NATIONAL COUNCIL ON SCIENCE, TECHNOLOGY, KNOWLEDGE AND INNOVATION FOR DEVELOPMENT

SCIENCE, TECHNOLOGY, KNOWLEDGE & INNOVATION NATIONAL STRATEGY FOR THE DEVELOPMENT OF CHILE - 2022

Photograph by Gerhard Hüdepohl
https://atacamaphoto.com

Andes foothills, near Diego de Almagro, Atacama Region.

CTCI

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TECHNOLOGY, KNOWLEDGE AND
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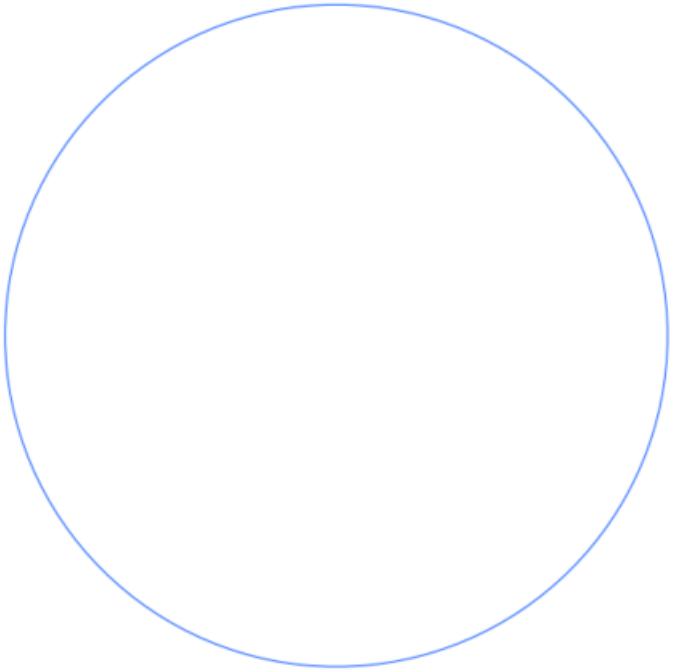
*STKI for its acronym in Spanish meaning Science, Technology, Knowledge and Innovation)
STKI for its acronym in English meaning Science, Technology, Knowledge and Innovation

The STKI Council, (STKI Council) also recognizes the members of the Transitional National Innovation Council (CNID) as participants of this Strategy: Claudia Bobadilla, Rodrigo Jordán, Bárbara Saavedra, Juan Carlos de la Llera, former Minister of STKI Andrés Couve and Lucas Palacios, former Minister of Economy.



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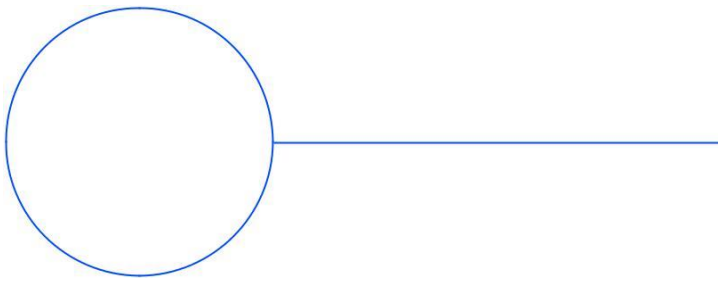

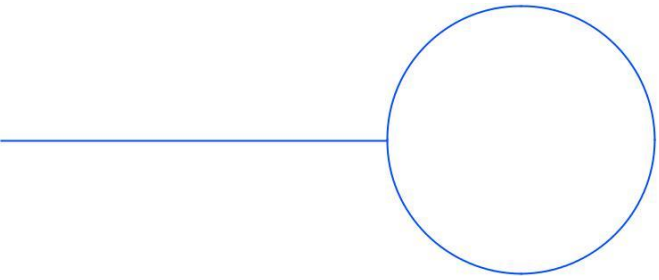

LETTER FROM THE CHAIRMAN

The Science, Technology, Knowledge and Innovation National Strategy for Development presented below is the first to be prepared within the new institutional framework for Science, Technology, Knowledge, and Innovation (STKI, for its acronym in English) which has created the corresponding Ministry. It has also created this Council as the successor of the National Council of Innovation for Development (CNID, for its acronym in Spanish).

The existence of this Council lies in the need - recognized by the Legislator - to have a strategic foundation for the decisions made in STKI, with a long-term perspective to contribute to the development of the country and its regions. Thus to provide consistency to the different governments' actions across different period in time.

The development of this Strategy began in August 2019, prior to the establishment of the final Council, which was appointed in December 2021. Until then, it operated provisionally by decree, and was formed by the Minister of STKI, Andrés Couve, the Minister of Economy, Lucas Palacios, four advisors -Juan Carlos de la Llera, Bárbara Saavedra, Rodrigo Jordán and Claudia Bobadilla - and a team of six people that make up the Executive Secretary and the undersigned President.

