education practices of social actors. They will promote the dissemination and circulation of the learning and knowledge acquired through research and direct work processes once these have been evaluated and validated, and they will implement formal and non-formal situated training of teachers and other participants. To this end, relevant programs that respond to the specific needs of the students, families, communities, and municipalities will be promoted.

Although eventually each municipal capital should have at least one center, we consider it pertinent to initially pilot the model before implementing it on a massive scale. The mission proposes to call for the establishment of public-private partnerships to adopt these centers for a municipality or a group of municipalities. The call for the creation of the centers will include proposals covering municipalities or groups of municipalities (with the centers operating as nodes for nearby municipalities). These pilots will begin in five regions with very different characteristics, to identify functional aspects in different contexts and aspects that can be improved in both design and implementation.

Universal access to diversified secondary education

The problems related to secondary education include both diversity and coverage. The Quality education for growth, equity and human development Mission proposes to increase the options that young people have to access secondary education in a flexible and diverse manner. The specific way in which flexibility and diversification will be sought will be determined by local and regional characteristics and potential. This will promote quality secondary education, with local impact, promote innovation and boost lifelong learning. Depending on the characteristics of each location, quality secondary education can be on-site, blended or distance learning. It can also be vocational, technical, technological or university. This will promote the offer of disciplinary, professional, and cultural education, which develops the individual's capabilities and later allows for a more fluid reconversion when the acquired skills become obsolete. In all cases, secondary education will be geared towards opening the individual's horizons and linking the young people to the production sector, the community, and local projects.

The areas of the country with the greatest resources can assume the commitment of universal access to secondary education by expanding coverage for grades 10 and 11 in the first phase 2020-2022. At the same time, different options for flexibilization and diversification can be considered, taking into account the recommendations mentioned above. In less-developed areas, Innovar regional innovation institutes could be reproduced and expanded with national resources. These centers are the result of the Science, Education and Development Mission convened by the Presidency of the Republic in 1993. The Innovar centers must provide on-site, blended and distance learning alternatives, as well as vocational, cultural, technical, technological and university education. It is therefore important to build transfer channels so that part of the studies can be carried out in the remote provinces with the possibility of complementing or completing them in institutions with greater resources.

To ensure coverage and quality, it is important to develop problem-based virtual education. Teachers could be trained or brought in to act as guiding tutors. ICTs should also be used by Innovar and its partners to share tools, experiences and knowledge. The goal for Innovar is to provide quality education for local development, which makes it essential to form alliances with the production sector to improve practices and bring products to wider markets under the logic of inclusive and sustainable business, as well as to encourage remuneration during the practical component of studies and integrate the modalities of higher education with business training. In order to increase the community impact, Innovar can be linked to early childhood and secondary education, providing support, recreational activities and valorization of indigenous cultural manifestations. To increase the community's impact, we can link Innovar centers with early childhood and high school education, providing support, recreational activities, and enhancement of local cultural manifestations. In order to maximize resources, Innovar centers can use existing infrastructure and these can be implemented in different municipalities or departments and gradually increase their coverage. Good public-private partnerships and community participation will help Innovar to be more successful. The centers should also be the result of cooperation between the Ministries of Education; Science, Technology and Innovation; Agriculture; ICTs, and local governments, mayors, the Sena, and local universities. Secondary education must build basic scientific, social and ethical foundations and must be connected to university and technical education.

The new teacher training

To achieve diversification and universal access to secondary education, quality access to early childhood education and to break the cycles of violence from childhood, we must significantly expand teacher training based on new evidence and experimental pedagogies. To this end, a parallel system of teacher training is proposed, together with the promotion of networks of teachers willing to update their knowledge and skills. The central components of training will be research in education, pedagogy based on experimentation, training in the development of socioemotional skills, linking teachers to local contexts and objects of study, and transformative innovation connected to the community.

To train the future "teachers of teachers", the Mission proposes the creation of the Higher Institute of Research in Education and Advanced Teacher Training (ISIE). In order to harmonize the goals of educational institutions, enhance their capacities and empower their agents. ISIE will also orient, through guides, training and education for administrative and managerial personnel. and management personnel. ISIE will deal with digital humanities, the comparison of pedagogical theories and the development of intelligence through the arts. As part of the curriculum, teachers in training will be trained to teach socioemotional skills for wellbeing, peace, and the development of democratic citizenship, hand in hand with education in historical memory.

Universities will promote the offer of courses or programs for those who want to become socioemotional skills instructors. Advice should be sought from organizations with experience in the development of socioemotional skills operating in Colombia to design the courses and training programs. This can be done through open calls or in direct agreement with those who provide free virtual training. For education in historical memory with a view to developing socioemotional skills, there are already manuals that can serve as the basis for future developments, explaining the methodology and offering teaching materials. ISIE will propose research programs and projects to the country's teacher training schools.

A parallel program should be developed to extend this new training to the different actors involved in the education of the country's children.

Social actors such as community mothers, young leaders, local government officials and members of NGOs in charge of the various modalities of education and care, especially in early childhood, will be included in the program's training efforts. This is considered a priority because recent evaluations consider that nearly 80% of the people in charge of early childhood are not suitable for this function.

How many new teachers do we need? A first estimation

Country-wide coverage of comprehensive education from 0 to 5 years and of quality secondary and middle education requires a considerable number of teachers to be trained for these levels. Based on the most recent data on coverage and population in Colombia (2017), children at these educational levels are estimated as follows:

Table 14.

Educational level	Population in this age group	Population with educational coverage	Population without educational coverage	Percentage Without educational coverage
Early childhood (0 to 5 years)	5220203	1589599	3630604	69.55
Secondary (11 to 14 years)	3405852	2440634	965218	28.34
Middle (15 to 16 years)	1713657	733273	980384	57.21

Article 11 of Decree 320 of December 10, 2002 establishes that "For the placement of teaching staff, the average number of students per teacher in the territorial entity shall be at least 32 in the urban area and 22 in the rural area." However, in countries with better quality education systems, such as Singapore, Finland and the Netherlands, this ratio does not exceed

15 students per teacher. This is the case in high-income countries and members of the OECD[39].

According to Ministry of Education regulations presented by the Board of Directors at Icontec on August 30, 2006, there is a minimum of 15 students per teacher and a maximum of 20 students per teacher at the early childhood level, considering that teachers often work hand in hand with community mothers; a maximum of 40 students per teacher at the secondary and middle school level; and a maximum of 12 students per teacher for special needs students. Based on the above, the numbers of new teachers needed to attend to the children currently not covered can be estimated at first glance and provisionally as follows:

Table 15.

Educational level	12 Students per teacher	15 Students per teacher	20 Students per teacher	30 Students per teacher	40 Students per teacher
Early childhood (0 to 5 years)		242040	181530	121020	
Secondary (11 to 14 years)				32174	24130
Middle (15 to 16 years)				32679	24510

However, the increase in the number of teachers for these levels should not compromise quality, as has been the case with other levels in the past. Quality education must be the priority. Hence the priority that must be given to educational research, analyzed and systematized educational innovation, training and continuing education and teacher training.

