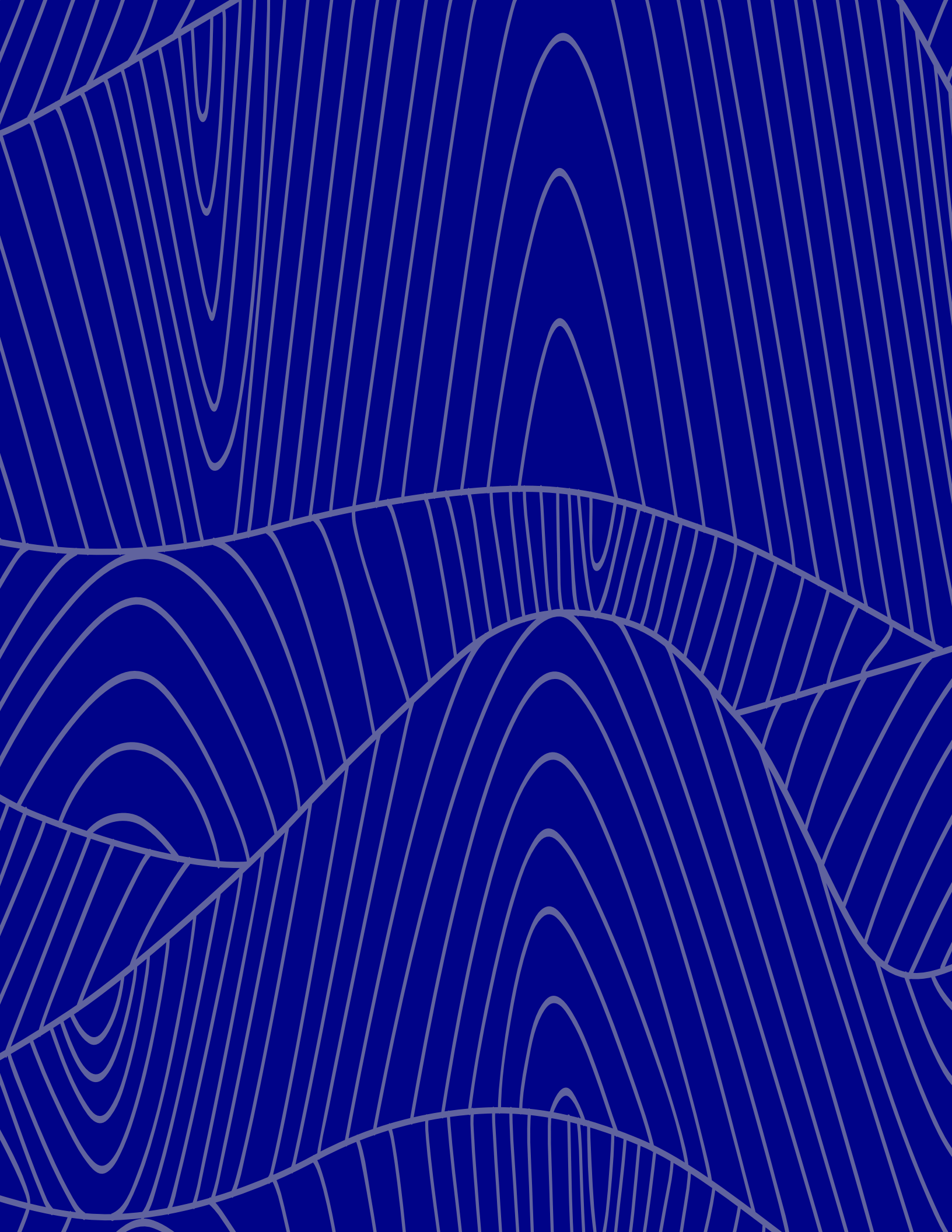

GREEN **BOOK 2030**

GREEN BOOK 2030

NATIONAL SCIENCE AND INNOVATION POLICY
FOR SUSTAINABLE DEVELOPMENT

Adopted through Resolution 0674 on 9 July 2018

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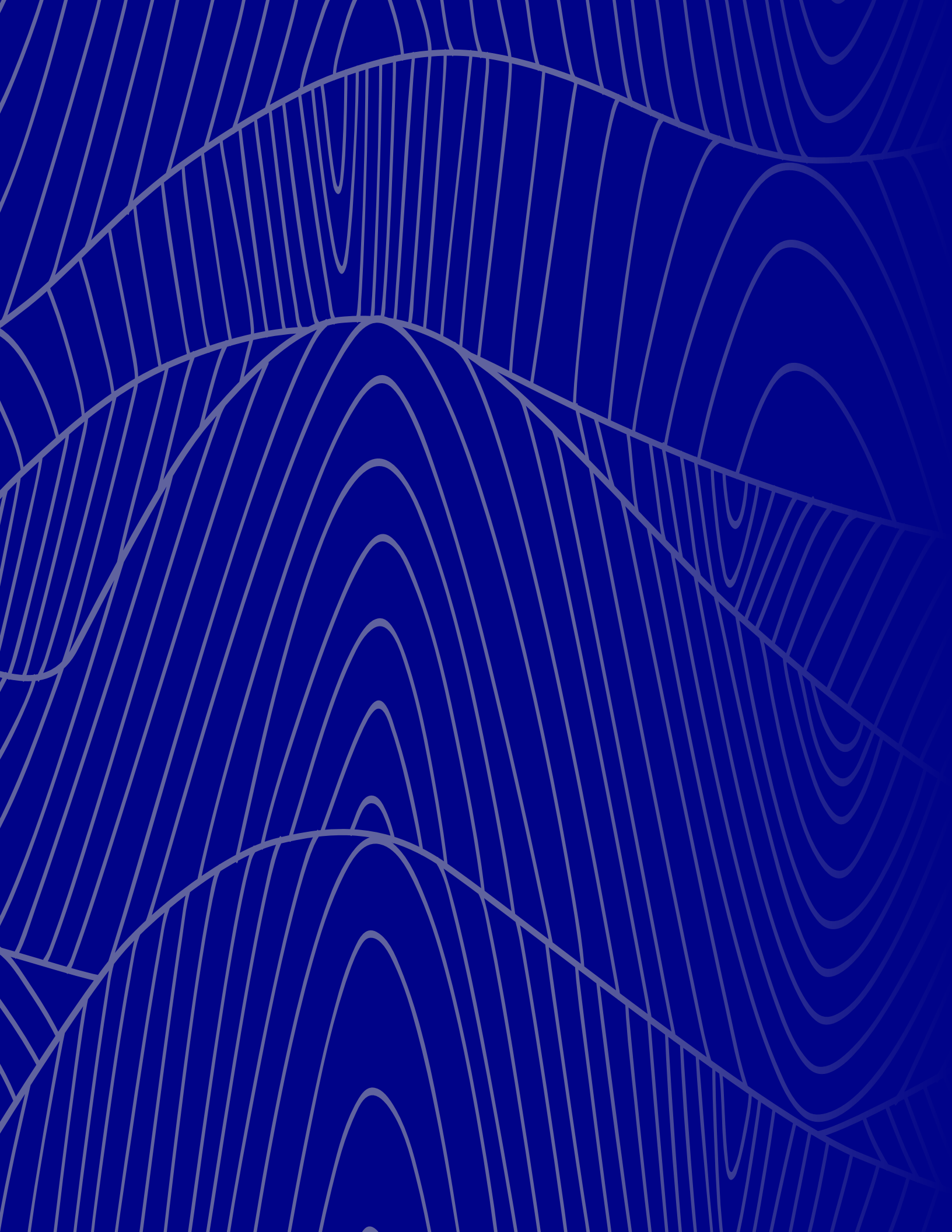

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Acronyms and abbreviations

CODECTI	Consejos Departamentales de Ciencia, Tecnología e Innovación (Departmental Science, Technology and Innovation Councils)
CONPES	Consejo Nacional de Política Económica y Social (National Council on Economic and Social Policy)
DNP	Departamento Nacional de Planeación (National Planning Department)
MDGs	Millennium Development Goals
OECD	Organisation for Economic Co-operation and Development
PAED	Planes y Acuerdos Estratégicos Departamentales en CTeI (Departmental Strategic Plans and Agreements in STI)
R&D	Research and development
RDI	Research, development and innovation
SDGs	Sustainable Development Goals
SNCTI	Sistema Nacional de Ciencia, Tecnología e Innovación (National System of Science, Technology and Innovation)
SPRU	Science Policy Research Unit
STI	Science, technology and innovation
STIA	Science, technology and innovation activities
TIPC	Transformative Innovation Policy Consortium
UN	United Nations Organisation

Presentation

The *Green Book 2030*, which Colciencias is presenting to the country, constitutes a first step in the renovation of national science and innovation policy – a step which grounded, in strategic terms, on defining conceptual foundations, principles and pathways for public action, as well as interactions among different actors in the National System of Science, Technology and Innovation (SNCTI).

This policy is being developed around what we have termed a "transformative focus", the central aim of which is to contribute to the solution of the major social, economic and environmental challenges our country is facing, as they are set forth in the Sustainable Development Goals (SDGs) of the United Nations 2010 Agenda[1] adopted by this county as a roadmap for sustainable development in the middle and long term.[2] To this end, our focus seeks to facilitate the transformation of current socio-technical systems to make them more sustainable.

Acquiring this transformative focus will require orienting scientific and innovative potential toward needed and desirable changes that contribute to solutions for these major challenges, as well as efforts to favor active links and dialog among different actors, disciplines and knowledge holders, in order to better understand the challenges and make progress toward their solution. In addition, the road to change and transformation necessitates exploring multiple working methods and alternative solutions; for this reason, transformative policy opens up a space for experimentation and learning as valid foundations for decision making based on an analysis and understanding not only of the results but also of the processes involved.

Considering that the search for solutions to the country's major social, economic and environmental problems goes beyond the scope of individual sectors and constitutes a challenge to be faced equally by the national government and regional and local administrations, as well as by the productive and academic sectors and civil society, adopting a transformative focus constitutes a possible pathway to interinstitutional, multilevel and multifactorial efforts aimed at making progress toward transformation.

1 Available at: http://unctad.org/meetings/es/SessionalDocuments/ares70dl_es.pdf

2 CONPES 3918 de 2018.

To implement the *Green Book 2030*, policies will advance along three fronts: i) promoting the adoption of a transformative focus within the SNCTI and other related systems, ii) guiding national science and innovation, and iii) supporting the adoption of a transformative focus to achieve the SDGs at the territorial level. The book will promote, in a cross-sectional manner, the incorporation of five fundamental principles or ideas to inspire action: directionality, participation, learning and experimentation, interdisciplinarity, and anticipation of outcomes and effects.

The *Green Book 2030* is the result of a process initiated nearly two years ago, when we created together with the Science Policy Research Unit (SPRU) and science and innovation agencies in Sweden, Norway, Finland and South Africa, the International Transformative Innovation Policy Consortium, in which we analyzed new possibilities to guide public science and innovation policy in a way that would better respond to major global and national challenges. This effort, involving the participation of nearly 1,500 persons, became the starting point for initiating, at the national and regional level, a series of conversations and reflections (interviews, panel discussions and workshops) on how to orient our science and innovation policy toward a transformative focus.

In addition we created a mentorship network with academics in eight departments, with whom we explored ideas on transformative policy and its contribution to our context. Moreover, we listened to the voices of nearly 500,000 citizens who expressed their most pressing concerns in relation to the proposed SDGs, as the setting in which transformations can be achieved. This exercise became the largest citizen consultation effort to date in the country with the aim of informing the design of public policy. A complementary effort consisted of a study of national scientific and technological capacities, which allowed us to identify the interests of national researchers in the last decade regarding the SDGs. On the basis of our interpretation and analysis of these inputs, a new national policy was developed, as set forth in this document.

Clearly, reinterpreting the meaning of science and innovation for development in our country, together with rethinking the tools, working methods and ways we relate with the different sectors and interest groups in the context of achieving major shared goals, are medium and long-term tasks that will require continuing reflection on how to consolidate the transformative focus this policy is centered upon. We are nonetheless convinced that the elements described and discussed herein show the way forward toward this aim. Accordingly, we invite all actors in the SNCTI to find their spaces and opportunities within this new focus.

Alejandro Olaya Dávila

General Director

1/

The transformative focus in science and innovation policy[3]

Twenty eight years ago Law 29 of 1990[4] emphasized the need to incorporate science and technology into economic and social development policies, when the country initiated its process of economic liberalization. Four years later the Science, Education and Development Mission (Misión de Ciencia, Educación y Desarrollo) proposed "a new world view led by advances in science and technology", to achieve "the prosperous, just country we dream of". [5] Subsequent efforts included a policy to promote science and innovation under the "Colombia builds and sows its future" plan of 2008, which aimed to become an essential tool to increase productivity and competitiveness, as well as to achieve social policy goals, which were linked to the Millennium Development Goals (MDGs) adopted by the United Nations Organization (UN) in the year 2000. Later, Law 1286 of 2009[6] established increasing scientific, technological and innovation capacities as a goal of state STI policy, not only to provide added value to national products and services, but also to "enhance well-being in the population, in all its dimensions" (art. 3). More recently, CONPES document 3582 of 2009 referred to knowledge as an instrument for the generation of wealth, income, equity and social well-being (DNP, 2009).

The foregoing shows that the need to link economic and social objectives has been explicit in the view of science and innovation policy in Colombia.[7] This is not something to be overlooked, given the huge complexity and diversity of our national territory, as well as the scale of the challenges we face in achieving a more equitable and prosperous society.

In recent years these challenges have become even greater. Governments, citizens, researchers, and a growing number of businesses

The need to link economic and social objectives has been explicit in the view of science and innovation policy in Colombia.

3 Johan Schot and Matías Ramírez of the Science Policy Research Unit, University of Sussex, and Sandra Boni and Jordi Molas of the Instituto Ingenio made special contributions to this chapter.

4 By which are set forth dispositions for the promotion of scientific research and technological development, and special powers are granted.

5 Ministerio de Educación Nacional, 1994. Colombia al filo de la oportunidad. Recomendaciones de la Misión de Ciencia, Educación y Desarrollo.

6 By which Law 29 of 1990 is modified, Colciencias becomes an Administrative Department, the Colombian National System of Science, Technology and Innovation is strengthened, and additional dispositions are set forth.

7 The expressions "science and innovation policy" and "innovation policy" should be understood to refer to science, technology and innovation policies in this document.

face the need to seek growth that is sustainable not only in economic and social terms but also from an environmental standpoint. One of the most relevant expressions of this concern is the 2030 Agenda for Sustainable Development, adopted by the UN General Assembly in 2015. With its 17 goals and 169 targets, this Agenda represents the desires, aspirations and priorities of the international community for the coming years. Colombia, as a UN member state, recognizes this Agenda as a roadmap for sustainable development in the country, in the medium and long term.[8]

The Sustainable Development Goals (SDGs) that make up the 2030 Agenda, in contrast to the previous MDGs, not only give equal importance to economic, social and environmental dimensions, but also go beyond a declaration of the aim to "leave nobody behind", placing people's equality and dignity at the center of the discussion and inviting us to change our approach to development for one that entails greater responsibilities toward the environment.[9] For Colombia this is especially important in light of the clear differences in development between regions and the natural wealth within its territory.