According to the decree that gave life to the current Council, the National STKI Strategy must be delivered to the incoming President during the month of May of his first year in office, in this case May 2022. Hence, the new Council had to lean on the discussions, interviews, workshops, consultations and documents that the transitional Council had conducted during the previous 28 months, specifically, the STKI White Paper (2019) and the Strategy's Base Line (2021). Despite the limited time available, work has been intense and based on what had previously been done, adding more meetings, discussions and consultations since the start of the new Council, the text delivered hereby has emerged. It is my duty to acknowledge the effort made by this Council to undertake this task under said circumstances and appreciate the extraordinary and permanent support of the team led by Katherine Villarroel in all the required matters.

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Flavio Salazar
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Isabel Behncke
Loreto Bravo
Verónica Cabezas
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Since this Strategy is the first one prepared within the new institutional framework, it is conceived foundational: it collects and emphasizes concepts on which a relative global consensus has already been generated, so the future Councils can focus on those aspects that, in their opinion, deserve greater attention.

This document harnesses the accumulated work of this very Council in its previous versions and collects the contribution of many people who share the common dream of a better country for its inhabitants. It highlights those issues that are considered particularly important for the development of STKI: its decisive contribution to value creation in the country, positively impacting the welfare and progress of its inhabitants; its use as a critical tool to preserve ecosystems and existing biodiversity, the ultimate sustenance of human life. It emphasises the role of a critical and democratic reflection to which STKI can contribute so that modes of coexistence and social organization achieve the purpose of equity and inclusion which the country aims at.

Thus, the institutional process begins according to the law, focused on drawing up a STKI four-year National Strategy for Development that will serve as guide for the incoming government to develop its policies in this area. The purpose of this Strategy is to stimulate a reflection and encourage actions that will transform the STKI into an essential part of Chile's identity, thus becoming a source of national pride and a pillar of its international positioning.

We are convinced that Chile has what it takes to fulfill this goal.

Álvaro Fischer Abeliuk

Chairman
National Council of Science, Technology, Knowledge and Innovation for Development.
Santiago, May 2022

EXECUTIVE SUMMARY

SCIENCE, TECHNOLOGY, KNOWLEDGE AND INNOVATION NATIONAL STRATEGY FOR THE DEVELOPMENT OF CHILE - 2022

This Strategy -the first since the enactment of the law creating the Ministry of STKI (for its acronym in English) and this Council- has a foundational vocation based on its conceptual framework and the Vision and Purpose guiding its content.

The set-out Vision -*Chile, a country that sustainably and integrally generates development and well-being supported by a Knowledge Society*- is based on the fact that in the XXI century knowledge in its various forms, pervades the vast majority of society expressions.

Its Purpose, "*that Science, Technology, Knowledge and Innovation (STKI) become a fundamental pillar of society to promote value creation understood in its broadest sense, contributing to the preservation of the biosphere, its ecosystems and biodiversity, and to the development of an inclusive and ethical society*," seeks to achieve development and thus satisfy the population's individual and collective goals, for which STKII is crucial.

Said vision is also responsible for guiding this development towards a direction that preserves the physical and biological substratum - ecosystems and biodiversity - on which human life stands, a relevant issue given the looming threats. In turn, it acknowledges that the above must inevitably incorporate the democratic debate that society makes on its forms of coexistence and social organization, so that it guides them, based on ethical principles, towards inclusion and equity. The disciplines associated to the Social Sciences and research in Arts and Humanities, integrated in the STKI are also very important.

To move forward with a Strategy of this kind, it is essential for society to promote a STKI Ecosystem with conviction and perseverance. Said Ecosystem consists of a set of institutions performing research and promoting STKI

activities, governmental and non-governmental organizations supporting them, local and national knowledge systems, companies of varied sizes, universities and educational centers, among many others. Said Ecosystem constitutes a complex network of hubs and their interactions, whose activities, with different purposes and interests are intertwined. This interaction promotes the creation, exchange, and transfer of knowledge. It is within this process that the relevant value for society as a whole is created and emerges. The essential attributes are the diversity of disciplines and activities it contains, the strength of the connection between its nodes, the network logic underlying its operation and a strong link with the needs of society during operation. Additionally, it is crucial to have the required human skills for this to occur.

This Strategy delivers a series of directives and guidelines to strengthen the STKI Ecosystem. Public awareness of the contribution that STKI can make is required to promote the country's development and social welfare. Thus the interaction between the ecosystem and society provides virtuous feedback.

To delve into the multiplicity of disciplines that the ecosystem promotes and the diversity of roles and trajectories that those who participate in it is fundamental. Likewise, international bonds must be strengthened to achieve a critical mass and reach the scale required to make significant contributions, taking advantage of the country's territorial singularities.