The general lines of this Mission coincide in its purposes with some of the goals of the present administration's National Development Plan

39 Comparison of World Bank student-teacher ratio figures at primary, secondary and tertiary levels: https://datos.bancomundial.org/indicador/SE.SEC.ENRL.TC.ZS

2018-2022. The prioritization of the most vulnerable and impoverished children is one such overlap. However, it is important to move beyond the current plans and throughout the territory towards universal access to comprehensive care, appealing to private organizations and additional state funding. Thus, the goals set forth by this Mission go beyond the objectives of the administration, and they set a course for future administrations. Quality educational coverage for early childhood should exceed 2000000 children, representing 38.4% of the population aged 0 to 5 years (the current government target)[40] by 2022, and should reach 3123850 children by 2025.

Higher Institute for Research in Education and Advanced Teacher Training (ISIE)

- The institution in charge of the academic orientation of these training programs for new teachers and the strengthening of the pedagogical capacities of former teachers will be the Higher Institute for Research in Education and Advanced Teacher Training (ISIE). The ISIE will train teacher trainers, who will then serve in the country's teacher training colleges and schools of education. The ISIE will focus its activities on research and will propose eclectic and holistic teacher training. This will pave the way for an academically articulated system of training, research and innovation, organized around the dual purpose of guiding research and shared learning of teachers, as well as training teachers in teacher training colleges and faculties of education across the country to make the two proposed strategies viable.

ISIE will offer graduate programs, following the modalities described in Law 115 of 1994 and Decree 272 of 1998. Its professors will all be researchers and educators, whose experience in training colleges and

40 Basis for the National Development Plan 2018-2022. Retrieved from https://colaboracion. dnp. gov. co/CDT/Press/PND-2018-2022.pdf

their direct connection with regional needs will be valued. They will have research functions in groups that they will form with their colleagues and students. They will also guide multicenter research to be carried out by the centers and networks of education innovation centers in different parts of the country. The networks of education innovation centers will be connected to six regional participatory research centers, which will be implemented following the Mova model[41].

In their learning process, ISIE students will adopt the "cascade learning" strategy similar to the one proposed for the Everybody Learning (*Todos a Aprender*) program[42], which will allow the school's students to disseminate and share their knowledge with networks education innovation centers.

ISIE will have two educational annex institutes, one for the rural area and the other for the urban area, where the students will embark on internships at the early childhood, middle school (15 to 16 years old), and elementary school (5 to 14 years old) levels. These will be developed progressively and will serve as an internship opportunity for teachers studying at ISIE. Teacher-researchers will encourage research for education based on the needs of the context, aiming at concrete interventions and generating social impact.

ISIE will be funded via the national budget, as will the coordination body for the networks of education innovation centers. The programs related to early childhood education will have investment components that will be financed with national, departmental, and municipal resources

41 Mova is a city-based public policy that focuses on training teachers, school administrators, and educational agents in Medellín, in compliance with Agreement 019 of 2015. Mova was born as a city proposal to train the type of teachers we want: teachers who create, innovate, research, contribute and validate. With four lines of training (human development, situated training, methodological reflection and research), it has three campuses and an infrastructure of 8000 m2 in the north of the city (Alcaldía de Medellín, 2019).

42 Educational Quality Transformation Program of the Ministry of Education's sectorial plan "Quality education, the road to prosperity" 2010-2014. Retrieved from https://www.mineducacion.gov.co/1621/articles-299245_recurso_1.pdf

and, subsequently, with royalties from 15%, in addition to the percentage currently allocated to STI activities, as proposed by the Mission to ensure the reconversion of the economy toward a base of accumulation centered on human capital and knowledge. The creation of ISIE will help to enhance the prestige of the teaching profession by guaranteeing its linkage to schools of education, annexed and normal institutes, among others; and by ensuring that pedagogy is recognized as an area of knowledge in constant evolution in which different disciplines converge, since those who engage in this field must participate in advanced processes of knowledge creation and implementation.

Consolidation of the training colleges

There are currently 137 teacher training colleges (Escuelas Normales Superiores - ENS) in the country. As part of the education program proposed by this Mission, the existing network of teacher training colleges (ENS) will be strengthened in the areas of personal teacher and leadership training, research, and broader and more advanced content. Since their creation, the ENS have stood out for their training of teachers with a vocation; however, this Mission maintains that it is necessary to add a research component to this training, and to ensure its adaptation to changing global, national, and regional needs. The creation of new knowledge and, above all, pedagogical knowledge is a key tool for achieving the goals for this Mission and SDG No. 4, universal access to quality education.

Various MEN documents indicate an insufficient capacity to design pertinent curricular proposals that would allow teachers and candidates to correctly approach the transformations of social realities of a very specific nature, such as that of the displaced population and the urban fringe. Also of concern is the fracture revealed in the process of scientific research, due to the ENS being isolated from the academic universe. The MEN indicates that this fracture in research is mainly due to the lack of knowledge of the internal and external context of each ENS in the formulation of problems, the collection of information, and the implementation of methodological proposals.

This mission proposes to fill these gaps. ENS need to have an articulating national institution that coordinates, monitors and guarantees minimum standards in teacher training, within the autonomy offered by the PEIs, in order to not only close the gaps between rural and urban areas, but also to encourage the formation of critical and inquisitive thinking in teachers' knowledge. In the same way, and based on what was described in the previous paragraph, this mission intends to respond to the need for a research program by creating research centers focusing on the local contexts of each teacher training college. The Mission also proposes to create new ENS in vulnerable areas, whose most important objective will be train teachers to address the problems of the environment.

Subregional networks of education innovation centers

This strategy proposes the establishment of networks of "education innovation centers," understood as spaces to share learning, pursue pedagogical and contextual research, and link teachers with the local culture and communities. The education innovation centers will operate in close connection with cultural centers will seek to bring together of education and local production. The networks of education innovation centers will receive the support of regional universities, cultural centers and ISIE, which this Mission invites to participate in this strategy. This will allow for the development of locally relevant research and the circulation of valuable teaching materials and methodologies. These networks will provide training in socioemotional and citizenship skills, and peacebuilding using the same mechanisms and resources that ISIE will make available, plus those that teachers find relevant.

Socioemotional skills, citizenship skills, and historical memory

Decades of multiple forms of violence have left deep scars on Colombian society. Mental health problems in the population, especially among young people, have increased substantially: children and young people are suffering from increasing rates of anxiety, depression, and suicide is on the rise. The country also faces profound challenges in educating committed citizens who cooperate with each other, comply with the law, and demand respect for democracy. Some of these challenges are greater in areas affected by the armed conflict, not only because of the violence they have suffered but also because they live under the armed tule of criminal groups.

Considering the benefit and value of socioemotional and citizenship skills, their enhancement should be a priority. Despite the progress made in terms of citizenship skills, we need to implement and scale up programs that have been shown to have an impact in this area, as well as those that successfully promote socioemotional skills and general wellbeing. It is fundamental that these programs incorporate components of education in historical memory that integrate and build upon these skills. The programs that achieve the expected goals will be extended to other territories with similar characteristics. Operating through calls for proposals, a system of incentives will be promoted to encourage diverse actors to join forces in the implementation of comprehensive programs with local support and participation. These programs will be geared towards: (1) training teachers as part of their pedagogical training, (2) training of in-service teachers, and (3) training of students and parents.