Having led the process of consensus building for this global Agenda, the country has taken decisive steps to implement it. The first step was the creation of the High Level Interinstitutional Commission on the Preparedness for and Effective Implementation of the SDGs (Comisión Interinstitucional de Alto Nivel para el Alistamiento y Efectiva Implementación de los ODS) (Decree 280 of 2015), of which Colciencias recently became a member.[10] The most recent step was the approval of CONPES document 3918 of 2018, which defines country-specific indicators and goals, approaches for establishing dialog with nongovernmental actors, and the resources needed to attain the SDGs. This CONPES document also emphasizes the importance of participation by a variety of actors, and thus brings to light the challenge to be faced in coordinating intersectoral and inter-regional efforts (DNP, 2018).

To continue to advance along these lines, it is now necessary to develop a perspective that makes it possible to understand and address the full implications of the 2030 Agenda, and that is able to attract different sectors of Colombian society, in a way that underscores the sense of meeting the specific goals and targets. This is precisely the direction that the *Green Book 2030* points to.

One of the less explored aspects of the 2030 Agenda until now has been the contribution that science, technology and innovation will make toward its implementation, a fundamental issue for public science and innovation policy, insofar as it is necessary to understand that doing things the same way as before will not suffice. For this reason, Colciencias has decided to embrace this challenge as an excellent opportunity to build new foundations for science and innovation policy in Colombia, which will make it possible to address major social, economic and environmental challenges. Progress in this direction, however, requires openness and a willingness to explore new principles and ideas such as those proposed in the *Green Book 2030*.

The road ahead to this policy began to appear in the year 2016, when Colciencias undertook a search to develop new ways of thinking about STI policy in conjunction with the well known Science Research Policy Unit (SPRU) at the University of Sussex, and peer agencies in Sweden (VINNOVA), Finland (formerly TEKES, now Business Finland), Norway (Research Council) and South Africa (National Research Foundation), co-founders of the Transformative Innovation Policy Consortium (TIPC).[11]

Colciencias has decided to embrace this challenge as an excellent opportunity to build new foundations for science and innovation policy in Colombia, which will make it possible to address major social, economic and environmental challenges.

8 See: DNP and DANE, (s. f.). La Agenda 2030 en Colombia. Available at: https://www.ods.gov.co/about

9 CEPAL, 2016, p. 7

10 Participants in this High Level Interinstitutional Commission include the Office of the President of the Republic, the Ministry of the Treasury and Public Credit, the Ministry of Foreign Affairs, the Ministry of Environmental Affairs, the National Planning Department, the National Department of Statistics and Social Welfare, the International Cooperation Agency, and Colciencias.

11 See: www.transformative-innovation-policy.net.

Today, a new policy is being presented to the country, after a process of reflection, learning and experience arising from active participation in the Consortium. All these inputs have been discussed and adapted in different spaces (interviews, panel discussions, workshops, expert consultations and mentorships) with the involvement of different actors at the national level (government, civil society, academia, businesses and international organizations). This new policy, through a transformative focus, aims to guide science and innovation so that they can contribute to solutions for the major challenges set forth in the 2030 Agenda. Here, a transformative focus is understood to mean one which stimulates long-term changes in current socio-technical systems to make them more sustainable. The expression "socio-technical systems" refers to the configuration of social and technical elements that interact, evolve and reinforce each other in a broad sense, and thus determine the orientation and behavior of types of production, usage and consumption.

This new policy focus complements the more traditional approaches in the country, which have been fundamental in the construction of a knowledge base, technological modernization, and the strengthening of productive capacity, but which did not explicitly address sustainable development and open participation by all sectors of society among its foundational ideas, in the way a transformative focus does. Thus the combination of mechanisms, initiatives and tools developed to promote advances in science and innovation in the country will continue to consolidate the institutional bases of governance and scientific knowledge, while at the same time new initiatives and tools will need to be designed to make progress toward technical and social changes that lead to sustainable development.

The justification and orientation of the *Green Book* are structured around four fundamental ideas, as explained below. The first is that the solution to social, economic and environmental problems posed in the SDGs requires transformations, both in the understanding of these problems and in the approaches to their possible solutions. The second is that STI policy is fundamental to achieve these transformations; this is the reason why policy needs to evolve, that is, to acquire new aims, embodiments and types of participation – our third fundamental idea. Finally, the fourth idea is that transformation requires changes at the socio-technical systems level.

1.1 The SDGs require transformations

In addition to representing the aspirations of the international community, the 2030 Agenda, in its very title, calls for a transformation of society: "Transforming our World: The 2030 Agenda for Sustainable Development". In this sense, progress toward a path for sustainable development requires, among other things, transformations in how we use natural resources, generate and use energy, produce and distribute food, organize the means of transportation, and achieve competitive production processes with low carbon emissions, among other goals (European Commission, 2015). In other words, it requires "fundamental changes in the way we live, work and do business" (United Nations, 2015). For this reason, incorporating the SDGs into policies and their subsequent implementation in practice are a worldwide challenge.

Based on previous experience with the SDGs, the main strategy that has been set in motion is to incorporate the SDGs into existing structures, programs and indicators. Establishing goals and defining indicators are undoubtedly fundamental aspects, but focusing attention on them may deflect attention from the actual aims, particularly those related with transformation[12] and sustainable development. In this sense, it is much more useful to establish a single overarching aim,

A new policy is being presented to the country – one which, through a transformative focus, aims to guide science and innovation so that they can contribute to solutions for the major challenges set forth in the 2030 Agenda.

12 This limitation of the SDGs is discussed by Fukuda-Parr, Sakiko; Yamin, Alicia and Greenstein, Joshua, 2014.

Establishing goals and defining indicators are undoubtedly fundamental aspects, but focusing attention on them may deflect attention from the actual aims, particularly those related with transformation and sustainable development.

interconnected goals, and a coherent vision of the type of development proposed by the SDGs in their totality (International Council for Science and International Social Science Council, 2015). The policy proposed here is oriented in this direction, with the concept of transformation as its basis.

1.2 Science and innovation policy as a means for transformation

In the *Green Book 2030* we propose a science and innovation policy with a transformative focus (hereafter, transformative policy) as a necessary step forward to overcome difficulties and gaps that arise in policies oriented toward the resolution of specific shortcomings (in the market or the system). This focus, by recognizing the complexity and interconnectivities that underlie the problems set forth in the SDGs, centers on the promotion of processes of both technical and social change, in order to give substance to the expected outcomes of sustainable development.

Firstly, transformative policy emphasizes that science, technology and innovation are cross-sectional elements in the implementation of the 2030 Agenda which go beyond Goal 9 "Industry, innovation and infrastructure", where they are mentioned explicitly. For example, generating clean, affordable energy, addressing climate change, and improving health across the population require decisive contributions from STI to trigger transformative processes in these areas.

Secondly, this policy proposes rethinking the relationship between STI and economic, social and environmental goals. Traditionally, academics and policy makers have focused their attention on science, technology and innovation as motors of economic growth – the ultimate aim that policies are meant to achieve. In fact, despite the emergence of perspectives such as social innovation or inclusive innovation, the logic of economics tends to predominate. Transformative policy, on the other hand, is based on the growing recognition of environmental and social goals as strategic drivers of long-term growth and competitiveness,[13] and not simply as framework conditions to achieve these ends. Thus, science and innovation should be an engine of social and environmental as well as economic development.

Thirdly, transformative policy seeks to open spaces for the active participation of civil society, in the search for and construction of solutions to problems that affect society, in recognition of the fact that these solutions may come from a diversity of sources and may be developed in cooperation with the productive and academic sectors.

1.3 Science and innovation policy needs to evolve

If STI can be understood as a factor in successful efforts to solve problems or challenges such as those identified in the 2030 Agenda, some questions that arise are: To what extent is current STI policy appropriate for this purpose? Can STI policy address all SDGs and drive transformation? The view being proposed here is that in its current conception, this policy is limited in scope, and accordingly, new steps should be taken, which include – among other measures – a reconsideration of its aims, the actors involved in policy development and implementation, the tools and mechanisms used, and its goals and evaluation methods. The need for new approaches is intimated by the process of evolution of STI policy itself over time: its orientation and aims have changed in response to needs and priorities at different moments in history.

In general terms, STI policy has been built around three main frames: the linear focus on research and development (R&D), termed Frame 1, ii) the focus on the national innovation system, termed Frame 2, and iii) the focus on transformative

13 See: Lundin, Nannan and Schwaag, Sylvia, 2017.

change, termed Frame 3.[14] The first two are well established, whereas the last frame is relatively new and in the process of consolidation. Each frame is described briefly below.

1.3.1 R&D and the national innovation system in STI policy (Frames 1 and 2)

Frame 1 first emerged in the postwar period during the 1950s, in the context of enthusiasm for greater state involvement in research, and its upsurge lasted until the early 1980s. This frame centered on overcoming market shortcomings that resulted from low investment by businesses in R&D.[15]15 The aim of this policy was thus to provide incentives so that the market would produce the desired levels of scientific knowledge (R&D) in social and economic settings, or so that the Government would invest in public facilities, including universities, and in research infrastructure. In this context, the policy was focused mainly on science and technology, while innovation was left to the market. This frame has been implemented particularly through offers of incentives for R&D (subsidies, tax benefits, etc.) and the launch of a new regime of intellectual property rights that allows private investors to realize profits from R&D.

During the 1980s, policies began to evolve. A second frame arose in response to growing competition between countries and the widening gaps in industrial development, with the aim of making better use of scientific knowledge, supporting its commercialization, and closing the gap between science, development, technology and their commercial application or innovation. This frame emphasizes different types of learning, the links between different actors, the capacity to absorb technologies, science, technology, engineering and math skills, the generation of business capacities, and entrepreneurship. The reason for public intervention was system failure; i.e., the inability of actors to take the greatest advantage of available knowledge due to the absence or malfunctioning of framework conditions and the relationships among the main actors in the innovation system (businesses, governments and universities). Innovation policy began to focus on the creation of national, regional and sectoral innovation systems, to stimulate the spirit of entrepreneurship, and to promote public–private alliances.

It is clear that these two frames have influenced science and innovation policy in Colombia. They have formed the basis of support for universities and research groups, and of the development of infrastructure to generate knowledge and create human resources for STI. Specifically, since the 1990s there has been a growing emphasis on innovation and entrepreneurship, when the thinking of the national system of innovation was adopted, as evidenced by the creation of the National System of Science and Technology in 1991, which was complemented in 1995 by the National System of Innovation – an organism which later, in 2009, became the SNCTI.

1.3.2 Transformative change (Frame 3)

The most recent policy frame, i.e. transformative change or Frame 3, began to take shape during the fist decade of the 21st century. Its starting point was the reasoning that although the two previous frames had been of vital importance to: i) construct a knowledge base, ii) bring about technological modernization, and iii) enhance productive capacity, they did not address sustainable development. Thus initiatives such as policies focused on socially sustainable environmental innovation gained strength, through – for example – promoting the development of clean technologies, inclusive

Advances within this Frame 3 in policy configuration make even more sense in the Colombian context, considering the substantial inequalities in regional development and the concentration of science and innovation capacities.

14 These three frames offer an overall synthesis of the foundations and characteristics that have informed, in general terms, STI policy design worldwide, including in Colombia. See: Schot & Steinmueller (2018).

15 The assumption is that businesses do not invest because profits are realized only in the long term, making investment too risky.

In the area of transformative policy, real transformation can occur only with changes in socio-technical systems that impact the economy and society.

innovations, and social innovation. In this manner, policies began to broaden their understanding of STI to include civil society and citizens, not only as consumers of knowledge and innovation but also as promoters and generators of the same, in order to address social and environmental needs. STI policy also began to include new types of innovation centered on socio-technical changes, new business models, and new agreements for collaboration among actors, with environmental and social benefits that go beyond traditional public–private alliances.

In line with these developments, the most recent worldwide trends have led to the orientation of policy objectives toward sustainable development. To this end, mechanisms have been created that point toward solutions to problems, and that seek to extend the benefits of STI to society as a whole, that redefine the roles and relationships among social actors, and that have encountered a new setting for action (the socio-technical system), among other effects.

Some characteristics of Frame 3 are also apparent in Colombia. For example, in 2010 Colciencias began to make inroads in policies aimed at social innovation and the social appropriation of science, within the framework of the National Strategy for the Social Appropriation of STI (Estrategia Nacional de Apropiación Social de la CTeI),[16] the main objective of which was the inclusion of different communities and civil society in the dynamics of knowledge production and use (Colciencias, 2010). In subsequent years a number of instruments and programs have been characterized by a focus on social innovation, where technology and knowledge are perceived as tools for development and social transformation.

Advances within this frame in policy configuration make even more sense in the Colombian context, considering the substantial inequalities in regional development[17] and the concentration of science and innovation capacities. Indeed, reducing these differences was one of the main motivations for creating an STI fund within the framework of the new General Royalties System (Sistema General de Regalías), which sought the development of less centralized regional initiatives that would be more inclusive in terms of economic and social development, with a program that provides investments aimed at solving specific local problems. Although this objective requires policies inspired by Frame 2, centered, for example, on building regional systems for innovation, this will not be sufficient given that many of the instruments contemplated within this type of policy prioritize mainly economic objectives over social or environmental ones. Moreover, policies inspired by Frame 2 tend to favor the concentration of STI activities and capacities. Thus policies and instruments within Frame 3 will be of key importance in deploying alternative routes to regional development, and will represent a significant advance in the evolution of National Science and Innovation Policy.

1.4 Transformation requires change in socio-technical systems

To make STI policy truly transformative at both the national and regional level, and to ensure that it meets social and environmental needs, the policy must be refocused and endowed with new characteristics. The main consideration is that the focus must be on the pursuit of changes in "socio-technical systems".

As noted earlier, by socio-technical system we refer to the configuration of social and technical elements that interact, evolve and are mutually reinforcing, such that they determine the

16 See: http://www.colciencias.gov.co/sites/default/files/ckeditor_files/estrategia-nacional-apropiacionsocial.pdf

17 The term "regional" refers to different subnational levels, and can thus be applied to different levels of administrative division in Colombia, i.e. departments, cities or municipalities, as appropriate.

orientation and behavior of types of production, usage and consumption. These elements include, for example, people's practices and needs, the skills and capacities of the actors involved, the infrastructures, governance, regulation and industrial structure, along with artifacts or technologies. For example, there are socio-technical systems that fulfil social functions such as providing energy or food, public health, mobility, communication, and so forth. When we speak of changes in these systems, we refer to alterations in all (social and technical) elements that go into their make-up, as well as to the process of developing a new configuration and their integration in the economy and society in general.[18]

In view of the above, transformative innovation policies aim to change these socio-technical systems into new, more sustainable systems; this will require a reorientation of social and economic relationships, and of those between people and their setting. In this regard, transformative policies dovetail with the call for social, economic and environmental reform proposed in the 2030 Agenda.