It is important to enhance the territories' value through Regional CTI Strategies that are harmoniously articulated and that contribute to the National Strategy. This requires an administrative decentralisation for the decision-making process and a de-concentration of skills in the generation and use of knowledge, without implying a fragmentation of efforts or loss of purpose unity.

There is no doubt that a permanent reinforcement of the resources allocated to the STKI Ecosystem is part of this Strategy to provide its different components greater robustness, quality and relevance. Among them is the permanent generation of knowledge and technological development providing the necessary conditions for its permanent deployment and recognising its crucial role in the contemporary world. Also, to continue and strengthen innovation and entrepreneurship as activities whose impact on the creation of value is more intricately connected to the population's needs and goals and which currently play a critical role for the major transformations that society is facing. Additionally, to highlight the crucial role played by Social Sciences and research in Arts and Humanities, as mentioned above strengthens their contributions to the country's development.

Last of all, this Strategy proposes five Catalysts for the Vision that act as accelerators of STKI's transformative capacity to achieve the proposed Purpose:

1. STKI is part of a Country Narrative that makes sense to its people to generate both an internal and global identity based on Chile´s unique and particular conditions so that the country can attract world-class science and innovative technology. This will provide STKI the necessary enhancement to promote the country's development.

2. STKI is supporting the country's challenges and the needs of its inhabitants. There are numerous national challenges, whose solutions may also be exported to the world. These require multidisciplinary efforts and boosters of the entire ecosystem, in order to advance the transformations that the country and its people require. The Strategy provides several examples, such as the development of clean energy, focusing on water issues, boosting resilience to natural disasters, promoting healthy eating, and to address migration challenges, inclusion, or population aging, among many others. For all of them, STKI is primal.

3. STKI is a key in achieving the sustainability of ecosystems and the preservation of biodiversity, in an endangered world that has to fear for the future of humanity. Said challenges have to be tackled by STKI , to cause a huge energising impact on the entire STKI Ecosystem and on the value creation in innovative directions.

4. The role that STKI can play in public-private complementation needs to be powered vigorously. Just as the public sector has a unique role in knowledge generation processes and the promotion of technological innovations, the private sector plays a key part in bringing these results closer to society through productive implementation. Taking advantage of the capabilities of both and highlighting their roles will enhance the STKI in ways that have not been accurately assessed so far.

5. Education in STKI and STKI in Education is a fundamental development pillar. It is not feasible to achieve the objectives set forth in this Strategy

without boosting the education of future Chilean generations, increasingly interconnecting them with STKI and its progress.

The country is at a crossroad of institutional revision for which STKI can provide a realm to calm tensions and support a renewed consensus of purpose. A vision of the future sustained by the effective tools that knowledge provides, energising its citizens' creative forces to materialise their goals.

May 2022.

Photograph by María José Pedraza, Image representing the Chile Foundation.

La Moneda Palace,
Santiago Metropolitan Region, Chile.

SCIENCE, TECHNOLOGY AND INNOVATION NATIONAL STRATEGY OUTLINE

CHAPTER 1. VISION AND PURPOSE

VISION	Chile, a country that generates development and welfare in a sustainable and comprehensive manner based on a Knowledge Society.
PURPOSE	That Science, Technology, Knowledge and Innovation (STKI) become a fundamental pillar of society to promote the creation of value, understood in a broad sense, contributing to the conservation of the biosphere, its ecosystems and biodiversity and to the development of an inclusive and ethical society.

CHAPTER 2. STKI ECOSYSTEM

2.1. DESCRIPTION AND OPERATION OF THE ECOSYSTEM	The joint interaction of Science, Technology, Knowledge and Innovation constitute the Ecosystem in which knowledge is generated and transferred for the society's benefit. This requires that the different participating actors and different nodes of the Ecosystem be properly inserted in the social system. 2.1.1. KNOWLEDGE FLOW The flow, exchange and transfer of knowledge among its nodes based on the different purposes and interests of its actors in the most diverse combinations and within the regulatory and ethical frameworks established by society is essential to the STKI. 2.1.2. CRITICAL MASSES The STKI Ecosystem requires a critical mass of actors, both in quantity and in diversity of disciplines, skills, and roles, which allow a combining burst of connections. 2.1.3. THE ROLE OF THE PUBLIC AND PRIVATE SECTOR The State has the mission of fostering and promoting the generation and transfer of knowledge, ensuring its access as a common good and promoting its contribution to the country's development. The private sector is a required complement to the above to make it available to society and benefit its population.