Taking as a reference the lessons learned from outstanding programs in Colombia and the world, below are some of the characteristics that these programs should incorporate. In the case of socioemotional skills for wellbeing, the research highlights the following: (1) the success of incorporating contemplative practices such as yoga or mindfulness into the classroom, which have been successfully tested in several countries, (2) the added effect of involving the entire educational community, including principals and family, and encompassing all areas of school life, (3) the need for the teacher, not an outside instructor, to be in charge of delivering the program to his or her students, and (4) the need to adapt interventions to specific local contexts.

Finally, for the work on historical memory, several studies and evaluations have identified that we must: (1) develop a classroom environment that introduces student-centered participatory practices such as discussion and debate, (2) train teachers to approach history with questions rather than answers and to manage the emotional processes that arise in lessons, (3) to transcend the classroom to connect with the community by engaging parents and other social actors, and (4) to include stakeholder narratives that visualize the moral agency of individuals and avoid the moral misunderstanding that accompanies violent conflict.

Education in context and the development of creative and artistic skills

Education, in Colombia, requires an educational system in context and in response to the challenges that the world is currently facing, understanding fundamental problems such as climate change, the need to become aware of the importance of cultural and natural heritage, the rapid transformation of ecosystems and living environments, the importance of scientific and artistic knowledge and thought, the fundamental need to understand and comprehend the value and meaning of life in all its manifestations, the enormous speed of transformation in the areas of knowledge, the ever-increasing access to information and diverse sources of knowledge, the vertiginous development of new technologies, the historical and constructive relevance of ancestral knowledge, the enormous challenge of approaching and understanding an increasingly diverse multiculturality, the need to better understand ourselves in an environment associated and articulated with an incredible biodiversity.

Cosmology is heading in an articulated direction, towards the general integration of the conceptual bases of all areas of knowledge, in the promotion and development of a holistic, universal global thinking, dynamized and put into practice through games, social dynamics, and participatory mechanisms, among others. It also raises the importance of knowing and understanding the origin of things, our cultural, biological and personal history, the inclusion of various languages, such as those observed in art and science (music, programming, mathematics) and their origin and transformation in the various stages of our lives. Developing an educational model that contextualized is the purpose of the Cosmology project, initially proposed by Rodolfo Llinás in the 1994 Science, Education and Development Mission.

Artistic and cultural education is fundamental for the development of sensitivity and communication skills, openness to what is different, the cultivation of curiosity and the development of a sense of belonging, especially if it is based on local cultural content. Beyond forming outstanding talent, education in art and culture for the entire population is necessary if we are to educate a citizenry capable of appreciating, caring for, and taking advantage of the richness of the country's cultural and natural diversity. Understood as a form of knowledge production that develops basic skills not present in other learning, artistic practice at different levels of education should be nuclear and fundamental, rather than complementary or accessory. Aesthetic education should not be separated from other subjects. On the contrary, all basic education should be guided by an aesthetic perspective, without prejudice to the existence of specific spaces for the development of artistic expression itself. Finally, the inclusion of artistic and cultural education as a fundamental form of knowledge in the country's educational system, should encourage practices that favor collective creation, the consolidation of task forces and the interrelatedness of the different areas of knowledge.

The following goals are proposed:

- By 2025, the production of didactic materials should be multiplied by ten to make up for their absence in many parts of the country, given the problems concerning access to training, information, and technological support.
- By 2022, there will be a specific program to train teachers in artistic and cultural methodologies to be implemented through the ISIE, the training colleges, and the offer of continuing education at different universities.
- By 2020, the Ministry of Education must produce guidelines to achieve curricular, pedagogical and evaluative transformations in early childhood, basic, and middle education from an aesthetic approach; that is, one that develops perception, sensitivity and receptivity (stasis).
- By 2021, a national system of networks should be implemented that links teachers from different parts of the country, and promotes

the exchange of knowledge, the creation of new methodologies, and the development of pedagogical strategies.

Integration of research skills in education

Critical thinking skills must be developed by adapting curricula and teacher training (in the initial and continuous improvement stages) so that teaching is based more on questions than it is on predetermined answers.

To achieve this goal, we must increase experimentation in class, in the style of programs such as "little scientists" (*pequeños científicos*) or "get stuck in" (*la main à la pâte*) or via data and case analysis. The methodology must be adapted to the different levels. The intention is not to train all students to be scientists, but it is to train all students to be able to approach problems by analyzing them critically. It will also be essential to revise and update study texts to ensure that the focus is not on information but on research.

Our proposal is to build a program that encourages those studying at schools of education, natural sciences, and social sciences (with grants and contracts) to conduct graduate work that provides the necessary materials to accompany these training processes based on research. A program will be developed in collaboration with MinTIC to bring connectivity to dispersed rural communities and schools, and to provide them with access to new tools built to support these new pedagogical and didactic methods.

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Conclusions

The Mission of Experts 2019 was convened by President Ivan Duque following a conversation with the Colombian Academy of Exact, Physical and Natural Sciences shortly after his election as President. He assigned the task of its organization to Vice President Marta Lucía Ramírez, thereby signaling the very high level of priority he afforded it.

A group of Colombian and foreign experts joined the Mission, organizing their work into eight thematic pillars as follows: Biotechnology, Bioeconomy and Environment; Basic and Space Sciences; Social Sciences and Human Development with Equity; Life and Health Sciences; Sustainable Energy; Creative and Cultural Industries; Oceans and Hydrobiological Resources and Convergent Technologies (nano, info and cogno) and Industry 4.0. This highly inclusive composition recognizes the role of fundamental research, which in some areas they call "curiosity-based" and which is at the base of practically all modern developments. It also recognizes the social research that is so important for a society that lives in conflict and with great inequalities. It expresses its concern for the territory, the seas and biological diversity, and integrates all of this with important considerations of modern industrial development, alternative energies and biological technologies leading to a revitalizing bio-economy. It prioritizes its own cultural heritage and understands its importance for people's wellbeing and its sui generis potential for development. The Sustainable Development Goals, to which the country has committed itself along with 192 other nations of the world, are present in all concerns and all proposals.

The Mission's composition and structure ensured that the most important challenges facing the country with its high cultural heterogeneity would be considered in its effort to make science, education and culture the fundamental axes of the country's future development, as well as to allow it to integrate into the highly competitive global knowledge society. But, in addition to all that, it is a composition that represents a varied and heterogeneous scientific community and a system (not yet formally constituted) that is open and whose actors are researchers, groups, universities, centers, institutes, government agencies, companies, children and schools, and any other organization that includes scientific research among its objectives, along with the promotion of such research, its use and its dissemination.

The Colombian scientific community, although not extraordinarily large, is important and has been consolidated over the past three decades. There have been two science and technology laws, *Colciencias* has changed its position within the structure of the State, and increased in importance, to the point where it is now a ministry. Several universities have taken on research as a central mission, there are institutes and centers whose main role is scientific research, and there are numerous examples of scientific successes and joint ventures between the actors in the system. This community participated in the Mission's deliberations through surveys and multiple forums and in regional and national centers. Other civil society actors also participated in the consultations. Their problems and visions of the future were mostly reflected in the Mission's proposals to the government and society.