Within the Transformative Innovation Policy Consortium, different case studies were carried out which provided evidence that the transformation of socio-technical systems goes beyond simply developing new, radical technological solutions.[19] For example, STI policy can be centered on the introduction of electric vehicles and their weak point: overcoming their limited range by developing longer-lasting batteries. However, if electric vehicles are not widely seen as a substitute for current automobiles and we continue to use a system of mobility dominated by this latter artifact, achieving an inclusive, low carbon economy will remain a distant goal. In this sense, it is more appropriate to focus science and innovation policies in ways that support the appearance of new systems of mobility in which, for example, private automobile ownership is less important, and other modalities such as public transport, walking or cycling are used more widely together with electric vehicles, which could be made available by businesses devoted to providing mobility services. In a system such as this, mobility planning and hence reducing the number of trips would become an objective sought by all actors, and perhaps even a symbol of modern behavior; in other words, transformative change would come about. As a consequence, in the setting of transformative policy, real transformation occurs only with changes in socio-technical systems that achieve an economic and social impact.

This chapter presented the thinking that has led to the adoption of a transformative focus in science and innovation policy with the intention of contributing to solutions for the social, economic and environmental problems set forth in the SDGs. In the next chapter these problems will be explored in greater depth, insofar as they are issues that define the area for action in the policy to promote socio-technical changes.

Within the Transformative Innovation Policy Consortium, different case studies were carried out which provided evidence that the transformation of socio-technical systems goes beyond simply developing new, radical technological solutions.

18 See: Rip, Arie and Kemp, René, 1998 and Grin, John et al., 2010.

19 Some documented cases can be consulted at: http://tipconsortium.net/materials/

2/

The SDGs as a space for transformations

The SDGs are a political agenda that expresses an approach to what can be considered sustainable development in practical terms.[20] To better understand the challenge that this represents to defining and implementing a science and innovation policy with a transformative focus, some of the analyses carried out by Colciencias to prepare the *Green Book 2030* are offered below. These analyses approach the agenda from different perspectives with the aim of offering reflections and identifying needs that should be addressed by public policy and actors in the SNCTI, inasmuch as it is this setting where sociotechnical change is to be promoted.

It is important to clarify, nonetheless, that this chapter is not intended to present a diagnosis of the status of SDGs in Colombia, since this task is being undertaken judiciously by other entities such as the National Planning Department.[21] Instead, the following text aims to facilitate understanding of the SDGs as a space in which transformation will be promoted.[22]

2.1 The SDGs as a policy agenda

The commitment undertaken to the United Nations shows that the SDGs concern all countries worldwide; however, compliance raises the need for transformations and challenges that pertain specifically to public policy in each country. With this in mind, in-depth interviews were carried out with nine Colombian specialists from business, academia, the Government and organized civil society, who have a broad knowledge of science and innovation policy, or who are involved in areas related with sustainable development. The purpose of these interviews was to learn about their positions and orientations regarding the characteristics and scope of the 2030 Agenda, including

20 The concept of sustainable development has no single, unique definition. However, historians of this concept situate its origins in the environmental movement and in environmental economics (Meadows et al. 1972). Although the concept has several definitions, it can be concluded that sustainable development seeks a social, environmental and economic equilibrium. However, this balance is a "dynamic equilibrium" (Gallopín, 2001), because systems are in constant renewal. In current public policy, the idea of sustainable development has become a widely accepted framing, basically because of the impulse of multilateral organizations such as the United Nations (UN) and the Organisation for Economic Co-operation and Development (OECD). These organizations have brought different countries together over the years with a focus on joint programs for cooperation and shared aims. One such program is the 2030 Agenda.

21 See: www.ods.gov.co.

22 One of the working documents prepared within the framework of the project to compile the Green Book provides a context for the SDGs and the potential contributions to STI. This document is available at http://www.colciencias.gov.co/sites/default/files/objetivos_de_desarrollo_sostenible_y_aporte_a_la_cti_v_3.5.pdf

Global goals involve local actions that must consider interactions between goals, and foster intersectoral dialog and participation by different social groups.

its pertinence to Colombia, and to document the main challenges in science and innovation policy in order to support its implementation. Some of the most noteworthy points to come out of the information thus obtained are as follows:[23]

- Three fundamental characteristics of the 2030 Agenda are: globality, interaction and fostering changes. Briefly, the global goals involve local actions that require an awareness of the interactions between different goals (poverty and economic development, water and responsible consumption, etc.), fostering intersectoral dialog, and involving different social groups (citizens, entrepreneurs, academics and government representatives) in decision making processes. An additional point to be underscored is that any policy to contribute to the SDGs involves a change in the concept of development, from a focus on economic growth to one centered on an equilibrium between economic, social and environmental aspects.
- Achieving the 2030 Agenda may be compromised by three main risks: i) lack of commitment by different sectors (government, business, civil society) owing to inadequate dissemination; ii) a focus on indicators rather than actions, which can detract from the main aim, as expressed by one of the interviewees: "the challenge is to achieve actual improvement in conditions and not merely a change in the indicators", and iii) lack of adequate funding.
- The greatest challenges to public science and innovation policy in Colombia regarding the SDGs are: i) institutional strengthening of the organizations related with STI, particularly Colciencias; ii) better articulation both within the national government and in other sectors, especially civil society, and iii) prioritizing research agendas in connection with social needs.

In addition to the in-depth interviews, seven panel discussions were held[24] in which the participants reflected on STI policy and its contribution to the SDGs. Among the aspects noted as science and technology policy needs are the following:

- Achieving greater participation by different social groups in decisions about STI (Panel discussion V on climate change, and Panel discussion II on peace).
- Fostering interdisciplinarity and dialog among knowledge holders (Panel discussion VI on social transformation, and Panel discussion V on climate change).
- Developing the regional nature of solutions for sustainable development (Panel discussion V on climate change, and Panel discussion II on peace).
- Incorporating ethics and uncertainty into STI policy for sustainable development (Panel discussion VI on social transformation).
- The need to experiment in public policy (Panel discussion I on transition to renewable energy sources.

2.2 Citizenship and the SDGs

A notable aspect within the transformative focus or Frame 3 is that it generates spaces where civil society or actors who have not traditionally been

23 The document the provides a record of these interviews and analyses is available at: http://www.colciencias.gov.co/sites/default/files/percepciones_agenda_2030.pdf

24 The topics discussed were: sustainable productive development, paths toward transition and analysis of renewable energy sources to mitigate and adapt to climate change, STI in the construction of peace, STI in the consolidation of sustainable cities and regions, STI and climate change, oceans and life on land, STI and social transformation, and the role of water in the environment and society. In all, a total of nearly 1,200 people participated. Details of each panel discussion are available on the "Participación ciudadana" section at: www.libroverde2030.gov.co.

involved in science and innovation policy initiatives can become engaged in processes of change. One way to propitiate this engagement, which has gained ground in recent years, is through exercises in citizen consultation on the direction that should be imparted to public policy.[25] With regard to the SDGs, countries such as Finland, Greece and Turkey have used this type of consultation to define strategies related with their implementation (OECD, 2016).

In this regard, and with the aim of capturing the interest of different groups to propitiate their participation in science and innovation policy design, as well as to contribute to the dissemination of the SDGs, Colciencias carried out the "What road shall we take?" citizen consultation between October 2017 and January 2018. In this exercise, citizens, researchers, entrepreneurs (hereafter, groups consulted) were asked which SDGs they and their families were most concerned about, and whether they believed that the status of these SDGs in Colombia had improved or not in the last two years.[26] A total of nearly 500,000 responses were received – the greatest level of participation thus far for the purposes of informing the design of science and innovation policy in the country. Tables 1 and 2 present the overall results.[27]

Among the possible analyses of the results of this consultation, two in particular are of relevance to inform science and innovation policy oriented toward SDGs. The first analysis, centered on the main concerns expressed by different groups consulted, disclosed noticeable similarities between concerns noted by citizens and by researchers. Both groups concurred in ranking "Quality education" (SDG 4), "Clean water and sanitation" (SDG 6) and "Health and well-being" (SDG 3) in the top three positions. Entrepreneurs, for their part, reported somewhat different levels of relevance for different goals, noting "Industry, innovation and infrastructure" (SDG 9), "Decent work and economic growth" (SDG 8) and "Quality education" (SDG 4) as their greatest concerns. Respondents in this group shared this last SDG with citizens and researchers. The differences may be a result of discrepancies among stakeholders / actors lógicas who rarely participate in dialog in this country; in this connection it should be recalled that both sociotechnical change and meeting the SDGs require participation and dialog among different groups, especially for the construction

Table 1. Overall participation in the consultation by group consulted

Group	Women	Men	NR	Total
Citizens	210,380	228,529	-	438,909
Researchers	6,920	11,173	11	18,104
Entrepreneurs	5,250	12,455	289	17,994
Total	222,550	252,157	300	475,007

Source: Results from the "What road shall we take?" citizen consultation.

Table 2. Number of responses by region*

Region	No. of responses
Bogotá D. C.	150,734
Eje Cafetero	125,462
Pacífico	69,573
Caribe	53,832
Centro oriente	46,164
Centro sur	11,885
Llanos	6,266
Not reported	11,091
Total	475,007

Regions shown here are identified according to designations used by government agencies in Colombia. The capital district Bogotá D. C. is shown separately.

Source: Results from the "What road shall we take?" citizen consultation.

25 Within the area of science these consultations are intended to motivate participation "as a mechanism to improve the efficiency, quality and relevance of research, and improve transparency and trust in science" (OECD, 2017, p. 5). Examples of research agendas shaped with citizen participation are CIMULACT in the European Union, the Great New Zealand Science Project, RISTEX in Japan, and X-Project in South Korea (OECD, 2017).

26 This part of the consultation was carried out in alliance with UNO, as part of the "My World 2030" world survey.

27 The results of this consultation are available as a set of dynamic tables that can be accessed at: http://colciencias.gov.co/la-ciencia-en-cifras.

of shared visions and expectations (direction) in the face of change.

Table 3 shows the results of the consultation by group, with the SDGs ranked in decreasing order of concern expressed by different groups.

The second analysis centers on the consultation results at the regional level, a pertinent approach considering the predominant need to interpret the 2030 Agenda in the light of territorial realities. In general, the concerns were similar across all regions. The main consensus is that "Quality education" (SDG 4) is the greatest concern. There is also agreement that "Clean water and sanitation" (SDG 6), "Climate action" (SDG 15), "Heath and well-being" (SDG 3) and "Life on land" (SDG 15) are the other goals of greatest concern, although the rank order varies somewhat across regions. The main difference is seen in the Llanos region, where "Affordable, clean energy" (SDG 7), "Industry, innovation and infrastructure" (SDG 9) and "Zero hunger" (SDG 2) are among the top five concerns, whereas "Climate action" (SDG 13) and "Clean water and sanitation (SDG 6) are accorded a different level of importance. Table 4 shows the totals from the consultation in each region, ranked from highest to lowest number of responses.

These figures constitute an initial step in our region-by-region analysis, which will require further study. Note, for example, that although the goals ranked by citizens as having the most widespread levels of concern overlap across territories, the most appropriate solutions in a given territory may differ or require adaptation.

2.3 Research and the SDGs

Regarding the importance of STI in meeting the SDGs, particularly the central role of scientific research and technological development, a study was undertaken to identify the dynamics in Colombia in topics related with different SDGs in recent years, which would give us a preliminary idea of the greatest current strengths and point to

Table 3. Results of the citizen consultation according to group consulted

SDG	Name	Aggregate	Citizen	Researcher	Entrepreneur
4	Quality education	348,785	336,230	8,013	4,542
6	Clean water and sanitation	206,330	198,252	5,487	2,591
3	Health and well-being	201,573	195,035	4,335	2,203
13	Climate action	200,925	193,298	5,072	2,555
15	Life on land	177,402	170,923	4,455	2,024
1	End poverty	176,966	169,785	4,549	2,632
8	Decent work and economic growth	174,297	165,541	3,814	4,942
11	Sustainable cities and communities	171,937	166,192	2,868	2,877
7	Affordable, clean energy	162,874	156,617	3,810	2,447
2	Zero hunger	161,481	155,896	3,501	2,084
16	Peace and justice, strong institutions	147,313	140,922	3,749	2,642
10	Reduced inequalities	145,462	138,309	4,176	2,977
12	Responsible production and consumption	122,381	116,006	2,998	3,377
9	Industry, innovation and infrastructure	119,141	110,654	3,523	4,964
5	Gender equality	90,386	86,661	1,989	1,736
14	Life below water	81,243	77,136	2,954	1,153
17	Partnerships to achieve goals	55,927	53,960	1,079	888
	Total consulted	475,007	438,909	18,104	17,994

Source: Results from the "What road shall we take?" citizen consultation.

Table 4. Results of the citizen consultation by region

SDG	Name	Total	Bogotá	Caribe	Centro oriente	Centro sur	Eje Cafetero	Llanos	Pacífico
4	Quality education	341,276	109,661	40,641	33,894	8,893	89,782	5,402	53,003
6	Clean water and sanitation	204,737	67,459	23,128	23,678	5,608	51,359	2,160	31,345
13	Climate action	197,172	59,057	23,011	18,488	6,742	56,156	2,175	31,543
3	Health and well-being	195,985	54,312	24,765	21,119	5,226	54,175	3,307	33,081
15	Life on land	173,814	57,220	18,271	18,734	4,958	44,406	2,925	27,300
1	End poverty	172,186	54,891	19,037	17,345	3,933	46,499	1,893	28,588
8	Decent work and economic growth	168,146	51,962	21,242	16,331	5,906	47,395	1,778	23,532
11	Sustainable cities and communities	167,762	53,551	21,212	14,757	3,959	47,928	1,682	24,673
7	Affordable, clean energy	158,776	50,856	17,505	16,423	3,838	42,530	3,265	24,359
2	Zero hunger	157,072	51,058	14,599	16,196	4,101	43,011	2,222	25,885
16	Peace and justice, strong institutions	142,582	45,999	18,318	14,519	3,430	38,657	1,928	19,731
10	Reduced inequalities	142,424	45,246	15,854	16,737	1,952	40,885	2,034	19,716
12	Responsible production and consumption	120,155	43,471	14,362	11,458	3,402	30,239	1,471	15,752
9	Industry, innovation and infrastructure	115,685	39,544	14,100	8,081	2,418	32,011	2,066	17,465
5	Gender equality	88,357	31,172	8,639	9,200	2,218	24,487	888	11,753
14	Life below water	79,642	30,396	7,547	4,984	1,225	21,846	234	13,410
17	Partnerships to achieve goals	54,642	20,257	5,446	4,444	1,113	16,088	559	6,735
	Total consulted	463,916	150,734	53,832	46,164	11,885	125,462	6,266	69,573

Source: Results from the "What road shall we take?" citizen consultation.

areas that need strengthening. For this purpose, the analysis centered on scientific and technological production related to the SDGs during the period from 2007 to 2016[28] (hereafter, bibliometric exercise). The results have been grouped into three main topics: i) bibliographic output and impact, ii) collaboration, and, iii) patenting.

i) Bibliographic output and impact

Table 5 presents the number of bibliographic products (original articles, literature reviews or conference presentations) by Colombian authors (CO) and the leading countries in bibliographic output worldwide in different SDGs: United Kingdom (UK), United States (US), China (CN) and Australia (AU): figures for Brazil (BR) and Mexico (MX) are also shown for comparison with research outputs by Latin American countries. The total worldwide bibliographic output in the SDGs between 2006 and 2017 was 247,188 products, with the largest numbers of products in "Life on land" (SDG 15), "Climate action" (SDG 13), "Life below water (SDG 14) and "Responsible production and consumption (SDG 12). For Colombia, the number of bibliographic outputs during this period was 1,081. The numbers of products dealing with different SDGs, in decreasing order, were as follows:

1) Life on land (SDG 15).
2) Climate action (SDG 13).
3) Life below water (SDG 14).
4) Responsible production and consumption (SDG 12).
5) Health and well-being (SDG 3).
6) Industry, innovation and infrastructure (SDG 9).