CHAPTER 3. DIRECTIONS AND GUIDELINES FOR STRENGTHENING THE STKI ECOSYSTEM

3.1 EXPANDING CONVERGING ASPECTS OF THE STKI ECOSYSTEM	The contribution of STKI to social welfare and the citizens' understanding of its relevance and impact on their lives generates a virtuous circle for the country's development. 3.1.1 DIVERSE STKI, CONNECTED TO THE WORLD • Promote the development of a multiplicity of disciplines. • Encourage a diversity of roles, career plans and interactions of the people involved in STKI. • Take advantage of the STKI results as evidence for the State in generating public policies and laws. • Create international connections that facilitate a critical mass and reach the required scale to make significant contributions. • Take advantage of Chile's territorial and geographic characteristics to generate international alliances. 3.1.2 STKI TO HIGHLIGHT THE VALUE OF THE TERRITORIES • Integrate the regional strategies, contributing to the STKI National Strategy for a harmonious development. • Promote administrative decentralization for the decision-making processes and the breaking-up of capacities at the generation and use of knowledge. • Create value linked to the territories' natural and cultural heritage, reinforcing their identities.

3.2 THE BOOST REQUIRED BY STKI ECOSYSTEM's DIFFERENT COMPONENTS	Recognize and enhance the relevance of permanent investment in STKI. 3.2.1 SUSTAINED PRODUCTION OF KNOWLEDGE AND TECHNOLOGICAL DEVELOPMENT • Strengthen the national educational system for people dedicated to STKI, supplemented with international education. • Ensure a balanced financing system between a competitive and baseline approach that enhances STKI and its capabilities over time in a balanced manner. • Boost associative research, strengthening the role of scientific and technological centres and ITPs (acronym in Spanish meaning Professional Institute of Technology). • Promote technological development through multidisciplinary projects that link supply and demand, national challenges and the generation of transformative enabling technologies. 3.2.2 SCIENTIFIC-TECHNOLOGICAL INNOVATION AND ENTREPRENEURSHIP AS DRIVERS OF ECONOMIC DEVELOPMENT • Take advantage of scientific-technological innovation and entrepreneurship for a sustainable transformation of productive processes and systems (sector challenges). • Use innovation to generate new value proposals based on knowledge (natural laboratories). • Enable productivity leaps through technological adoption and entrepreneurship. 3.2.3 ARTS AND HUMANITIES RESEARCH, SOCIAL SCIENCES AND THEIR ROLE AT STKI • To recognize and value research in Arts and Humanities, as well as in the social, natural and exact sciences, ensuring rules that acknowledge their distinct nature and encourage their multidisciplinary integration. • Promote and encourage the development of Social Sciences and research in Arts and Humanities, interconnected with CTCE (for its acronym in Spanish meaning Science, Technology, Innovation, and Entrepreneurship), jointly forming the STKI Ecosystem.

1.1. KNOWLEDGE SOCIETY	Society in which knowledge penetrates every aspect of human life.
1.2. VALUE CREATION	Understood as everything considered valuable that contributes to individual and collective welfare.
1.3. SUSTAINABILITY AND PRESERVATION OF BIO-SPHERE AND ITS ECO-SYSTEMS	The need to sustain the societies' development and welfare, preserving the biosphere - its ecosystems and biodiversity – this threat being humanity's greatest challenge.
1.4. INCLUSIVE AND ETHICAL SOCIETY	Result of a democratic reflection on social coexistence, geared towards equity and inclusion, based on ethical foundations.

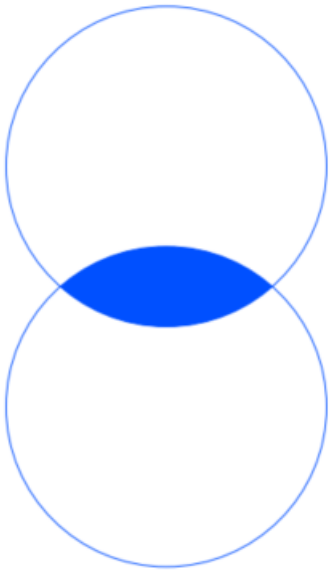
2.2. ECOSYSTEM ROBUSTNESS AND DENSITY	The STKI Ecosystem's robustness and density is based on the following attributes: its diversity, the links between its nodes, its network structure and bond with the society at large.
2.3. STKI's ECOSYSTEM AND HUMAN SKILLS	The Ecosystem is a vast network of researchers, technicians, disseminators, entrepreneurs among others, who are an important part of the country's human capabilities, the Ecosystem's basic pillar.