These proposals made by the Mission are essentially a roadmap that will help the country to make a qualitative leap in its human, economic, social, and cultural development strategy. A strategy that places education, science, technology, innovation and creation as the mainstays of wellbeing for all of society, not for particular groups or sectors, and that commits various sectors to a joint effort. The roadmap contains three different types of proposals, all three equally important and relevant. One is to give impetus to much of the research through flagship missions (as defined by economist Mariana Mazzucato). The mission-oriented research approach adopted by many countries around the world, has been inspired by the great American project that decided to put a man on the moon in, what seemed at the time, an unrealistically short period. It is the approach behind the creation of the internet and the revolutionary developments in areas such as biotechnology, nanotechnology, and green energy technology. The mission-based strategy focuses on specific societal challenges that can be solved with interaction across multiple disciplines and sectors. These missions involve mathematics and the basic and natural sciences that solve fundamental impediments, the social sciences that make it possible to incorporate results into people's lives, engineering, design, business, and finance. The mission-based approach recruits public and private resources in the most efficient way possible, and has made it possible to build institutions that learn and manage uncertainty and risk, and to develop mechanisms in which the public and private sectors share risks and rewards fairly.

The Mission's proposal is intended to concentrate additional efforts on the purposes described above, but in no way does it replace the permanent and necessary quality endeavors in terms of the basic and applied sciences, nor those pertaining to the social sciences, humanities and the arts. These should be continuously promoted. The budgets for the Missions will be additional to those destined to the system's normal activities and initiatives. Each Mission involves several of the pillars, all of which are included in several of them. It was jointly decided that these Missions are aimed at solving three challenges: Productive and Sustainable Colombia, Biodiverse Colombia, and Equitable Colombia. Five Missions are defined in the framework of these three challenges: to generate a new productive and sustainable model, to gain in-depth knowledge of and promote the use of mega-biodiversity (terrestrial, marine and cultural) to address climate change and water management, and to improve education at all levels by including science, and to increase equity by producing knowledge that eliminates barriers to human development.

Another type of proposal is that of some policies that could have an important impact on the development of science and culture in the country. Among these, it is worth mentioning:

a) Policies to support and develop research centers and institutes. Based on an analysis of the existing situation and the problems faced by the various institutional modalities, a number of strategies are proposed to enable them to function properly. Some proposals are aimed at creating new regional centers that will act as an interface between research and business, and there is a proposal to promote productive integration between various public science and technology institutes.
b) Additional policies for education. In addition to the Mission, which is limited to priority and measurable actions, other strategies of a more general nature are proposed that will likely have a very positive impact on the education sector at all levels and in the long term, training the population for the labor market but also to satisfy their scientific curiosity, artistic creation, social cooperation, non-violent interaction, the exercise of democracy and for the wider exercise of freedom to choose a path in life.
c) Science governance policies. The Mission proposes policies that allow a more efficient administration of science. It made recommendations concerning the structure of the Ministry of Science, Technology and Innovation (STI) and the STI system. It analyzed existing regulations (including the current ones for the general royalty system) and recommended considering others that are more streamlined and appropriate specifically for research activity. It also proposed one to promote the internationalization of science and adequate mobility to communicate with the major centers of technological development in the world.

Finally, and as a factor of utmost importance, a very careful review of the financing system for all this activity is proposed. In order to achieve greater private sector participation, it will also be necessary to substantially increase State investment. The Mission offers a number of models that may help the government to identify additional sources of funding and to optimize combinations of these sources according to the nature of each project. An adequate solution to the chronic problem of underfunding, in addition to providing a major boost to scientific activity, will solve the issue of poor transfer of results from the laboratory to industry.

This roadmap should conclude with an urgent and loud appeal to the government; universities; the various science, technology and research institutions; entrepreneurs; and society in general. The capacity for economic growth and for solving social problems depends, to a large extent, on our actions today. There is a great gap between our country and the most developed countries, and we will only reach the levels of wellbeing they enjoy, if we manage to close that gap. Postponing solutions, as has happened in the past, will drive us away from this goal, perhaps irreversibly. The call is for urgency and coordination. Using a common figure of speech, the call is for all of us to row vigorously in the same direction.


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Appendix: Main proposals of the International Mission of Experts

1. The 46 members of the Mission of Experts propose three great challenges to be addressed by Colombian society and its national and territorial governments over the course of the next ten years: (i) to take advantage of our water resources, biodiversity and cultural diversity to confront climate change, and to develop the bioeconomy and the creative economy; (ii) to modify the country's production structure towards industries and services with high technological content, taking advantage of convergent technologies and Industry 4.0, and to develop technologies for the use of non-conventional energy sources; and (iii) to convert knowledge, social innovation and education, especially in early childhood, into instruments to lay the foundations for an equitable Colombia.
2. To achieve these goals, it is essential to establish an agreement for knowledge and education between society, the national government, territorial governments, entrepreneurs and civil society organizations, which will allow development to be oriented towards a model in which the basis of growth is human capital, scientific research, innovation and its application to the human development of the population and all production sectors.
3. The Mission proposes that Colombian society and the Government adopt the goal that by 2045 all young people who, by the time they turn 18, will have received education with comprehensive care from 0 to 5 years, and will have had access to at least a diversified secondary education or a dual high school diploma (traditional + technical).

4. This implies having achieved universal education with comprehensive care for children from 0 to 5 years old by 2026, and having universal secondary education: either the diversified curriculum or the dual high school diploma (traditional + technical) by 2030.
5. The Mission proposes that the country's teacher training system be restructured by improving teacher training colleges and putting the Higher Institute for Research in Education and Advanced Teacher Training (ISIE) at the head of the system. This institute will guide a major national program of research in education and train, through research, the "teachers of teachers" throughout the system.
6. It calls on universities to open high-quality education programs.
7. It recommends setting up a set of regional and sub-regional networks of centers of innovation in education, which will be spaces for teachers to meet and learn from each other, where, through research, cultural activities and interaction with the community, the quality of teaching work will be improved.
8. The Mission proposes a redesign of technical education, from high school to technological careers, linking it to innovation, opening channels for technicians to improve and retrain, and ensuring that it is based on solid science.
9. The Mission calls on all public and private educational institutions in the country to incorporate study and training in the arts, the environment, climate change, citizenship skills, social-emotional skills and coexistence in their institutional educational projects (PEI), supporting people's human development and enhancing their contribution to society. Artistic education must be implemented as a fundamental area in the curricular guidelines and established in the IEP, from early childhood and through all levels and modes of basic and secondary education.
10. Education at all levels must connect multiple actors, contexts and territories to support lifelong learning. Educational institutions must take on society's goal of preparing people for change and

the fact that their productive activities may be reconfigured, to the extent that they may become obsolete.