28 The study was carried out by Elsevier for Colciencias in 2018. Detailed results can be consulted on the Green Book 2030 website: www.libroverde2030.gov.co. Although the analysis was based on information in the "high impact" databases, the methodology, technical descriptions of the databases used, and search algorithms are open access for anyone who wishes to extend this type of analysis to other scientific publication databases. See: http://www.colciencias.gov.co/sites/default/files/portada-intro-anexos.pdf

Table 5. Number of publications dealing with each SDG by country (world values shown for reference)

SDG	Name	World	CO	BR	MX	UK	US	CN	AU
15	Life on land	170,280	717	5,368	1,607	13,856	33,006	25,541	8,909
13	Climate action	136,651	620	4,650	1,453	12,382	27,423	16,939	7,666
14	Life below water	104,312	498	3,768	1,061	10,727	24,572	6,856	7,123
12	Responsible production and consumption	78,468	363	3,179	839	5,936	14,993	10,023	
9	Industry, innovation and infrastructure	74,897	274	1,998	564	6,238	14,202	9,751	3,963
17	Partnerships to achieve goals	60,652	266	1,483	541	6,735	12,678	4,462	4,067
11	Sustainable cities and communities	59,895	229	1,531	525	5,261	11,359	8,867	3,146
6	Clean water and sanitation	58,404	212	1,806	595	4,087	12,364	10,545	3,200
7	Affordable, clean energy	45,587	191	1,268	361	3,083	10,167	5,660	
2	Zero hunger	40,363	240	1,972	635	3,111	8,040	4,994	2,582
1	End poverty	21,462	114	591	222	2,325	4,465	1,495	1,345
8	Decent work and economic growth	20,592	79	428	160	1,775	3,356	3,888	1,133
10	Reduced inequalities	9,860	55	371	106	1,069	1,917	1,117	562
16	Peace and justice, strong institutions	9,219	70	244	97	1,128	2,003	619	577
3	Health and well-being	6,810	284	1,860	668	835	1,874	452	377
5	Gender equality	6,810	37	163	80	835	1,874		452
4	Quality education	5,204	19	71	33	662	1,263		603

Note: Empty fields indicate that the country is not one of the top 5 non-Latin American countries in the respective SDG.
Source: Prepared by the authors of this document based on Elsevier, 2018.

7) Partnerships to achieve goals (SDG 17).
8) Zero hunger (SDG 2).
9) Sustainable cities and communities (SDG 11).
10) Clean water and sanitation (SDG 6).
11) Affordable, clean energy (SDG 7).
12) End poverty (SDG 1).
13) Decent work and economic growth (SDG 8).
14) Peace and justice, strong institutions (SDG 16).
15) Reduced inequalities (SDG 10).
16) Gender equality (SDG 5).
17) Quality education (SDG 4).

The main difference between Colombia and worldwide output is in "Health and well-being" (SDG 3), which ranks fifth in the number of outputs from Colombia but fifteenth worldwide.

Regarding the impact of bibliographic production in terms of the numbers of citations received (citation impact), Table 6 shows that this impact for Colombia is equal to or greater than the world average for eleven of the SDGs, and is particularly notable for SDG 5, "Gender equality". This result indicates that research produced in Colombia is being used in SDG-related studies at a worldwide level, and that in some fields, such as gender equality and research on reducing hunger, Colombia attains citation levels very similar to those of leading countries.

ii) Collaboration

One hundred seventeen institutions from 28 countries make up the network of collaboration by Colombian researchers in SDG-related topics, based on a cut-off point of 20 collaborators to identify the most active ones in terms of the number of bibliographic outputs for each SDG. The countries with the greatest levels of collaboration with Colombia are the United States, Spain, the United Kingdom, France and the Netherlands.

Table 6. Citation impact for each SDG in different countries (ranked with reference to values for Colombia)

SDG	Name	World	CO	BR	MX	UK	US	CN	AU
15	Life on land	1.1	1.1	0.9	1.1	1.7	1.5	0.7	1.6
13	Climate action	1.2	1.2	1.0	1.2	1.8	1.6	1.0	1.8
14	Life below water	1.2	1.0	0.9	1.3	1.8	1.6	1.2	1.6
12	Responsible production and consumption	1.3	1.2	1.2	1.1	2.0	1.7	1.1	
9	Industry, innovation and infrastructure	1.1	1.0	0.8	1.2	1.7	1.5	0.8	1.6
17	Partnerships to achieve goals	1.2	1.2	1.1	1.5	1.8	1.5	0.9	1.6
11	Sustainable cities and communities	1.0	1.3	0.9	1.0	1.6	1.4	0.7	1.5
6	Clean water and sanitation	1.1	1.0	1.0	1.0	1.7	1.4	0.9	1.7
7	Affordable, clean energy	1.4	0.0	0.0	-0.2	1.9	1.7	1.3	
2	Zero hunger	1.2	1.8	1.2	1.4	2.1	1.8	1.0	1.8
1	End poverty	1.0	1.4	1.1	1.2	1.7	1.5	0.8	1.5
8	Decent work and economic growth	1.0	1.1	1.0	1.2	1.8	1.5	0.7	1.6
10	Reduced inequalities	1.1	1.2	1.0	1.6	1.9	1.6	1.1	1.8
16	Peace and justice, strong institutions	1.1	1.4	0.8	1.2	1.7	1.4	0.9	1.7
3	Health and well-being	1.1	1.2	1.2	1.5	1.9	1.6	1.5	1.6
5	Gender equality	1.1	2.1	1.3	3.2	1.9	1.6		1.5
4	Quality education	1.0	0.6	1.0	0.7	1.0	1.0		1.1

Note: Empty fields indicate that the country is not one of the top 5 non-Latin American countries in the respective SDG.
Source: Prepared by the authors of this document based on Elsevier, 2018.

Outputs from these collaborations account for approximately 65% of the bibliographic production associated with the SDGs. The five institutions that collaborate the most with Colombia are, in decreasing order, Wageningen University & Research (Netherlands), Stanford University (United States.), Universitat Politècnica de Catalunya (Spain), Imperial College London (United Kingdom), and the International Crops Research Institute for the Semi-Arid Tropics (India).

Figure 1 shows the collaboration between Colombia and different countries, together with the predominant SDGs. The SDGs are shown as yellow nodes, and countries are shown as green nodes. These relationships are based on the number of coauthored publications, with thicker lines indicating larger numbers of publications. Larger nodes indicate greater numbers of coauthor relationships. As shown, the SDGs that benefit most from collaboration are "Life on land" (SDG 15), "Climate action" (SDG 13) and "Life below water" (SDG 14).

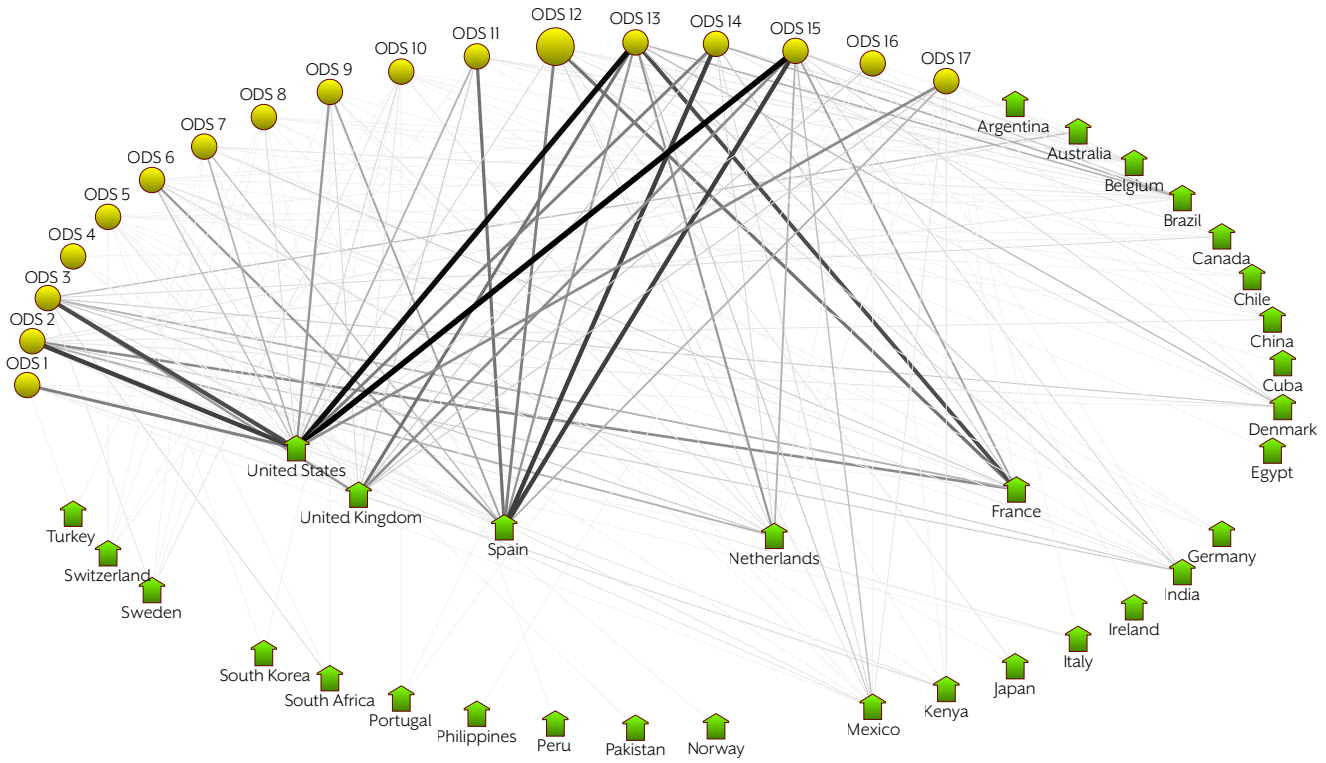
iii) Patenting

A total of 7,783 patents for inventions were awarded worldwide in relation with SDGs.[29] The SDG with the largest number of associated patents is "Climate action" (SDG 13), which accounts for 17%. This SDG together with "Responsible production and consumption" (SDG 12), "Affordable, clean energy" (SDG 7) and "Life on land" (SDG 15) accounts for 56% of all patents for inventions. As in other areas, the largest number of patents is concentrated in the United States (80%), whereas Latin American countries including Colombia account for a small contribution (0.29%). Table 7 shows the number of patents for SDG-related inventions awarded to each applicant country.

In synthesis, the bibliometric exercise shows that the production of SDG-related research in Colombia is growing at an annual

29 The source consulted for this study is Lexis Nexis (www.lexisnexis.com), a platform that compiles data from the US Patent Office, Esp@cenet and WIPO.

Figure 1. Countries that collaborate with Colombia on SDGs



Source: Prepared by the authors of this document based on Elsevier, 2018.

rate of 30% and surpasses the worldwide citation average by 20%, although this figure varies across specific SDGs. Of the total Colombian SDG output, 15% is situated among the most widely cited worldwide. These indicators reflect the high level of impact and usage of Colombian research production in sustainable development, although the total number of bibliographic products is still low compared to other countries such as the United States, Spain, the United Kingdom, France and the Netherlands. It is also below that of the countries closest to Colombia geographically and culturally, such as Brazil and Mexico. Moreover, the number of patent awards in Colombia for different SDGs is very low. The above results offer valuable inputs to inform public policy regarding the incentives that should be generated as a way to favor the development of scientific research and technological development pertaining to the SDGs. In principle, these stimuli should focus on: i) SDGs with the greatest research dynamics, ii) SDGs that require a fresh impetus in R&D, iii) opportunities for international cooperation, and iv) opportunities for technological development and innovation.

2.4 Citizenship, research and SDGs

Sections 2.2 and 2.3 above set the scene for exploring the relationships in Colombia between scientific research dynamics, technological development and citizens' concerns regarding the SDGs. In a way, this analysis is an opportunity to bring together the ideas in policy Frame 1, which assumes that knowledge creation is translated "naturally" into

Table 7. Patents awarded for SDG-related inventions in different applicant countries

Country	US	GB	CN	AU	DE	CO	MX	BR	World
SDG 13	1,041	20	25	40	38	2	1	1	1,339
SDG 12	887	19	27	41	4	2	1	1	1,186
SDG 7	763	17	14	20	4	2	1	-	956
SDG 15	711	13	17	32	22	-	1	2	914
SDG 9	510	5	21	30	8	-	1	-	638
SDG 14	490	6	31	7	6	1	1	-	601
SDG 6	416	5	14	8	18	-	-	1	531
SDG 3	371	4	3	20	17	-	-	1	483
SDG 2	338	6	14	1	23	1	-	1	434
SDG 11	303	1	10	10	2	-	-	-	362
SDG 17	101	5	1	1	2	1	-	1	130
SDG 8	-	73	-	-	-	-	-	-	81
SDG 10	55	-	1	2	-	-	-	-	74
SDG 1	19	-	-	-	-	-	-	-	21
SDG 5	13	3	-	-	1	-	-	-	19
SDG 16	11	-	-	1	-	-	-	-	14
SDG 4	-	-	-	-	-	-	-	-	-
	6,029	177	178	213	145	9	6	8	7,783

Source: Prepared by the authors of this document based on Elsevier, 2018.

economic and social benefits, and the ideas in Frame 3, which emphasize policy orientation toward solving social problems, with the participation of and guidance from society.