CHAPTER 4. VISION CATALYSTS

4.1. STKI WITHIN A CHILE NARRATIVE THAT MAKES SENSE TO ITS PEOPLE THAT STRENGTHENS ITS DOMESTIC AND INTERNATIONAL IDENTITY.	Generate a narrative where STKI is part of the country's identity: – Based on the domestic territory's unique characteristics as an attractor of world-class science and state-of-the-art technologies. – Transforming it into a source of pride and international positioning. – Integrating STKI into different social spaces, providing understanding, reflection and innovation improving life quality and achieving a sustainable and inclusive development.
4.2 STKI SERVICING NATIONAL CHALLENGES AND CITIZENS' NEEDS	• Create an institutional capacity to define, prioritize and address long-term challenges that organise STKI's contribution. • To have a body that, based on said challenges, defines specific missions.
4.3. STKI DECISIVELY CONTRIBUTING TO SUSTAINABILITY OF ECOSYSTEMS AND BIODIVERSITY PRESERVATION	• Introduce innovative technologies that mitigate environmental damage, restore degraded ecosystems and promote a circular economy. • Promote the ecosystems' sustainability and biodiversity preservation through different initiatives and projects. • Promote methodologies that measure and help preserve the "natural capital" when deciding on development.
4.4. PUBLIC-PRIVATE COMPLEMENTATION TO ENHANCE STKI's TRANSFORMATIVE ROLE	• Promote an integration between the public sector, the private sector and the academy: – Leveraging each other's abilities in multilateral development challenges. – To address National Challenges and technological missions. – Achievement of Sustainable Development Goals.
4.5. EDUCATION IN STKI AND STKI IN EDUCATION	• Promote an education that emphasises the role of imagination, curiosity and critical thinking based on a more reflective and innovative society that values STKI. • Promote an alliance of the STKI Ecosystem with the world of Education at all levels.

Photograph by Gerhard Hüdepohl.
https://atacamaphoto.com

Paranal Observatory.
Antofagasta Region, Chile.



CHAPTER 1

VISION AND PURPOSE

VISION

Chile, a country that generates sustainable and comprehensive development based on a Knowledge Society.

PURPOSE

That Science, Technology, Knowledge and Innovation (STKI) become a fundamental pillar of society to promote the creation of value in a broad sense thus contributing to the preservation of the biosphere, its ecosystems and biodiversity and to the development of an inclusive and ethical society.

The **Strategy**'s **Vision** is the full incorporation of the country into a **Knowledge Society** to achieve a sustainable and integral development based on knowledge for the benefit of its inhabitants through value creation. This knowledge must also be geared towards the **preservation of the biosphere**, which sustains human life. It must also be committed to achieving an **inclusive society** as the result of a permanent **critical reflection** based on **fundamental ethical** considerations.

Its **purpose** is to **strengthen** and **expand SKTI**, so that its contribution to **value creation**, understood in its broadest sense, contributes to the **welfare** of society as a whole. As a result, it considers the need to **improve and expand** the general conditions under which STKI and its participants operate. The greater value generated hereby will attract the necessary resources to continue this process, giving rise to **virtuous feedback** that will lead to the ideal scenario set forth in the Vision.

Photograph by Gerhard Hüdepohl.
https://atacamaphoto.com

Los Puquios Lake,
Llamará Salt Lake,

Tarapacá Region, Chile.

Photograph by Juan Ernesto Jaeger,
Imagen de Chile Foundation.

Nevados de Sollipulli.
La Araucanía Region, Chile.

1.1.
KNOWLEDGE SOCIETY

Knowledge Society is a concept that reflects the ubiquitous nature of knowledge and its influence on all spheres of human life. It is embedded in the **goods and services** that a society produces and that people exchange. It is set up in the different modalities that people use to **mobilize, communicate or associate**. It is implicit in the growing options for **artistic, cultural and sports recreation** in which citizens can engage. It is part of the **link with the history** and **heritage** of societies, and constitutes the cornerstone of their **philosophical reflections**, **ethical deliberations** and **creative expressions**.

Traditionally, progress towards this type of society has been sought through strategies that integrate Science, Technology and Innovation as sources of knowledge. Entrepreneurship is added to put the above into practice. This Strategy integrates and considers, as additional critical knowledge, research in **Arts and Humanities** and **Social Sciences**, whose directions, methodologies and objectives are more oriented to **normative, interpretative, expressive or creative** propositions, thus expanding the previous scope to now include Science, Technology, Knowledge and Innovation (**STKI**).

1. Regarding ancestral knowledge, advisor Andrés Antivil Álvarez, in collaboration with advisor Bárbara Saavedra, produced a paper with their vision, to be found in the STKI Council Document platform: https://docs.consejoSTKI.cl/documento/los-conocimientos-tradicionales-y-saberes-ancestrales-de-los-pueblos-indigenas-de-chile/.

SOCIETY, SCIENTIFIC KNOWLEDGE, AND ANCESTRAL KNOWLEDGE[1]

Knowledge, the cornerstone of this Strategy, has been built throughout history by carefully observing the environment. Or else it is incorporated into the forms of social organization and of interaction that people use.