11. The government and educational institutions must remold the role of the teacher to make them a role model, a manifestation of the 21st century learner, showing flexibility and openness in the face of new attitudes, knowledge and practices, without dispensing with the rigor inherent in scientific and educational activity.
12. A strong system of incentives must be put in place to address regional disparities in education, while promoting remedial programs that prevent school abandonment and allow less advantaged students to catch up.
13. The Mission recommends that accredited universities offer the option of a double degree in the core subject and in journalism to students of basic and social sciences as a way to contribute to the qualified dissemination of science. They should also offer, with the support of the State, lifelong education programs for journalists in mathematics, natural sciences, environment and statistics.
14. In a context marked by a long history of violence, pilot projects should be carried out to experiment with different ways of developing socio-cognitive skills, improving the appreciation of cultural diversity, and promoting interaction and dialogue between diverse peoples and cultures.
15. It is necessary to ensure that education for work and the training of technicians and technologists follows on from previous training founded on a sound scientific basis and preparation in basic skills, guaranteeing them versatility and the ability to reinvent themselves when technological progress makes their occupations obsolete.
16. The Ministry of Education must produce guidelines to achieve pedagogical transformations in early, basic and middle childhood from an aesthetic approach, developing students' perception, sensitivity and receptivity, giving priority to the dialogue between different knowledge systems from both the regions and the center.
17. In education, methodologies must be implemented that appeal to and develop the plasticity of the brain, especially in early childhood,

privileging creativity at all levels as a way of solving problems or addressing challenges, without unique and pre-established answers, and giving priority to innovative solutions as a fundamental part of the training processes.

18. The educational model must be reformed, moving from a model based on teaching to one based on contextualized learning, which teaches people to think, encourages constructive criticism, aims to address challenges using innovation and creativity, and enables different solutions depending on the context.
19. Education that creates an emotional bond must be implemented from the initial stages. It must encourage a love and passion for knowledge, culture, science, and art; reinforce trust, dialogue, amazement, and discovery as tools and methodologies for the exploration, creation, and construction of knowledge; recognize and value diversity, ancestral knowledge, personal knowledge, cultural heritage, and the biological and cultural resources of the regions; and it must allow for interaction with the national construction, validation, and development of forms of knowledge.
20. Taking into account the role that universities have played in the development of STI in the last fifty years in Colombia and their research potential, it is proposed that the State generate funding models for science, creation, humanities and technology that make their efforts sustainable in the long term.
21. Colombia has the opportunity to reduce social inequality, multidimensional poverty and exclusion, based on scientific knowledge and social innovation.
22. The main ways in which knowledge and its recommendations can contribute to reducing inequality and exclusion are by universalizing early childhood education with comprehensive care; conducting research in health and nutrition to address the diseases that prevail in the territories; increasing digital coverage; using new technologies for equitable access to drinking water; developing national heritage and the recognition of local cultures; and promoting economic circuits within the communities.

23. The country has a gap in its institutional framework for the initial stages of knowledge transfer, which is necessary for product and process innovation. In order to fill this gap, it is proposed that the State create on demand regional technical and technological research centers or institutes.
24. The Mission proposes differentiated strategies for the promotion and strengthening of autonomous research institutes, technological development centers, science centers, national institutes, Cenis, Centers of Excellence and on demand regional research centers. The policy of no or minimal "overheads" for the projects financed by the Nation should be revised, as this policy currently creates financial difficulties in the operation of the institutions that host these projects.
25. The Mission proposes an expansion of the capacity of the National System of Science, Technology and Innovation to address problems that are currently neglected and to open occupational niches for human resources that have been prepared at the highest level.
26. It is necessary to advance a national program to renovate and share robust equipment for universities, centers and research institutes.
27. It is necessary to develop a national policy of open data that favors the democratization of knowledge, transparency, and citizen and regional empowerment for science to become more dynamic and within everyone's reach.
28. It is essential to consolidate a science diplomacy program that connects with the Colombian diaspora and promotes national and international mobility programs for scientists and scientists in training.
29. It would be beneficial to develop a broad program of support for processes of patenting and intellectual property.
30. The Mission proposes to organize the bulk of its research into challenges and missions, which call for multidisciplinarity and complementarity between different actors and communities. In addition to these missions, research based on curiosity will be

promoted (which should always be the case) as an essential strategy to open up new alternatives and opportunities for the country.

31. Colombia will enhance its water wealth by developing knowledge to ensure its quantity, quality and variability in medium and extreme conditions, as well as to guarantee universal access to drinking water, optimal management of the resource and protection of society from climate change and other extreme events.
32. The social appropriation of the knowledge of the country's inland, estuarine and marine water resources will allow less favored regions and communities to develop.
33. Knowledge and science are part of a nation's cultural heritage. Ensuring that science and knowledge are exchanged and transferred among the entire population is necessary in a society that aspires to award knowledge a prominent role.
34. In Colombia the infrastructure for the social appropriation for science is scarce. The Mission considers that children have the right to interact with science. To bring the arts and sciences closer together, science centers for children and young people will be promoted (planetariums, natural history museums, botanical gardens, interactive centers, science fairs and events).
35. The Mission proposes that a distributed network of museums and other interactive spaces be progressively established with the support of specialists, based on different themes and approaches that awaken scientific and developmental vocation. The project is complemented by digital means to ensure access to these resources by children and adults, regardless of where they are located. This network should cover all departmental capitals and will be financed by national or territorial governments, by the private sector or by public-private partnerships.
36. To enhance the bioeconomy, as well as to overcome the current climate crisis and achieve the Sustainable Development Goals, it is necessary to adopt a development paradigm that integrates the social, economic and environmental.

37. The fundamental pillars of environmental management, the development of the bioeconomy and the conservation of biodiversity are scientific knowledge and consideration of geographical and cultural contexts.
38. Biotechnology is the tool for discovering, learning about and developing an extraordinary range of processes, bioproducts, bioenergy and new agriculture that guarantees nutritional security, health and the environment.
39. Climate change and the destruction and degradation of ecosystems are the main cause of biodiversity loss, as well as presenting a threat to development and quality of life. Under these circumstances it is necessary to promote science, technology and innovation.
40. The Mission proposes that the Colombian Space Agency be created and attached to the STI Ministry, in order to restart space projects for the placement of satellites and ground stations.
41. It is essential to strengthen basic science programs working on different technological solutions for energy transformation and environmental conservation.
42. The Mission proposes that the Energy Research Center promote the creation of instrumentation industries, the control of biorefineries and support the development of intelligent cities (energy efficiency, buildings, electric transport).
43. The Mission recommends the installation of high-speed connectivity throughout the national territory. In this way, the digital transformation of the State will be enhanced beyond the goals of the current National Development Plan (PND), improving the instruments of territorial management, environmental monitoring systems, disaster prevention and urban mobility. New technologies such as big data, IoT, blockchain and artificial intelligence will be basic tools for transformation.
44. It is important that the State offer credits and incentives to integrate small and medium enterprises (SMEs) into the dynamics of the fourth industrial revolution.

45. Tax incentives for investment in STIs should be restructured to avoid displacement of funds (crowding out). Thus, large companies will receive these incentives for their investments in basic research and contributions made to research centers and institutes or to projects developed by universities or SMEs. SMEs will have access to special lines of credit with shared risk and incentives in the form of tax credits. The State will promote and partner with venture capital funds, managed under the delegation model by experienced private banks. Calls for proposals will be launched for large companies to serve in projects as an anchor for SMEs.
46. Scientific and technological research is, by definition, highly uncertain and involves risks; it is an exploration into the unknown. The Mission prioritizes the existence of risk investment funds, which should be complemented with regulations that understand that it is possible to obtain unforeseen results, that could even contradict the initial expectations of the projects.
47. The Mission proposes the implementation of "Creative Incubators," a flagship initiative consisting of a four-fold relationship model (company, university, state and society) for the Creative and Cultural Industries, which integrates the characteristics of creative laboratories, business incubators and centers whose program is open to the public.
48. It is critical to improve the health and wellbeing of populations by addressing the determinants of health and wellbeing in an articulated manner based on science and advances in technology.
49. The Mission proposes to bolster the scientific ecosystem through the integration of the human and technological capabilities of the Public Institutes of Science, Technology and Innovation, contributing to fulfillment of the sustainable development goals.
50. It recommends the creation of translational research nodes in health centers and universities in the 32 departments of the country, leading to the creation and application of knowledge to the particular contexts of each region.