Viewing the results for citizen concerns in the light of the dynamics of bibliographic production, considered here as research intensity, identified four types of relationships:

- High research interest and high citizen concern.
- High research interest and low citizen concern.
- Low research interest and high citizen concern.
- Low research interest and low citizen concern.

The seven SDGs that accounted for the greatest national bibliographic production were classified as high research intensity, and the six SDGs that were reported as of greatest concern by some of the groups consulted (citizens, researchers or entrepreneurs) were classified as high citizen interest. The results of this classification are shown in Table 8.

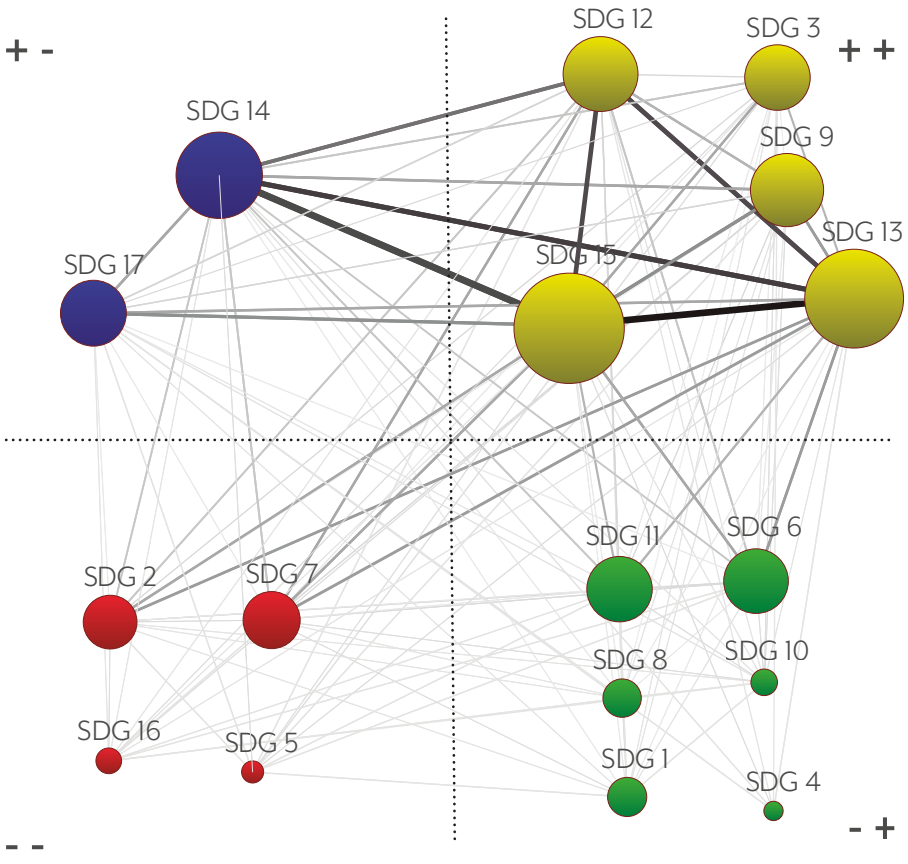
To provide a broader vision of the relationships between research, citizen interest and the SDGs, Figure 2 below illustrates a projection of the first two factors on a relationship map of the SDGs. The relationship map was built from worldwide citations to SDG-related bibliographic outputs. Nodes in the network represent SDGs, with larger nodes indicating higher proportions of Colombian publications for a given SDG. Relationships among SDGs are shown as lines, with thicker lines indicating larger numbers of citations among linked SDGs. Different colors are used for nodes in each of the four quadrants in Table 8. Yellow indicates high research intensity interés and high citizen interest. Green indicates low research intensity and high citizen interest. Red indicates low research intensity and low citizen interest. Blue is used to indicate high research intensity and low citizen interest.

Table 8. Classification of SDGs according to research interest and citizen concern

		Citizen concern	
		Low	**High**
Research interest	High	Life under water (SDG 14) Partnerships to achieve goals (SDG 17)	Life on land (SDG 15) Climate action (SDG 13) Responsible production and consumption (SDG 12) Health and well-being (SDG 3) Industry, innovation and infrastructure (SDG 9)
	Low	Zero hunger (SDG 2) Affordable, clean energy (SDG 7) Peace, justice and strong institutions (SDG 16) Gender equality (SDG 5)	Sustainable cities and communities (SDG 11) Clean water and sanitation (SDG 6) End poverty (SDG 1) Decent work and economic growth (SDG 8) Reduced inequalities (SDG 10) Quality education (SDG 4)

Source: Prepared by the authors of this document based on results from Elsevier, 2018, and from the "What road shall we take?" citizen consultation.

Figure 2. SDG network, citizen interest and research intensity



Source: Prepared by the authors of this document based on results from Elsevier, 2018, and from the "What road shall we take?" citizen consultation.

From the relationships thus identified among SDGs situated in different quadrants, it can be assumed that policy actions to link the dynamics of scientific research and technological development with citizens' interests can utilize the relationships among different SDGs to achieve leverage among them. This type of overarching vision, moreover, can also be extended to areas other than R&D, such as (for example) technologies, actors, or even public policy.

It should be noted that a transformative focus in public policy places emphasis on the active participation of different social groups in decision making about the direction and development of science and innovation agendas.

2.5 Frontier technologies and SDGs

As noted, technological artifacts are one of the components of sociotechnical systems targeted for transformation. In this connection, frontier technologies[30] are noteworthy for their potential to radically transform how we live. With specific reference to the SDGs, different international organisms including the OECD and UNO have emphasized the relevant role these technologies can play in achieving the goals. For example, technologies related with big data are helping to understand climate behavior at a worldwide level, improve medical diagnostics, and reach better decisions in complex scenarios. Artificial intelligence is making reasoning methods and performance more accurate, safer and more efficient in a variety of tasks. 3D printing makes the manufacture of complex products faster and more efficient. Significant developments in biotechnology and nanotechnology, and in renewable energy sources, are also having positive impacts on health, water supplies and climate change, among other challenges (UNCTAD, 2018). These developments are evidence of the potential of frontier technologies to contribute to solutions for the problems set forth in the 2030 Agenda.

Nevertheless, from a sociotechnical point of view, it is understood that the effects of frontier technologies are not limited to providing solutions, but can also have a variety of social and environmental applications – which may not always be positive. For example, it has been argued that big data, artificial intelligence and 3D printing technologies can have negative effects on employment by replacing human labor with automated processes. Moreover, there are ethical consideration regarding the use of these technologies, because they can be used for purposes of espionage, information manipulation and market control. Further concerns are related with the fact that because frontier technologies are generated mainly in developed countries, they widen the gap between wealthy and poor countries. Consequently, policies focused on sustainable development should create mechanisms to evaluate, anticipate and weigh the risks and implications of the development and implementation of these types of technology.

2.6 Relationships between SDGs and sociotechnical change

Just as they have made it possible to identify relationships among SDGs in terms of scientific research, the conceptual bases of transformative policy also allow relationships to be discerned among SDGs from the standpoint of sociotechnical systems and the direction of transformations. As a starting point for these insights, three types of SDGs are distinguishable:

- Type 1: SDGs covering sociotechnical systems that perform specific social functions by providing goods or services, or by protecting a resource. Among these are SDG 3 in health, 4 in education, 6 in

The emergence of Frame 3 does not imply the complete displacement of other policy frames but acts in contrast to complement them.

30 The term "frontier technologies" refers generally to technological areas in the process of development or refinement and are therefore not widely commercialized, although they have great application and market potential. Currently the main frontier technologies are, among others, robotics, drones, autonomous vehicles, augmented reality, artificial intelligence, digital manufacturing, big data, biotechnology, the Internet of Things, blockchain, and synthetic biology.

clean water and sanitation, 7 in affordable, clean energy, 9 in industry, innovation and infrastructure, 14 in life below water, and SDG 15 in life on land.

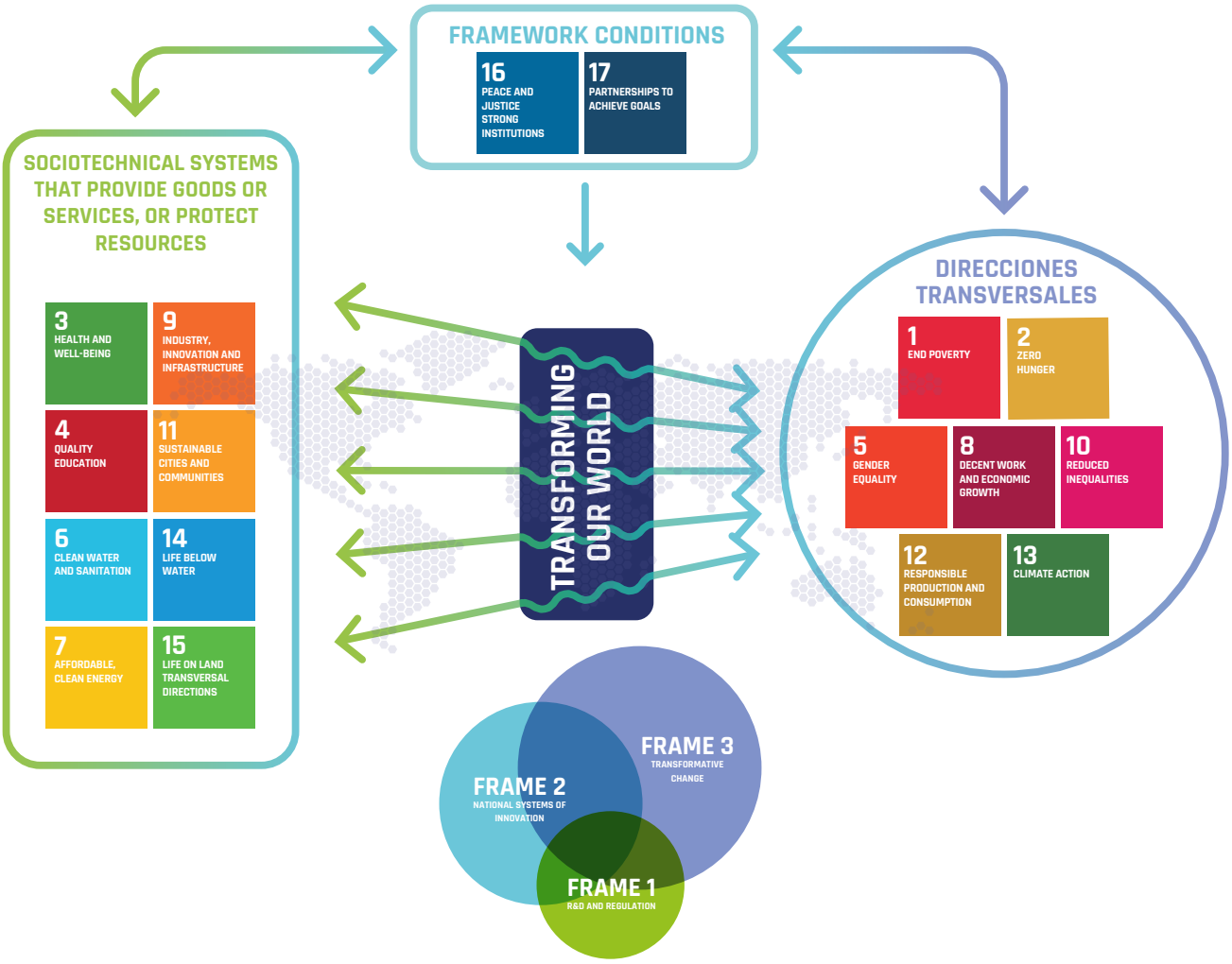
- Type 2: SDGs that emphasize directionality, i.e. that indicate pathways for progress toward specific outcomes. Among these are SDG 1 on the end of poverty, 2 on zero hunger, 5 on gender equality, 8 on decent work and economic growth, 10 on reducing inequalities, 11 on sustainable cities and communities, 12 on responsible production and consumption, and SDG 13 on climate action.
- Type 3: SDGs centered on the setting conditions needed to carry out transformation, including governance arrangements between the State, the market, civil society and science. These framework conditions are generally not predefined, and therefore need to be developed as part of the process of change. This type comprises goal 16 on peace, justice and strong institutions, and goal 17 on partnerships to achieve the SDGs.

This SDG classification makes it possible to identify connections and types of relationships between the goals that are not explicit in presentations of the full set of seventeen goals, or when individual goals are considered separately. For example, to ensure attainment of the overarching goal of the 2030 Agenda, i.e. sustainable development, ideally initiatives[31] associated with SDGs that perform social functions (type 1) should be linked with at least one of the SDGs that emphasizes directionality (type 2). It is this interaction between SDGs which considerably enhances the potential of different initiatives for impact and transformation, and thus makes such links a relevant topic in policy.

This interpretation of the possible relationships among SDGs is illustrated schematically in Figure 3. The central panel shows the space where transformative initiatives are carried out thanks to the connectivity between type 1 (left panel) and type 2 SDGs (right panel), which is further influenced by type 3 SDGs (upper panel). The lower part of the diagram illustrates the three policy frames noted earlier, which, together with different types of intervention, stimulate the development of transformative initiatives. It is important to keep this in mind, given that the emergence of Frame 3 does not imply the complete displacement of other policy frames, but acts, in contrast, to complement them. While policies inspired by Frame 1 may be focused, for example, on achieving specific SDG targets through the generation of knowledge and capacities, policies inspired by Frame 2 can facilitate greater participation by civil society in processes of innovation and productive development. Because this will not be sufficient, policies within Frame 3 will come into play to facilitate and stimulate transformative change. Moreover, attributes of transformative policy can be incorporated into policies within Frames 1 and 2, thereby generating further conditions for the emergence of sociotechnical change.

31 The term 'initiatives' refers to programs, projects or instruments implemented by the national government, departments or municipalities aimed at solving SDG problems, such as projects undertaken by specific organized communities or social groups that seek to advance in the same direction.

Figure 3. Approach to different SDGs via transformative innovation policy



Source: Prepared by the authors of this document based on Schot, Johan et ál., 2018.

3/

Goals and principles in transformative science and innovation policy

The goal of this national policy is to guide science and innovation so that they contribute to solutions for the country's social, environmental and economic problems, from a transformative focus, i.e., by acting as catalysts of change at the socio-technical level. Initially, these problems will be considered as the ones set forth in the SDGs, which have been adopted by the national government as a roadmap for sustainable development in the medium and long term.

To carry out this task, policy will be oriented in three directions: i) promoting and supporting the adoption of a transformative focus in the SNCTI and other related systems; ii) guiding national science and innovation in order to meet the SDGs; and iii) promoting and supporting the deployment of a transformative focus to achieve the SDGs at the territorial level. Advancing in any of these directions will require the strategies and mechanisms used to for policy implementation to be endowed with specific features, as a way to generate favorable conditions for change –in other words, for transformation– within socio-technical systems.