However, the accelerated value creation observed in the last centuries and particularly in recent decades, is fundamentally associated with knowledge derived from the scientific method and its applications. Nevertheless, it also seeks to include knowledge gleaned from other cultural processes.

In this sense, the need to enrich scientific knowledge from other sources has opened a space for a modern cross-disciplinary and cross-cultural approach. Even so, the epistemological validity of the scientific method is based on the thoroughness of its observations, systematization of its corroborating experiments and institutionalized criticism to which it submits its conclusions.

The knowledge of Indigenous people and their ancestral worldviews is characterized by their practical dimension of territorial entrenchment, its collective character, its lineage or historical origin, its oral-linguistic intergenerational tradition and its cultural matrix. Although its generation has methodological and epistemological differences, it has a potential validity for the rest of the population and can be applied for social benefit. If its use is to be extended beyond a specific cultural group, this potential must be corroborated by scientific methods, for instance, in certain health treatments or special properties of certain materials. In that case, such applications should be recognized and adequately compensated to those who are their collective owners.

Likewise, other cultural forms accumulated over time by said indigenous people, be it linguistic distinctions, philosophical formulations, world views or ways of living together and using the territory, constitute an enriching knowledge for contemporary societies. It is up to society as a whole to collect these cultural forms through careful recordings, with the help of their performers. If it is possible to systematically identify the generated value addition, and after discussing and critically reflecting, these enriching lessons will be incorporated into the heritage of a society as a whole.

There is space for learning about the ancestral knowledge and wisdom of indigenous peoples, which the society should explore as a valuable contribution to better understand the world we live in and the ways we have to inhabit it. Their recognition is a future task that needs to be approached through dialogue and mutual understanding.

1.2.
VALUE CREATION

A common feature of **human history** has been the persistent **creation** and **increase of value** that people sought to make available for their communities through the production of goods and services, but also through deeper transformations of world organization and understanding. The path of human beings has been constantly shaped by creations, inventions and innovations that proved useful to people and consequently have been judged as **valuable** for **their lives** and those of others, **increasing individual or collective welfare** based on accumulated knowledge. This has been the case of **hunter-gatherers** who began to **manufacture utensils**, such as hand axes or tame fire to obtain their sustenance and protect themselves from dangers. This is still the case with the **modern inhabitants of the XXI century**, who inhabit a digital world where an analog reality coexists with a **digital** reality.

This process of gradual increase in value over time arose from the knowledge that human beings accumulated and integrated into their cultures during said period. This has been "**bundled**" in the artifacts we use in our daily lives, as well as in the interpretation and explanation we make of the natural world. Also in the ideas and conceptual frameworks that give rise to legal codes, ways of **group** - or national **organization** and **philosophical** world views that permeate our current life. In a way, this has marked the course of history and is permanently inherent to people's lives.

The **Vision** set forth in this **Strategy** seeks to align the country's development path with the establishment of a **Knowledge Society**, in which value creation is intricately linked to STKI. Likewise, it grants STKI a **fundamental role** in the **development** process that achieves the **welfare** of its inhabitants. In turn, its **Purpose** is to promote, strengthen and expand the deployment of **STKI** so that the **Value Creation** process is constructively geared towards a **Sustainable** and **Integral** development.

BOX 1_

STKI FACING A GLOBAL PANDEMIC

The corona virus (SARS COV-2) outbreak in early 2020 caused serious havoc on the health of millions of people and posed numerous challenges that could only be addressed thanks to the STKI capabilities already established in several countries, including Chile.

On the one hand and directly related to the disease, the rapid sequencing of the virus and the open communication to the scientific community allowed the manufacturing of the much-needed diagnostic kits. Likewise, our scientific community took part in the scientific and clinical development of the different vaccines approved for our population. This has proved effective to control the pandemic. Science also successfully explored innovative strategies to develop vaccines, such as mRNA and adenovirus vaccines, which allowed us to have, in less than a year, multiple options for a safe and effective vaccination; thanks to the work that science has been developing for years. It was also necessary to build or expand factories to manufacture billions of doses and thus provide safe protection to the world population. Likewise, the installed capacities for the collection and analysis of health data allowed timely evaluations. It was possible to compare the pandemic's evolution among different countries and territories and assess the results of the different treatments and preventive measures.

On the "non-health" side, the contributions of the scientific disciplines in areas such as education, economy, statistics and data science have also been particularly important. They tackled the challenges that the pandemic has imposed in these areas with new methodologies, which are so important for our society. For example, the pandemic accelerated the transition to online interaction, changing the way human, social, educational and work relationships are conducted, which is expected to remain even when the restrictions on travel and gatherings are left behind. That too is based on technology, in this case digital.