51. It is important to establish centers of excellence or programs run by universities and research centers/institutes that conduct research and develop health technologies, essential in the prevention and treatment of diseases deemed neglected, emerging and priority by the Ministry of Health.
52. It is necessary to promote research on regional resources and heritage in order to contribute to the design of sustainable alternatives in the regions based on an understanding of the world views, learning styles and lifestyles of a region's population.
53. The STI Ministry will lead a joint effort that links all state entities that promote the country's knowledge production, and will maintain an especially close relationship of cooperation and harmonization of policies with the Ministries of Culture, Education and ICT. The creation of a national program of experimentation is proposed, to be designed and coordinated by the STI Ministry that connects the Missions and different projects around social and environmental transformations for sustainable human development.
54. The STI Ministry will further the integration of research + creation into activities of research, development, innovation, promotion, dissemination and social appropriation of knowledge.
55. The National System of Science, Technology and Innovation shall be autonomous in all its actions and shall seek to articulate or associate with other research systems and other entities with which it has common interests.
56. The State shall promote and support the efforts of companies and organizations that contribute to education and science programs to ensure that their impact gains visibility.
57. The initial efforts of the STI Ministry will focus on developing mechanisms for dialogue and long-term agreements between the State, entrepreneurs, researchers and the regions; on designing the rules of governance and incentives for the actors convened by the missions and managers of the centers and institutes; and on increasing funding for research and development activities.

58. An agency for the management of combined finances (integrating heterogeneous sources of funding), attached to the STI Ministry, will be created to provide resources to the National Science and Technology System.
59. Regulations will be developed to facilitate quadruple helix alliances to support the five missions proposed by the Mission.
60. The requirements for importing laboratory materials and equipment and controlled inputs will be reviewed and streamlined; the issuance of registrations and technical standards for new products, procedures, services and technological equipment will be reformed and facilitated.
61. Permitting multi-year execution periods in public institutions for this type of activity is recommended.
62. Regulations will be defined for the presentation of scientific projects that take into account the specificities of these projects, which are very different from other state contracts. Likewise, the monitoring and evaluation of these projects should be carried out in accordance with the flexibility required by scientific research processes.
63. It is essential to contract a USD 300 million loan for R&D with multilateral banks and raise the percentage of royalties destined for STI and education with comprehensive early childhood care to 25% (from the current 10%) (which requires constitutional reform).
64. State leadership and a major funding effort with public resources are needed to achieve the transformations that are being projected. The path of investment in research and development (R&D), the index used internationally in the analysis of the relationship between STI and productivity, must visualize two phases: in Phase 1 ‘patient public capital’, the State undertakes the majority of effort, and in Phase 2 ‘private R&D take-off’ private investment will start to take over some of the responsibility.
65. By the end of Phase 1 in 2028, total R&D investment could reach 1.20% of GDP (where public investment should be 0.80 % and

private investment 0.40 %); by the end of Phase 2, total R&D investment should be 1.80 % of GDP (where public investment should be 0.85 % and private investment 0.95 %). To start this trend, in 2022 public investment in R&D should reach 0.37% and private investment 0.26% of GDP.

ACKNOWLEDGEMENTS

Many people and organizations have supported the work of the Mission and it is impossible to mention them all. However, the members of the eight thematic pillars of the Mission of Experts 2019, their support teams and their rapporteurs wish to express our special thanks to the following individuals and the organizations to which they are linked, for their generous support in the fulfillment of our Mission.

General Acknowledgements

Marta Lucía Ramírez, Vice-President of the Republic; María Victoria Angulo, Minister of National Education; Cristina Garmendia and the Science & Innovation Link Office (SILO) team; Diego Hernández, Director of Colciencias; Sonia Monroy, Sub-Director of Colciencias; Adriana Paola Serrano; Program Directors and Advisors of Colciencias; Humberto Rosanía and Freddy Castro, the Office of the Vice-Presidency of the Republic.

Universidad del Rosario, Universidad de los Andes, Universidad Nacional de Colombia, Pontificia Universidad Javeriana, Universidad Industrial de Santander, Universidad del Norte, Universidad Jorge Tadeo Lozano, Universidad del Valle, Universidad de Antioquia, Universidad EAFIT.

Tiziana Laudato, Ernesto Ardila (translators), Tim Osswald, Alec Redmann, Camila Montoya Ospina, Grace Acosta (proofreaders).

Acknowledgements for the Bioeconomy, Biotechnology and the Environment (BBMA) Pillar

Fernando Gaviria (Rector of Universidad Tecnológica de Pereira) and Martha Marulanda (Vice-Rector of Universidad Tecnológica de Pereira); Luz Marina Mantilla (Director of the SINCHI Institute) and María Soledad Hernández (Sustainability and intervention SINCHI Institute); Jorge Mario Díaz (Director of Agrosavia) and Juan Diego Palacios (Director of the Agrosavia's Tibaitatá Center); Ivan Montenegro; Pablo Navas (Former Rector of Universidad de los Andes), Alejandro Gaviria (Rector of Universidad de los Andes), Carlos Montenegro and Mirtza Arroyo (Universidad de los Andes); Clara Leticia Serrano (Asorinoquía); Wilmar Camilo Fonseca González, Laura Vanesa Rodríguez Arcila, Catalina María Bernal Murcia, Laura Bibiana Zuluaga Pineda, Lina María Rubiano Arias, Edgar Francisco Otálora Bohórquez (Research incubator at Universidad de los Andes); Arturo Luna (Manager of the Biotechnology Program of Colciencias, Manager of Colombia-Bio); Luis Miguel Renjifo (Vice-Rector of Research, Pontificia Universidad Javeriana).

Acknowledgements for the Basic and Space Sciences (BSS) Pillar

Enrique Forero, Colombian Academy of Exact, Physical and Natural Sciences (ACCEFYN) and participants of the permanent forum in support of the Mission; Dolly Montoya, Rector of Universidad Nacional de Colombia; Obdulio Velásquez, Rector of Universidad La Sabana and participants of the Industry-University forum; Fanor Mondragón, ACCEFYN; Camilo Yunes, Vice-Rector, Manizales Campus, Universidad Nacional de Colombia; professors and student volunteers who contributed to the organization of the Forum on Basic and Space Sciences. All the participants of our forums and meetings, who responded to our surveys, and the members of departmental and local governments who spoke with the focus commissioners.