The identification and definition of these features has been the outcome of several analyses: i) case studies of different initiatives with transformative potential carried out within the framework of the Transformative Innovation Policy Consortium,[32] ii) project mentorship in different departments,[33] iii) interviews with Colombian specialists in STI and sustainable development, iv) in-house workshops in Colciencias and with other actors,[34] and v) review of the diagnoses and proposals for the SNCTI.[35] These analyses were complemented by a review of the relevant literature.[36]

32 The methodology for the case studies was based on histories of transformative innovation developed within the framework of the TIPC (http://tipconsortium.net/). Seven common features indicating transformative potential were identified across all cases: directionality, system-wide impact, inclusion, space for dissent, focus on major challenges, and learning and experimentation.

33 The mentorship network is an experimental exercise carried out within the framework of the Green Book 2030 project by Colciencias and the Science Policy Research Unit at the University of Sussex. This network identified initiatives with transformative features in seven departments, which were provided with supplementary support to enhance their transformative potential. See: http://www.libroverde2030.gov.co

34 In all, four workshops were held: the over one hundred participants included employees holding different positions in national government bodies, regional STI agencies, researchers, and members of the Consejos Departamentales de Ciencia, Tecnología e Innovación (CODECTI) (Departmental Science, Technology and Innovation Councils).

35 See: Academia Colombiana de Ciencias Exactas, Físicas y Naturales, 2018 and Amigos de Colciencias, 2018.

36 See, among others: Kuhlmann, Stefan and Rip, Arie, 2014; OECD, 2010; Vessuri, 2016; Cepal, 2016; Cepal, 2017 and Kallerud, Egil et al., 2013.

Policy principles are viewed as fundamental ideas that must inspire action, and without which the transformative focus is weakened.

In light of these activities, five features were identified as essential to stimulate, promote and facilitate processes of transformative change. For this reason, it is felt that they should be incorporated into the different initiatives, instruments, programs or projects that implement this policy, and that are oriented toward compliance with the 2030 Agenda in Colombia, or other STI initiatives that aim to help solve complex problems. In addition, the presence of these characteristics can serve as an indicator of the transformative potential of a given initiative driven by public policy or by actors within the SNCTI, including civil society.

To emphasize the importance of these features and facilitate their uptake, they are here accorded the status of policy "principles", that is, they are viewed as fundamental ideas that should inspire action, and without which the transformative focus would be lost. Consequently, these policy principles should be kept in sight whenever the desired outcome is: i) to enhance the transformative potential of initiatives or instruments already under way, including those based on Frames 1 and 2, ii) to set in motion new initiatives, instruments, programs or projects oriented toward achieving the SDGs, or iii) to characterize the transformative potential of initiatives currently in progress. It is important to emphasize that their application will not be limited to bodies that implement public STI policies, but will also involve all actors in the SNCTI that carry out initiatives with potential to transform socio-technical systems. These five principles are described below.

3.1 Directionality

This principle refers to the collective process through which different alternatives are considered, in a way that brings to light their connections as well as their social and environmental consequences, in order to guide actions toward needed and desirable changes in the SDG setting. It constitutes a starting point for transformative policy, its instruments, and its initiatives. Further, it implies the creation of shared visions for a sustainable future in the long term.

3.2 Participation

This principle refers to active linking and dialog among different actors for the generation, use of and access to knowledge, and to transformative innovation that can contribute to sustainable development. The scope of this participation goes beyond receiving information, and aims to open spaces where processes of change can be influenced. Among the different actors are not only the dominant individuals, groups or entities within the socio-technical system to which the process of change is related, but also those from a variety of backgrounds who represent new potential alternatives, such as producers, civil society, users, consumers and policy makers.

Public policies should assume major responsibility for creating suitable conditions for participation, by helping actors overcome conflicts and generating greater trust in the process.

3.3 Learning and experimentation

This principle has to do with the creation of specific spaces and concrete actions for processes of reflection, and for the transmission and acquisition of knowledge and experience, which should reaffirm or reorient the directions of change and tailor public policy. These processes of reflection involve rethinking traditional ways of understanding and addressing social, economic and environmental issues, along with the comprehension and analysis of socio-technical systems.

A fundamental element related with experimentation is "niche" management, i.e. spaces in which transformative processes are created and developed on a small scale. Niche management is fundamental to explore the transformative potential of different possible paths to change, and constitutes one of the most effective vehicles for building or positioning a given practice within current socio-technical systems. For this

reason, niches should be identified and fostered over time to allow them to reach their potential.

3.4 Interdisciplinarity

This principle is understood as collaboration among different disciplines and knowledge areas in order to understand and seek solutions to complex problems, with the aim of exploring different alternatives that can generate socio-technical changes.

3.5 Anticipating outcomes and effects

This principle refers to the open evaluation and critique of the aims, motivations and intentions in processes of research and innovation, so that impacts and ethical limitations that might compromise sustainable development can be established. These exercises are carried out jointly by leaders in research or innovation processes and actors who may be affected or impacted.

Public policy plays an essential role in the promotion, incentivization and dissemination of this type of exercise.

Policy guidelines for a transformative focus

The complexities of meeting the goals proposed in the *Green Book 2030* via a new policy focus leads one to appreciate the need to work from a long-term perspective, with gradual advances on different fronts. The first of these fronts consists of opening spaces to understand the scope of a transformative focus in practical terms for all social sectors and actors. Accordingly, the first set of guidelines centers on the working methods to be incorporated, and how this focus is to be interpreted in specific settings where the greatest concerns have arisen during the process of producing the *Green Book 2030* (business sector and articulation with other public policies).

The second working front comprises the definition of specific actions that make it possible to envision potential approaches toward incorporating a transformative focus. Progress on this front will occur gradually, as the National System of STI experiments, learns and readjusts overall. In this connection, it should be remembered that only appropriate articulation and complementarity among the three policy framings, R&D and innovation systems, and transformative innovation will make it possible to advance toward meeting the SDGs with support and guidance from science, technology and innovation in the Colombian context.

4.1 Guidance for implementing the Green Book 2030

4.1.1 Working methods

Although many public policy initiatives (programs or instruments) currently under way were not designed with a transformative focus in mind, this does not mean that they lack potential or that they cannot be adapted in ways that incorporate the principles of transformative science and innovation policy. To achieve this, three working methods are suggested here; they should not be assumed to be sequential, given that each of them can be applied independently, depending on the type and scope of specific instruments or programs. Moreover, these working methods serve to stimulate, within public settings, the development of initiatives with transformative potential or that aim to solve problems related with the SDGs and that originate within civil society (“bottom up”).

Table 9. Orientation questions for the design of policy instruments and programs

Principle	Orientation questions
Directionality	How is the instrument/program/project oriented to specific social or environmental challenges, such as (for example) one of the SDGs? What alternatives were considered to address the challenge or provide solutions? Were the implications of these possible alternatives considered?
Participation	What spaces are generated to link all actors with a stake in the instrument throughout the process? What specific spaces are generated for the participation of civil society and end-users of the intended solution or change? What mechanisms have been considered to facilitate dialog and inclusion of all actors?
Learning and experimentation	What spaces are available for reflection on advances in the process of change? How are the lessons learned, failures and multifunctional inputs permanently incorporated in order to enhance the instrument/program/project? How can beliefs and ways of thinking influence the rate of change or progress toward solutions?
Interdisciplinarity	What spaces are provided for dialog among different disciplines and knowledge holders? Is the complexity of the problems acknowledged, and are they analyzed from different perspectives? Is the formation of interdisciplinary working groups promoted to develop transformative processes?
Anticipating outcomes and effects	Have the possible implications of progress toward a solution or transformation been identified at the social, environmental and economic level? Is society being informed about the possible effects, and are appropriate measures being taken? Are the possible effects being taken into account in decision making about the continuity of processes of change?

i) Deepening

This working method is applicable to initiatives already under way, whether "top down" or "bottom up", which take some of the principles of transformative policy into account, but where additional efforts could enhance their transformative potential. To this end, the responsible bodies will work to incorporate transformative policy principles that are absent or only weakly represented.

ii) Expansion

This working method is recommended for initiatives under way that have been identified as useful in solving SDG-associated problems, for purposes of demonstration. To support their expansion, bodies will work to widen the scope or coverage of the instrument, program or project, at the population, regional or national level.

iii) Acceleration

This working method is useful for initiatives with transformative potential, but in which the rate of transformation is insufficient to reach the targets set for 2030. To stimulate such initiatives, bodies will work to generate incentives or remove barriers and thus accelerate the process of change.

With regard to new policy instruments and programs, the *Green Book* seeks to ensure that they are designed with a view to applying the five principles of transformative policy. This can be done by using orientation questions such as those suggested in Table 9.

4.1.2 Managing transition

Transition management is centered on developing niches with transformative potential, and on integrating different actors in order to raise their awareness of the need for change, involving them in processes aimed at visualizing transformation and in pilot exercises or experiments.

Niches, understood as spaces in which transformative processes are managed or come about on a small scale, constitute the most basic level at which processes of change can be triggered within socio-technical systems, especially considering that the desired solutions to social, economic

and environmental problems may arise at different levels in the SNCTI and from different actors. For these reasons, niches are given particular attention in the sphere of transformative change.

As part of transition management, this policy proposes five activities which are not mutually exclusive; in fact they can be implemented in parallel and overlap with one another at different times depending on the level of maturity of a given niche, as explained below.

i) Identify areas of application or socio-technical systems targeted for transformation

Identifying which socio-technical systems to target for action is the starting point for managing transition. Several mechanisms can be used for identification, including sectoral agendas, territorial development plans, or specific exercises such as those utilized for this policy via the "Which road shall we take?" citizen consultation. Identification exercises will yield, as a result, a large variety of issues around which a strategy should be devised to stimulate and manage processes of transformative change.

Once the systems or issues that need to be addressed have been identified, existing initiatives and their level of maturity can be mapped, or pilot exercises and experiments can be designed (see subsection iii below). When strong initiatives that present options for change in current socio-technical systems cannot be mapped, transition groups can be established (see subsection ii below) as a mechanism to stimulate de novo initiatives. If more advanced initiatives have been mapped, pilot studies or experiments can be carried out (see subsection iii below), or support networks can be created (see subsection iv below).

ii) Create groups for transition

When complex problems such as the SDGs are faced, possible solutions may be incipient, fragmented or isolated; this will make it necessary to help frame them within the imaginarium of possible transformation. To this end, actors can be grouped according to their interest in exploring alternatives for change or transition in specific areas such as education, health, affordable energy, etc.

The transition groups can make progress in the creation of scenarios for transition, i.e., spaces where transformations are structured[37] by designing desirable futures along with their corresponding pathways and agendas. The latter should include actions to be carried out to advance along one or more of the previously defined pathways. In this connection, building transition groups is an exercise that makes it possible to put the policy principles into practice, e.g. directionality, by establishing desirable future scenarios; participation, by integrating different actors interested in the goals; learning and experimentation, by considering different pathways for progress toward the future scenario; interdisciplinarity, by considering the process of transition in all its dimensions; and anticipation of outcomes and effects, by choosing the most feasible and suitable pathways.

This group should be diverse, including civil society, producers, users, consumers, policy makers, and in general, agents of change[38] among its participants. This can take place not only at the national level by identifying major socio-technical systems, but also at the regional level, where partnerships can arise among different projects and actors committed to change.

iii) Perform experiments or pilots

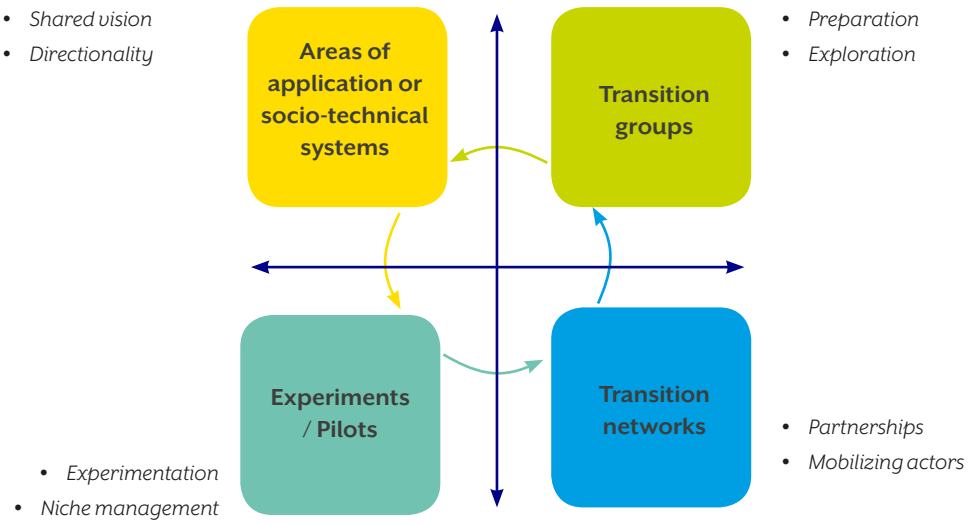
Experiments are spaces where users and designers of policies, programs and projects can interact, learn, articulate processes and build networks around technical design, user preferences,

Niches, understood as spaces where transformative processes are managed or come about on a small scale, constitute the most basic level at which processes of change can be triggered in socio-technical systems.

37 Two main tools are available to facilitate transition management: prospective and backcasting, sometimes called "retrospective".

38 Agents of change are persons or bodies that promote and enable change within a group, organization or social system.

Figure 4. Actions for transition management.



Source: Adapted from Frantzeskaki et al., 2017.

regulations, infrastructure requirements and cultural meanings[39] of desired solutions or changes.

A fundamental characteristic of experiments is that they should allow spaces for error, reflection and learning. Only in this way will they be able to generate results that are adaptable, transferable and scalable.[40] These are highly relevant aspects in the Colombian setting, with its marked diversity of regional contexts and experiences that can be transferred and then adapted.

iv) Support transition networks

These networks comprise sets of niches which may be near or far apart in spatial terms, and which share visions for the future. These networks make it possible to codify and formulate best practices, and to connect broad and diverse sets of actors through the transfer of different types of knowledge.

To build and galvanize these networks, intermediaries or mobilizers are needed, who will help to connect regionally disperse ideas and projects, bring users together and help establish new emerging systems. In addition, they can promote experiments and coordinate projects, aggregate knowledge, and aid in resource mobilization, among other tasks.

The actions described here are illustrated in Figure 4.

4.1.3 The business sector in transformative science and innovation policy

The *Green Book 2030* proposes that achieving the SDGs, from a transformative perspective, goes beyond the sectoral scope and constitutes a challenge for governments, civil society, the academy and the productive sector. In addition, it involves introducing changes at the socio-technical systems level, where goods and services provided by the business sector, along with the types of commercialization and production used, are among the essential elements in the construction of this process. In this connection, neither achieving the SDGs nor socio-technical

39 See: Rip, Arie and Kemp, René, 1998, and Geels, Frank and Raven, Robs, 2006.

40 See: Luederitz et al. 2017.

change will be possible unless there are active linkages among public and private businesses – of all sizes and in all sectors.