All of the above would not have been possible without a timely and decisive action and investment in multiple STKI disciplines, which, in turn, is based on a myriad of capacities previously installed in institutions and individuals in many countries.

Photograph by Max Donoso, Imagen de Chile Foundation.

Colchagua Valley. Libertador General Bernardo O'Higgins Region, Chile.

1.3. SUSTAINABILITY AND PRESERVATION OF THE BIOSPHERE AND ITS ECOSYSTEMS

The welfare of societies depends on nature and biodiversity, since its development is based on both. However, the operation of basic ecological processes required for life, including human life, is showing increasing levels of degradation, which may lead to a loss of biodiversity, hereby impacting these processes, thus establishing a perverse cycle.

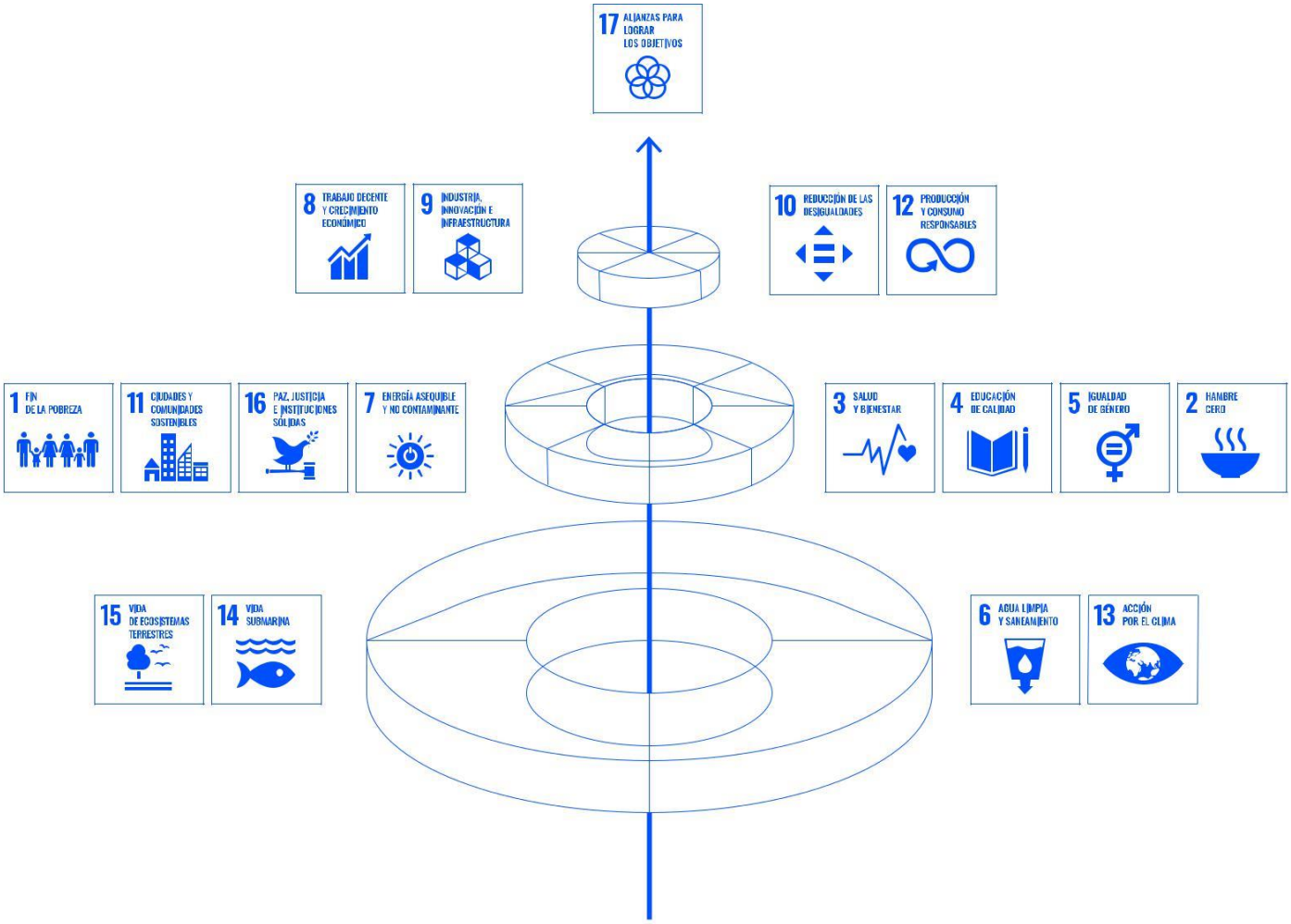
Therefore, the greatest challenge facing humanity is biosphere preservation. This includes the recovery and maintenance of its ecosystems as well as their species and populations, ensuring that the biophysical conditions of the atmosphere, hydrosphere and Earth itself required for life, be maintained. The integrity of ecosystems stems from the delicate interactions of living organisms with their physical environment whose forms and relationships are the result of evolution processes that occurred in the past and continue into the future. They are ecological, biogeochemical, related to the sustainability of tropic networks or the cycling of water, carbon or nitrogen, as well as the degradation and cycling of nutrients, among many others.