Acknowledgements for the Social Sciences and Human Development with Equity (CSDHE) Pillar

Universidad del Rosario and School of Human Sciences (Universidad del Rosario); Universidad de los Andes; Alejandro Acosta (CINDE); José Luis Villaveces; Luis Enrique Orozco; Carlos Eduardo Vasco; Eduardo Aldana; Fernando Chaparro; Hernán Jaramillo Salazar; John Sudarsky; María Piedad Villaveces; Margarita Peña; Germán Puerta; Andrés Casas; Manuela León; Víctor Restrepo; Siembra Colombia; Alberto Echeverry; Natalia Duque; Catalina Martínez; Juliana Ordoñez; Diego Montoya; Luisa Fernanda Urrea; María Camila Díaz Granados; María Villaveces; Beethoven Herrera; Rubén Darío Utria; Enrique Forero; Fanor Mondragón; Imelda Restrepo and her advisory team (ANDI); Academic and Management Committees of the Ten Year National Education Plan; Jairo Giraldo (Buinaima); Ingrid Rueda; Yadira Casas; Liliana Castro (Colciencias); Marieta Quintero (Universidad Distrital); Oscar Saldarriaga (Universidad Javeriana); Jaime Saldarriaga (Universidad de Antioquia); Claudia García (Universidad Libre de Pereira); María Camila Ospina, Héctor Fabio Ospina, Julián Loaiza and Daniela León (CINDE's Center for the Study of Childhood and Youth and Universidad de Manizales); Andrés Mauricio Mendoza (Figures and Concepts); Jorge Iván González (Universidad Nacional); Jorge Iván Jurado, María Piedad Marín, Alejandro Barrera, Edisson Castro, Alejandro Cardona, Ana María Hincapié, Claudia Munévar, Eliana Gallego, Carlos Urrego and Mónica Arango (Universidad de Manizales); Gabriel Vélez (Universidad de Antioquía); professors and PhD students at CINDE's Center for the Study of Childhood and Youth and Universidad de Manizales; directors of the nationwide Doctorate in Education; professors of the Faculty of Economic Sciences at the Universidad Nacional (Bogotá campus); Enrique Chaux; Ana María Velázquez; Arturo Harker; Andrés Moya; Oscar Sánchez; María Emma Wills; Alexander Ruiz; Educapaz; Centro Nacional de Memoria Histórica; El Arte de Vivir; Dunna; Alternativas Creativas para la Paz; RESPIRA; Programa de Desarrollo y Paz del Magdalena Medio; Sathya Sai School, Bogotá; The International Center for Transitional Justice; children and parents who participated in the workshops on the science and the future in different parts of the country.

Acknowledgements for the Life and Health Sciences (CVS) Pillar

John Jairo Arboleda Céspedes, Rector Universidad de Antioquía; Sergio Cristancho Marulanda, Vice-Rector of Research, Universidad de Antioquía; Gloria Valencia Bustamante, Assistant to the Vice-Rector of Research, Universidad de Antioquía; Luis Fernando Múnera Díez, Director, Fundación Universidad de Antioquía; Carlos Alberto Palacio Acosta, Dean of Medicine, Universidad de Antioquía; Esteban David Ahumada; Luz Adriana Martínez, Universidad de Antioquía; Julio Aldana, Director, National Institute for Drug and Food Surveillance (Invima); Pahola Pulgarín and Judith Mestre, Invima; María Teresa Domínguez,

Ministry of Health and Social Protection; Claudia Tinjacá and Diana Milena Calderón, Colciencias; Raúl Murillo, Director of the Center of Oncology at the Javieriana;

Margarita Ronderos, Universidad Javieriana; Esther de Vries, Director of the Doctorate Program in Clinical Epidemiology at the Javeriana; Angela Ruiz, Professor and Director of the Clinical Research Group, Universidad del Rosario; Gloria Sanchez, Professor and Coordinator of the Infection and Cancer Group, Universidad de Antioquia; Lyda Osorio and Lena Barrera, Professors of Public Health, Universidad del Valle; Marion Piñeros and Armando Baena, Epidemiologists at the IARC, Lyon; Maciej Orkisz, Professor at Université de Lyon, coordinator with the Universidad de los Andes and Javeriana; Eduardo Dávila, CNRS engineer in computer science Creatis; José Luis Méndez; Association of Colombian Pharmaceutical Industries (Asinfar); Industrial Pharmacist Chamber of the National Association of Industrialists (ANDI); Elkin Echeverry; Yessica Gutiérrez; Jorge Areiza (Ruta N); Salim Mattar (Universidad de Córdoba); Carlos Corredor (Universidad Simón Bolívar); Hernando Baquero; Pedro Javier Villalba (Universidad del Norte); William Reyes; Susan Benavides Universidad de Santander (UDES); Gabriel Jaime Tobón (Universidad ICESI); Norma Serrano (Cardiovascular Foundation of Colombia); Luis Guillermo Restrepo Vélez (Universidad del Rosario); National Academy of Medicine of Colombia; National Institute of Health; National Institute of Cancerology; Institute of Health Technology Assessment; National Institute of Drug and Food Surveillance (Invima); Pan American Health Organization.

Acknowledgements for the Sustainable Energy (ES) Pillar

Hernán Porras (Rector of Universidad Industrial de Santander), Guillermo González (Vice-Rector of Research and Extension), Farid Chejne Janna, Karen Cepeda, Yovany Portilla, Rafael Chona, Angie Martínez, Gonzalo Ordóñez, Rodolfo Villamizar, César Duarte, Gabriel Ordóñez, José Rincón, Juan Oviedo, Javier Solano, Humberto Rodríguez, Iván Serna, Horacio Torres and attendees of the forums with businesspeople and researchers from Medellín and Bucaramanga.

Acknowledgements for the Creative and Cultural Industries (CCI) Pillar

Tania Delgado, María Camila Cabezas and Iván Franco (Colciencias); Germán Rey, Marisol Cano and Javier Rodríguez (Universidad Javeriana); Ana Piñeres (Asocinde); Héctor Bonilla (Acofartes); Javier Vallejo (Ministry of Education); David Solodkow (Universidad de los Andes); Diego Molano (Bogotá City Council); Felipe Buitrago, Sandy Guerrero, Cleopatra Marrugo and William Otero (Department of Economic and Social Affairs); Carolina Romero y Julián Riatiga (National Copyright Office); José Luis Niño y Jimena Peña (Universidad EAN); Juan Pablo Salcedo (Universidad El Bosque); Diana Cifuentes (Observatorio Economía Naranja); Carlos Mora y Francisco Carrillo (DANE); Luis Astaiza, Alberto Tamayo, Oscar Corzo y Felipe Arango (Universidad Central); Yesenia Valencia (Smartfilms); Alejandra Álvarez (Corporación Universitaria Taller 5); Mónica Suárez and Diego Téllez (Corporación Universitaria Taller 5); Manuel Sevilla and María Consuelo Villamil (Pontificia Universidad Javeriana, Cali); Germán Flórez (Intellectual Property Think Tank); Paula Botero (Instituto Tecnológico de Medellín); Roberto Amador (Universidad Nacional de Colombia); Santiago Niño Morales (Universidad Distrital Francisco José de Caldas); Estela Barreto (Universidad de Bellas Artes de Cartagena); Lucy Cifuentes (Universidad Autónoma de Bucaramanga); Banco de la República, San Andrés; Lina Rodríguez and Gisela Pérez (Festival de Cartagena - FICCI); Felipe César Londoño (Universidad de Caldas); Luis Carlos Reyes (Fiscal Observatory, Pontificia Universidad Javeriana); David Melo, Angie Pinzón, María Cristina Díaz, Ulia Yemail, Cristian Estrella, José Argote and Carlos Dueñas (Ministry of Culture); Felipe Barrientos, Ignacio Gaitán and Miguel Olarte (Innpulsa); Carlos Baena (Ministry of Labor); Adriana Padilla and Marcela Corredor (Bogotá Chamber of Commerce); Mario Suárez and Juana Andrade (Bogotá Culture Secretariat); Ana María Fries and Jimena Puyo Posada (Artesanías de Colombia); María Claudia Páez (Cartagena