Regarding how the business sector in Colombia views the 2030 Agenda, the "What road shall we take?" citizen consultation showed that 92% of the nearly 18,000 entrepreneurs who responded indicated that they performed activities related with meeting the SDGs; the activities they reported most frequently were i) new sustainable business models, ii) integrating sustainability criteria into business processes and activities, and iii) cooperating with other businesses and actors to develop solutions for social and environmental issues.[41] These responses can be understood to reflect a clear willingness by the productive sector to contribute to achieving the SDGs.

In light of the above and considering, moreover, that the business sector currently participates in other national policies such as Productive Development (Desarrollo Productivo) (CONPES 3866 de 2016) and Green Growth (Crecimiento Verde), businesses and entrepreneurs are called upon to consider the following as priorities within the framework of transformative science and innovation policy:

i) Explore new business opportunities to provide solutions for problems set forth in the SDGs, by developing innovations that meet sustainability criteria and represent opportunities to diversify the system of production.

ii) Develop new sustainable business models, to put solutions into practice for SDG-related issues.

iii) Incorporate green technologies that make it possible to improve business productivity through sustainability criteria, along with responsible and sustainable business practices, not only in environmental terms but also in social and economic terms.

iv) Participate in co-constructing alternative, sustainable ways to provide goods and services, for example by interacting with different actors (users, scientists, policy makers) to develop technical designs, identify infrastructure or regulatory needs, or redefine cultural meanings, among other steps. This will help to diversify the system of production.

4.1.4 Regional deployment of transformative science and innovation policy

Regions, understood as all forms of territorial organization within the country, will play a vital role in interpreting the transformative focus in order to work together with Colciencias toward its implementation. Firstly, the proximity of actors in geographical spaces that share similar issues favors more participatory processes; this in turn facilitates the emergence of sustainable solutions that meet territorial needs. Secondly, science and innovation have gained relevance in regions as a result of specific resources allocated to strengthen them through the STI Fund of the General Royalties System.[42] In this scenario progress has been made toward the consolidation of a type of governance able to notably enhance the scientific and technological potential to achieve the SDGs from a transformative focus at the regional level, as noted below.

Achieving the SDGs, from a transformative perspective, goes beyond the sectoral scope and constitutes a challenge for governments, civil society, the academy and the productive sector.

41 Responses from entrepreneurs in the "What road shall we take?" citizen consultation, along with other actions taken, can be consulted on the Colciencias website in the "La ciencia en cifras" section, available at: http://www.colciencias.gov.co/la-ciencia-en-cifras/que-camino-cogemos/ods-empresarios

42 Law 1530 of 2012, by which the organization and functioning of the General Royalties System are regulated. Available at: https://www.sgr.gov.co/LinkClick.aspx?fileticket=EZij8T5b0Jc%3D&tabid=95&mid=517

The geographical proximity of actors with similar issues favors participatory processes that allow sustainable solutions for territorial needs to emerge.

i) The CODECTI, as organs that articulate the National System of Science, Technology and Innovation,[43] and which stand as the advisory bodies to departmental governments for the formulation, implementation and management of their STI policies (art. 2, Decree 584 of 2017),[44] ensure that different sectors of society will be represented. This favors the creation of shared visions in STI matters and greater commitment by all actors.

ii) The Departmental Strategic Plans and Agreements (Planes y Acuerdos Estratégicos Departamentales; PAED),[45] as regional planning exercises, make it possible to prioritize investments according to regional development needs, and in consonance with national STI targets, which can be interpreted in the light of the SDGs.

iii) The integrated agendas for competitiveness, science, technology and innovation, conceived as the mechanism to put into practice the aim of integrating the working agendas of the SNCTI and the National System of Competitiveness and Innovation[46] and which "contain high-priority projects of a cross-sectoral nature and sectoral priorities identified by regions to enhance the system of production",[47] are a strategic mechanism to articulate efforts by different actors toward solving issues associated with the SDGs in the territories.

4.1.5 Links with other policies

The *Green Book 2030* is connected in different ways with other development policies in the country. The main connections are with the Productive Development Policy (Política de Desarrollo Productivo), the Green Growth Mission (Misión de Crecimiento Verde) and CONPES 3918 related with the SDGs. The *Green Book 2030* shares with the Productive Development Policy the need to diversify economic activities and issues with articulation among governmental bodies and the private sector. It also shares the need to regionalize public policy in a country like Colombia, characterized by diversity, and the need to improve conditions for innovation and enterprise. To these areas the *Green Book* adds the need to view economic growth and productivity within the context of social and environmental sustainability, insofar as it considers these components to be just as important as economic sustainability. Moreover, introducing the concept of socio-technical systems broadens the policy spectrum and calls on different actors to participate in transformation, which may well be achievable through environmentally and socially responsible strategies.

The growth mission also shows that in addition to fiscal and economic policy, cross-sectional policies need to be undertaken in order to stimulate green growth at the systemic level, through innovation and research. To this end, the mission identified necessary actors related with STI for sustainable development, and also identified technical and financial instruments, including those managed by Colciencias, that favor green growth. Two important shortcomings were identified by the green growth mission: i) some of these instruments, although directly related with green growth, have not been fully developed in terms of their potential to contribute via STI; and ii) STI in the country

43 Article 19 of Law 1286 of 2009, by which Law 29 of 1990 is modified, Colciencias becomes an Administrative Department, the Colombian National System of Science, Technology and Innovation is strengthened, and additional dispositions are set forth. Available at: http://www.colciencias.gov.co/sites/default/ files/upload/reglamentacion/ley_1286_2009.pdf

44 Decree 584 of 2017, by which regulations are set forth for the Departmental Scinece, Tehcnology and Innovation Councils (CODECTI). Available at: http://www.colciencias.gov.co/normatividad/decreto-584-2017

45 The PAED are the instruments through which territories and the nation reach agreements and articulate efforts and resources to prioritize, specify and harmonize their STI plans. In addition, the PAED are intended to serve as the mechanism for prioritizing strategic and impact-generating projects for departments in harmony with national STI targets. See: http://www.colciencias.gov.co/ portafolio/gestion-territorial/planes-de-acuerdo/paeds-ctei

46 Article 186 of Law 1753 of 2015.

47 See: http://www.colombiacompetitiva.gov.co/sncei/Paginas/Agendas-Integradas-Departamentales-CCTI.aspx

lacks a concrete mission to contribute to green growth, although the potential is there. The *Green Book 2030* is a proposal for advances in these two directions: it suggests ways to design STI policies and instruments related with sustainable development, and to construct a conceptual framework for understanding the role of STI in social, economic and environmental challenges, some of which transcend the achievement of green growth.

CONPES resolution 3918, "Strategy to implement the Sustainable Development Goals (SDGs) in Colombia" (Estrategia para la implementación de los Objetivos de Desarrollo Sostenible (ODS) en Colombia), marks a national undertaking that identifies strategies to comply with the 2030 Agenda in this country. To this end, it establishes national baseline indicators and sets forth clear targets, with institutional responsibilities. In addition, it proposes stronger statistical approaches, a territorial strategy, and the need to build partnerships to meet the 2030 Agenda targets. Among these is the partnership for knowledge, to be spearheaded by Colciencias. This initiative seeks to create a space where the academy, the private sector, the government and other citizen groups build knowledge to contribute to sustainable development. In addition, the *Green Book* provides a perspective for understanding and addressing the 2030 Agenda in its entirety, by calling upon different actors and contributing working methods and organizational approaches to achieve the goals and targets.

In recent years we have seen how regions have taken the initiative to deliberate on their STI policies. For example, the Public Policy on Science, Technology and Innovation for the region of el Valle incorporates principles of sustainability. Bogotá is also developing an STI policy that includes transformative principles for sustainable development. Likewise, the Medellín policy was intended to address major challenges in three areas, e.g. (among others) energy, health, and information and communication technologies. These initiatives illustrate how concerns about sustainability and major challenges form part of the agenda in regional policies. In this connection, the *Green Book 2030* underpins this perspective and provides a framework for policy implementation at the regional level.

4.2 Policy actions

4.2.1 Adopting a transformative focus

- Colciencias will continue to participate as a member of the Transformative Innovation Policy Consortium throughout its 5-year program. Within the framework of this program, it will bring SNCTI actors to the table to advance along the following fronts: i) development of a TIPC program and research network, ii) development of capacities and capacity-building programs for transformative innovation focused on researchers and policy makers, iii) development of tools for policy experimentation, and iv) development of new practices, techniques and metrics for the evaluation of socio-technical change and transformative policy.
- Promote the systematic integration of different STI governance bodies at the national and regional level (Advisory Council on Science, Technology and Innovation (Consejo Asesor de Ciencia, Tecnología e Innovación), the National Commission on Competitiveness, Science, Technology and Innovation, CODECTI organs, and the Regional Commissions on Competitiveness (Comisiones Regionales de Competitividad), University-Business-State Committees, among others), to engage in reflections and analyses similar to those carried out in the construction of this policy (citizen consultations, panel discussions and specific studies, among

The *Green Book* adds that economic growth and productivity should be viewed within a context of social and environmental sustainability, considering these components just as important as economic sustainability.

Table 10. Working methods to guide Colciencias instruments toward a transformative focus

Instrument	Deepening	Expand	Accelerate
Fiscal benefits	✓		
Innovation systems (innovation management)	✓		
Knowledge and technology transfer (Convenio 700 and 701, cofunding, Bancoldex credit line)	✓		✓
Science ecosystem	✓		
Funding calls for applied research	✓	✓	
A Ciencia Cierta		✓	✓
Ideas para el Cambio		✓	✓
Colombia Bio		✓	

Colciencias will drive the development of initiatives with potential to contribute to socio-technical transformations, with due attention to the principles of transformative policy.

others), in order to support the implementation of the 2030 Agenda, articulate the different organizations involved, broaden understanding of the role of science and innovation in generating transformations in the setting of the SDG, and report on advances in public policy.

- Colciencias will drive the development of initiatives (both bottom up and top down) with the potential to contribute to socio-technical transformations, with due attention to the principles of transformative policy in order to incorporate the elements needed to create favorable conditions for change. To this end, in coordination with the other actors in the SNCTI, it will design and implement a new portfolio of promotional instruments to be used in meeting the needs arising from processes of socio-technical change in its various stages and dimensions.
- In order to gradually guide some of its main instruments toward a transformative focus, Colciencias determined their transformative potential based on the presence or absence of elements related with transformative policy principles. On the basis of this exercise, working methods for short- and medium-term adoption are proposed here, as detailed in Table 10.
- To enable actors in the SNCTI[48] and other governmental institutions to determine the transformative potential of their policy instruments, and to take measures to incorporate the principles of transformative policy, Colciencias will create an in-house working group to help guide these processes and build capacities in different organisms.
- Colciencias, as the organism charged with formulating, orienting, directing, coordinating, executing and implementing state STI policy,[49] should rethink how it operates and undertake institutional redesign, as a way to gain access to the tools needed to face the responsibilities and challenges of transformative policy. This institutional make-over will not only consider aspects concerned with organizational architecture, but will also focus on ensuring the availability of human capacities able to drive processes of transformative change.

48 To increase the visibility of different actors that take part in the SNCTI, in 2016, Colciencias enacted the National Policy on Actors in the National System of Science, Technology and Innovation. See: http://www.colciencias.gov.co/sites/default/files/ckeditor_files/politiciadeactores-snctei.pdf

49 Article 5, Chapter II of Law 1286 of 2009.

4.2.2 Guiding research and innovation toward the SDGs

- Colciencias, through dialog with other actors in the SNCTI and other related sectors, will help to redesign the National STI Programs related with the SDGs, in order to guide resources (human, physical and financial) toward major RDI initiatives that can leverage transformative changes for issues that have been designated as high priorities. This make-over will take into account the principles of directionality, participation, learning and experimentation, interdisciplinarity, and anticipation of outcomes and effects. Within the framework of these new national programs, 5-year agendas will be devised for scientific research, technological development and innovation, with the participation of different population groups.
- Redesign of the National STI Programs and their respective 5-year agendas should consider the organization and promotion of basic research as a basis for frontier knowledge generation, which will make it possible, in the long term, to develop innovative solutions for issues designated as high priorities in the 2030 Agenda.
- Colciencias, through dialog with actors in the SNCTI, will structure the Special Programs in Science and Innovation (Programas Especiales de Ciencia e Innovación, PECI), with the aim of articulating human, physical and financial resources to respond to regional interests with impact on a national level. The PECI will create conditions that allow economies of scale, establish connections among issues in different parts of the country, and generate links with other national science and innovation initiatives or programs.
- Colciencias will create a national program to guide research and development in frontier technologies that contribute to solutions for sustainable development problems, as set forth in the 2030 Agenda. This program will be interdisciplinary and intersectoral, and will carry out prospection exercises to explore possible areas of application, anticipate their possible effects, and reach appropriate decisions. Among other tasks, the program will consider the effective exploitation of technology transfer for national capacity development, along with mechanisms of cooperation, scientific collaboration and access to existing frontier technologies.
- Based on the principle of experimentation, Colciencias will lead the creation of transition groups in the six SDGs for which the greatest levels of concern were expressed by citizens, entrepreneurs and researchers, as a way to explore desirable and necessary transformations. These SDGs are education (4), clean water and sanitation (6), climate action (15), health and well-being (3), life on land (15) and ending poverty (1). The learning obtained from these experiments will be used as a reference to set up transition groups in other SDGs.
- Colciencias, through articulation with the other national and regional organisms that promote business innovation, will incentivize business R&D and the introduction of innovations in the setting of type 1 SDGs (SDG 3, 9, 4, 11, 6, 14, 7 and 15), aimed at helping to meet type 2 SDGs (SDG 1, 2, 5, 8, 10, 12 and 13).
- Colciencias will call on other national- and regional-level organisms to design and carry out a national program to scale up and accelerate green technologies that enhance business productivity sustainably

Colciencias, through dialog with actors in the SNCTI and other related sectors, will help to redesign the National STI Programs.

Colciencias will work to consolidate a network of researchers and transformative policy managers in science and innovation.

and help to enrich and diversify systems of production.