Chamber of Commerce); Nicolás Carrizosa (District Secretariat for Economic Development); Fernando Vicario (Organization of Ibero-American States); Javier Machicado (Lado B Consultant); Julián Riatiga (National Copyright Office); Fabián Dangond (Government of Cesar); Giovanny Peña Betancur (Redecon); Antonio Cortés (Government of Cundinamarca); Diego García Reyes (Bogotá Design Festival); Juan Carlos Gaitán

(Prana); Cesar Sanchez and Betsy Gelves (Ten Year Education Plan Management Committee); Yesid Bernal (Ministry of Information Technology and Telecommunications); Lina Parra (Sala del Ocio y la Fantasía, SOFA; Carlos Reyes (IGDA); Dilia Robinson, Joseph Dan Bush Murillo, Elkin Robinson and Louis Gregory Robinson (Providence Island); Gloria Patricia Zapata (Ministry of Education); Cesar Augusto Zambrano (Universidad de Tolima); Raiza Deluque and Roberto Hinestroza (Youth Council); Lina Arbeláez (UNDP); Leticia Gennes (World Entrepreneurs); Juan Diego Ortiz (Asanfe); Villa de Leyva Mayor's Office, Instituto Técnico Central (ITC); Jorge Mario Bergoglio (IED); Uniandinos; Fundación Universitaria Juan N Corpas; Corporación Universitaria Minuto de Dios (Uniminuto); Universidad Pedagógica Nacional; Universidad Pontificia Bolivariana; Lasalle College Institute (LCI); Institución Universitaria Pascual Bravo; Universidad Externado de Colombia; Philharmonic Orchestra of Bogotá; Universidad del Rosario; Universidad Jorge Tadeo Lozano; Universidad Antonio Nariño (UAN); Universidad de Boyacá; Corporación Universitaria Unitec; Arcadia Sonora; Sopó Culture Sectretariat; Universidad de San Buenaventura; Corporación Lidérate; Corporación Escuela de Artes; Universidad Santo Tomás; Mola Hub Moda Sostenible; Tarpui; Professional Commision of Industrial Design; Lápiz de Acero Award; Ascun; Curupira SAS; Universidad Tecnológica de Pereira; Tuition Colombia; Directorate of Vocational Training SENA; Designall, Art Not SAS; Colpensiones; Connect Bogotá Región; Polifonía – Escuela Reúsate y Platzi.

Acknowledgements for the Oceans and Hydrobiological Resources (ORH) Pillar

Diego Torres, Cecilia María Vélez, Margarita Peña, Isaac Dyner, Ingrid Paola Barragán, Martha Cortés, Luz Estela Gómez, Luz Piedad Arrigui, María del Pilar Blandón, Paola Noreña, Carl Langebaek, Jorge Molina, Manu Forero Shelton, Tatiana Rey, Enrique Forero Marcela Macías, Captain (r) Francisco Arias, Jesús Antonio Garay, Sandra Rincón, Paula Cristina Sierra, David Alonso, Luz Marina Mantilla, Carlos Alberto Mendoza, Edwin Agudelo, Adriana Santos, Nestor Campos, Sven Zea, Arturo Acero, Ernesto Mancera, Claudia Vaca, Luisa

F. Owners, Vice-Admiral (r) José William Porras, Admiral Mauricio Soto, Admiral Edgar Romero, Captain (r) Ricardo Ariza, Captain (r) Carlos Alberto Andrade, Rear Admiral Francisco Hernando Cubides, Captain Alejandro Rueda, Lieutenant Commander Julio Monroy, Lieutenant Diana Sánchez, Captain Juan Camilo Forero, Mónica López, Carlos Alberto Ramírez, Juanita Goebertus, Iván Agudelo, Luis Fernando Barrios, Luis M. Manjarrés, Juan Mayorga, Juan Carlos Alonso, José Saulo Usma, Luz Stella Gómez Giraldo, Luis Fernando Gómez, Analinda Torres, Gina Ortiz, Hilayalith Rodríguez, Ana Carolina Barrera, Nicolás Bustamante.

Acknowledgements for the Convergent Technologies and Industries 4.0 (TCeI4.0) Pillar

Markus Eisenhauer, Fraunhofer Institute FIT (Germany); Juan Luis Mejía (Rector of Universidad EAFIT); Adolfo Meisel Roca (Rector of Universidad del Norte); Raimundo Abello Llanos (Universidad del Norte); Oscar Caicedo, Mauricio Arroyave Franco, José Alejandro Montoya, Olga Lucía Quintero, Nora Cadavid Giraldo and Diego Leal Fonseca (Universidad EAFIT); Andrea Álvarez (Universidad del Norte).

LIST OF ACRONYMS

Bioeconomy, Biotechnology and Environment (BBMA)
Centers for Teacher Innovation (MOVA)
Science, technology and innovation (STI)
Life and Health Sciences (CVS)
Social Sciences and Human Development with Equity (CSDHE)
National Council for Economic and Social Policy (Conpes)
National Copyright Office (DNDA)
Sustainable Energies (ES)
Creative and Cultural Industries (CCI)
Unique Scientific and Technical Infrastructure (ICTS)
Higher Education Institutions (IES)
Colombian Agricultural Institute (ICA)
Colombian Institute of Anthropology and History (ICANH)
National Institute of Health (INS)
Higher Institute for Research in Education and Advanced Teacher Training (ISIE)
Research + Creation (R+C)
Research and Development (R&D)
Adjusted General Methodology (MGA)
Ministry of Environment and Sustainable Development (MADS)
Integrated Territorial Action Model (MAITE)
Sustainable Development Goals (SDG)
Oceans and Hydrobiological Resources (ORH)
Organization for Cooperation and Economic Development (OECD)
Total Factor Productivity (TFP)
Gross Domestic Product (GDP)
National Accreditation Council (CNA)
Institutional Educational Projects (PEI)
Decentralized Energy Resources (RED)
National Academic Network of Advanced Technology (RENATA)
Autonomous Planning Regions (RAP)
National Environmental System (SINA)
National System of Science, Technology and Innovation (SNCTI)
National System of Information on Higher Education in Colombia (SNIES)

The *International Mission of Experts 2019* brings together the contributions on education, science, technology and innovation of a group of 46 scientists and experts convened by the President of the Republic. This first volume is the Mission's central document.

It starts by envisioning Colombia as it will look for the next generation, and proposes that the State and society commit themselves to five flagship Missions: creating equity using knowledge; universalizing education from 0 to 5 years; conserving water; developing the bio-economy; and opting for a creative and productive economy. These are the first steps for education and knowledge to progressively replace non-renewable natural resources as the basis for national development.

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