- To make steady advances in the adoption of a transformative focus with due appreciation for the implications of incorporating new criteria and working methods into the SNCTI, progress will be needed to explore new evaluation, follow-up and supplementary support methodologies for actors within the SNCTI, to ensure that measures are consistent with this focus.
- Colciencias will work to consolidate a network of researchers and transformative policy managers in science and innovation with three aims: i) to broaden the understanding of processes of transformative change through knowledge generation, ii) to support the implementation of a transformative focus on the regional and local levels, and among different actors, and iii) to generate spaces to reflect upon and identify good practices, as a way to simulate transformation.
- A new institutional architecture will be proposed to stimulate the growth and consolidation of existing public research institutions and centers in the country that are affiliated with or linked to different national government organisms. This architecture should consolidate its leadership in strategic areas for the solution to social, environmental and economic problems in the country, and facilitate their articulation with private centers and institutions. The structuring of a proposal for this new architecture will be coordinated by Colciencias and the participating institutions, within the framework of the National Commission of RDI Institutes.

4.2.3 Deploying a regional policy

- Colciencias will create a supplementary support strategy for the CODECTI, in order to convert them into regional leadership spaces to consolidate the transformative focus for solving social, economic and environmental challenges faced by different regions in the country. This strategy will include, among other aspects, i) the preparation of orientation documents to reinterpret and incorporate transformative policy at the department and local levels, and ii) the generation of spaces where experiences and knowledge can be exchanged among the CODECTI.
- The following recommendations are offered to regional governments, CODECTI and other regional actors who wish to become involved in the implementation of the *Green Book 2030* as a way to adopt a transformative focus at the regional level:

  - » Work to identify and interpret challenges presented by the SDGs at the territorial level, recognizing that the types of issues and levels of concern will vary from one territory to another. To this end, participatory exercises such as citizen consultations can be broadened and deepened.[50] In addition, information generated by the National Planning Department on the status of SDGs at the departmental level constitutes an important reference.[51]
  - » Incorporate meeting the SDGs via a transformative focus into science and innovation policy and regional planning instruments such as the PAED and the integrated agendas for competitiveness, science, technology and innovation, in a way that channels regional efforts toward these aims. To this end, it is anticipated that future regional STI policies will incorporate the principles and guidelines proposed in the *Green Book*. Those policies that have already been formulated

50 Department-level results for the "What road shall we take?" consultation can be viewed on the Colciencias website, in the "La ciencia en cifras" section: http://www.colciencias.gov.co/la-ciencia-en-cifras/que-camino-cogemos/ods-empresarios

51 Department-level advances in meeting national SDG goals can be consulted at: https://www.ods.gov.co/departments.

should be updated to incorporate these principles and guidelines.

» Define strategies to identify, manage and provide supplementary support for niches with transformative potential in the setting of the SDGs at the regional level, in accordance with the recommendations in section 4.1.2 (Managing transition) to include, among other aspects, the adoption or creation of specialized agents or intermediaries who work closely with different actors to carry out the followingactivities (among others): promote and guide policy experiments, connect niches, promote their growth, and mobilize resources for growth.

4.2.4 Follow-up indicators

Table 11 shows the indicators proposed to verify progress in the implementation of policy actions described here. However, this set of indicators is not yet exhaustive, insofar as there are plans to design a detailed evaluation strategy.

4.3 Guidance for science and innovation funding

Estimates by the UNO show that to achieve the 2030 Agenda goals, developing countries will need to invest approximately 4.5 trillion dollars annually. However, the estimated investment gap amounts to 2.5 trillion dollars per year, which reflects the lack of resources being devoted for this purpose (UNCTAD, 2014). Part of the resources needed corresponds to investments in STI, which have historically been low in these countries. In Colombia, investment in STI is below both the OECD average and the average for Latin America, indicating that available resources are in sufficient to bring about the transformations needed to comply with the 2030 Agenda. To implement a transformative focus, the proposals in this policy document as a way to meet the 2030 Agenda goals require considerable increases in both public and private investment. Colciencias estimates that the national investment in science, technology and innovation activities (STIA) should be at least 1.5% of the GDP by the year 2022, and 2.5% in 2030. The Colciencias budget should be at least 700 billion pesos in 2019. In addition, the share of private investment is expected to stabilize at 60% and that of public investment at 40% from 2019 onward. Table 12 summarizes these estimates.

On the basis of the figures given here, Colciencias will present to the national government

Table 11. Indicators of progress

	Indicators of progress	2021 Goal	2025 Goal	2029 Goal
Adoption of a transformative focus in the SNCTI and other related systems	Actors/bodies that adopt the five principles of transformative policy	20	40	70
	Experiments in transformative policy	7	14	50
	Citizen consultations to support decision making	2	5	10
	Proposal for the institutional make-over of Colciencias	100%	-	-
Orientation of national science and innovation to achieve SDGs	Redesign of the National Programs for STI	100%	-	-
	5-Year agendas for scientific research, technological development and innovation	5	5	5
	Support for green technologies	50	110	200
	Creation of transition groups	6	12	15
	Models for appropriate measurement and follow-up	40%	70%	100%
	Members of the network of researchers and transformative policy managers in science and innovation	30	60	100
Support deployment of a transformative focus to achieve SDGs at the territorial level	Supplementary support strategy for the CODECTI	100%	-	-
	PAED that prioritize investments to achieve the SDGs	33	33	33
	Specialized agents or intermediaries for niche support	10	15	28
	Support for transformative niches	20	50	100

Table 12. Estimated national STI investment and Colciencias budget

	2019	2022	2030
STIA as % GDP	1 %	1.5%	2.5%
Public STIA	40%	40%	40%
Private STIA	60%	60%	60%
Colciencias budget	700 billion pesos	1.5 trillion pesos	5.5 trillion pesos

Note: These estimates assume 2.5% growth in GDP for the country in 2018, 3% growth from 2019 to 2024, and 3.5% growth from 2025 to 2030. The Colciencias budget is estimated as 50% of public investment in STI actions. Source: Oficina Asesora de Planeación, Colciencias

Colciencias estimates that national investment in science, technology and innovation activities (STIA) should be at least 1.5% of the GDP by the year 2022 and 2.5% in 2030.

the estimates and proposals needed to attain these levels of investment.

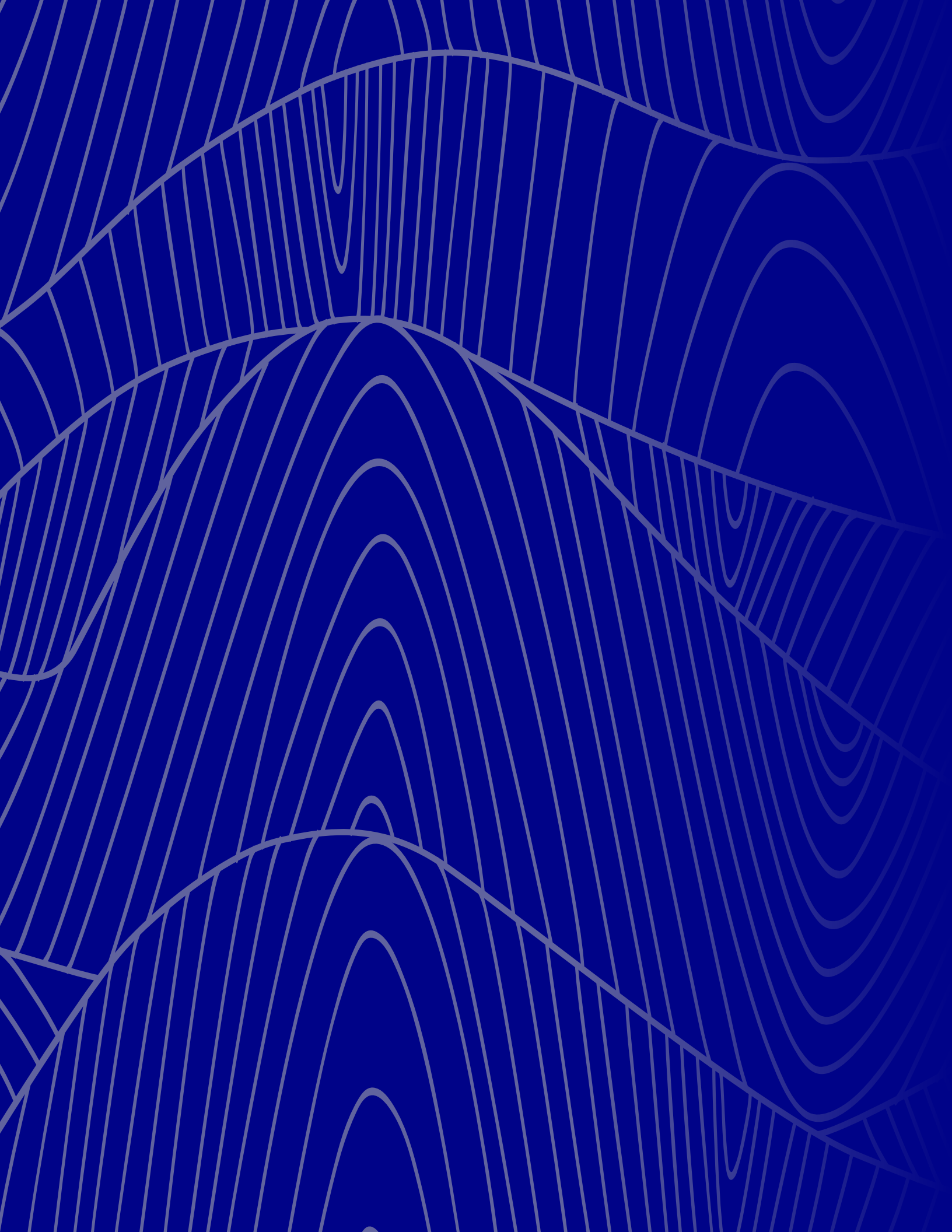
Moreover, to impart directionality to the investment of the resources detailed here, and to broaden their scope and impact, the dispositions set forth in Law 1286 of 2009 need to be enacted regarding the development of a framework for investment in science, technology and innovation, in order to make it possible to identify and articulate all resources that national government bodies will devote to STI.

4.4 Guidance for evaluating the Green Book 2030

Evaluation in the context of transformative policy is a continuing process that should serve not only to audit the use of resources and verify compliance with proposed actions and investments, but also to learn and reach decisions that enhance their implementation. An evaluation of this nature should be grounded on the goal that policy seeks to attain, which is "to guide science and innovation so that they contribute to solving the country's social, environmental and economic problems, thus acting as catalysts for change at the socio-technical level" (see Chapter 3). Accordingly, this goal constitutes the overall focus of policy evaluation.

Given that implementation of the policy proposed in the *Green Book* covers the time frame up to the year 2030, an evaluation plan should be designed that goes at least two years beyond this date. Two types of evaluation should be carried out within this period. The first is a formative evaluation with the aim of generating knowledge to enhance policy implementation. The second is a summative or outcome evaluation with the aim of examining the extent to which actions proposed in the *Green Book* have been achieved. In principle, formative evaluations should be performed in two-year cycles, while outcome evaluations should be done at three times: in spring 2022, in 2026, and in 2031.

In view of this proposal, Colciencias will design, within the framework of the TIPC and through interactions with Colombian researchers and specialists, a plan for both formative and outcome evaluations. The outcome evaluation plan should be developed to take into account how well the actions proposed in the *Green Book 2030* have been achieved, while the formative evaluation plan should focus on analyzing the processes of incorporation of public policy principles, the experiments performed, the implementation of actions for deepening, expansion and acceleration, as well as the work with transition groups. In addition, these plans should take into account the ways in which information from the evaluations will be disseminated and internalized by Colciencias and the other actors that participate in policy implementation.



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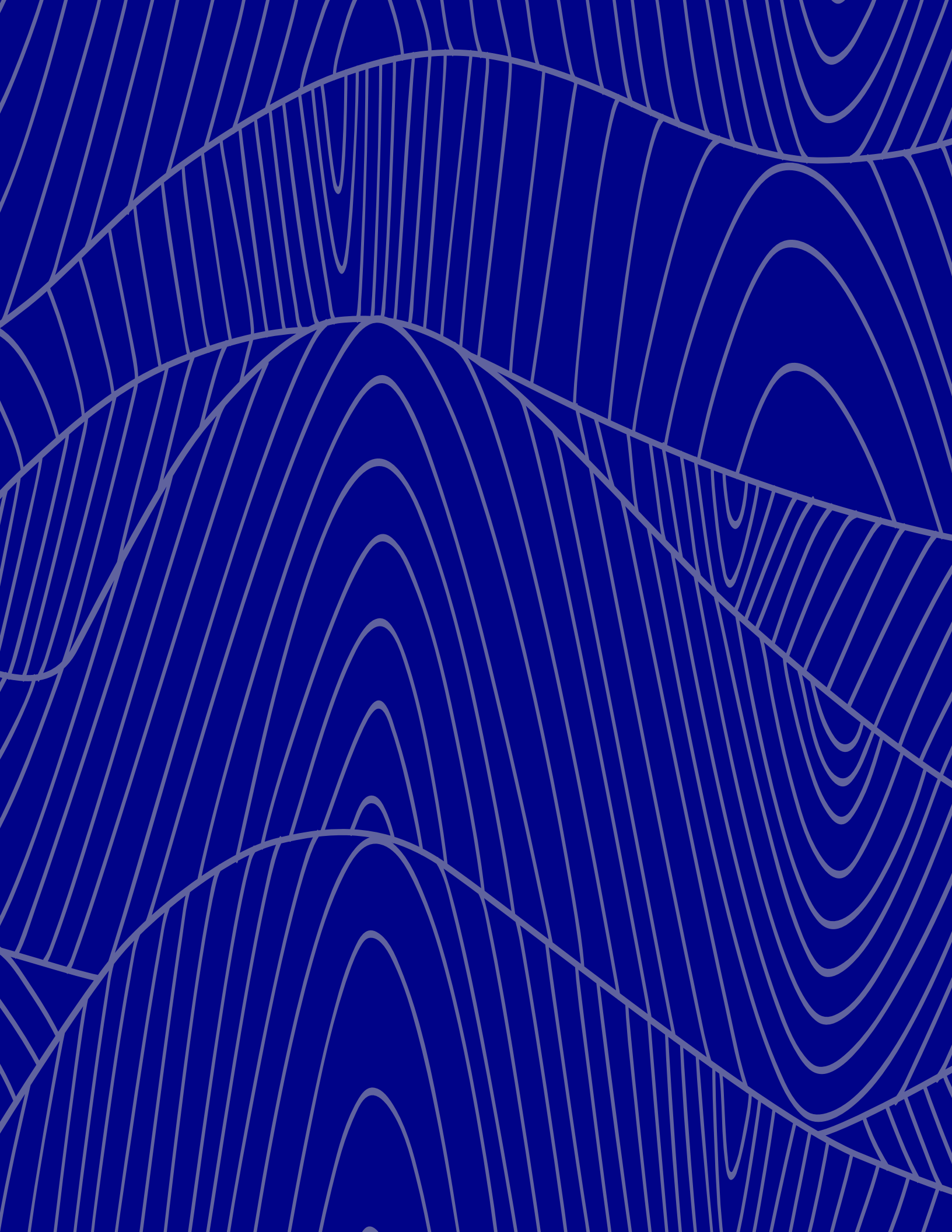
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