Figure 1.
ODS.
Source: Stockholm Resilience Centre, "The SDGs wedding cake" https://www.stockholmresilience.org/research/research-news/2016-06-14-the-sdgs-wedding-cake.html

Photograph by Gerhard Hüdepohl. https://atacamaphoto.com

Holanda Glacier at the Beagle Channel,

Magallanes and Chilean Antarctica Region, Chile.



17 = PARTNERSHIPS FOR THE GOALS

ECONOMÍA = ECONOMY

8 = DECENT WORK AND ECONOMIC GROWTH

9 = INDUSTRY, INNOVATION AND INFRASTRUCTURE

10 = REDUCE INEQUALITIES

12 = RESPONSIBLE CONSUMPTION AND PRODUC-TION

SOCIEDAD = SOCIETY

1 = END OF POVERTY

11 = SUSTAINABLE CITIES AND COMMUNITIES

16 = PEACE, JUSTICE AND STRONG INSTITUTIONS

4 = QUALITY EDUCATION

7 = AFFORDABLE AND CLEAN ENERGY

3 = HEALTH & WELFARE

5 = GENDER EQUALITY

2 = ZERO HUNGER

BIÓSFERA = BIOSPHERE

15 = LIFE ON LAND ECOSYSTEMS

14 = UNDERWATER LIFE

6 = CLEAN WATER AND SANITATION

13 = CLIMATE ACTION

All **human development** is based on the presence of the aforementioned biophysical relationships. Throughout history, particularly during the last three hundred years of the **Industrial Revolution**, and more rapidly during the last thirty years of the **Digital Revolution**, value creation has been sustained by a vigorous **technological development**. This has permitted to sustain the growth of world population, but at the same time it has imposed an increasing burden on the **biosphere**, changing its delicate balances and threatening the contributions that nature provides - its **ecosystem services**- which are what **sustains** human life.

This threat has **impacts** beyond the economic aspect, directly affecting **people's daily lives** in several dimensions: scarce water, zoonotic diseases or pollution among others; it even eventually puts the very **survival** of the species at risk.

One form in which this damage has already manifested is the increasing concentration of **greenhouse gases** in the atmosphere. This includes CO_2, resulting from the use of fossil fuels as an energy source and **methane**, due to cattle breeding, among other causes. Said issues trigger a **planet climate change** - a rise of its **average temperature**, **melting** of ice reserves, which raises sea levels and affects inhabited coastal areas and produces a greater frequency of **extreme weather** events. These issues make the conditions in which human communities develop more difficult, giving way to the phenomenon known as **climate change.**

Furthermore there is the loss of biodiversity as a direct result of land use transformation, mainly for agriculture and livestock as well as its pollution at large.

In the face of this vital threat the process of **value creation** based on STKI must consider that social and economic development ensure the recovery, maintenance and protection of its foundational base, the biosphere (Figure 1). Its success can only be achieved by building and taking advantage of the available knowledge and generating new, diverse and useful knowledge to that end. If, as some predict, the world population stabilizes in the second half of this century at about **ten billion** human beings, it does not seem feasible to return to **previous technological stages**, as this would seriously affect the people's life quality. The goal is to put STKI's capabilities at the service of sustainability, **creating value** that **preserves the biosphere.** This should happen through the recovery of **degraded ecosystems**, the **mitigation** of existing impacts and above all, the adaptation of society to a changing world, fostering creative, critical and ethical thinking that allows us to move towards **ways of life** in harmony with nature. This **challenge** should be at the centre of any current **STKI** strategy.

1.4.
AN INCLUSIVE AND ETHICAL SOCIETY

The development of **STKI** is a cornerstone of the **value creation** process that generates welfare. A sustainable and integral development in addition to preserving the biosphere requires building an inclusive and democratic society that cares of its people's social **welfare**. This requires **modes of coexistence** susceptible to be ethically meditated and judged, which needs a **critical reflection** capacity to seek and **discern** the alternatives that best allow us to achieve this ideal.

The **complexities** of contemporary societies demand this reflection to be conducted with the broadest possible **knowledge.** This arises largely from **Social Sciences** as well as from research in Arts **and Humanities**, since these are the disciplines, whose orientation is aimed precisely at examining **human behavior**, to characterize, represent and express its manifestations. STKI can become a meeting place between ecosystem actors, who, by opening cross-disciplinary spaces for reflection and through **democratic political deliberations** with an **ethical** perspective, build possible futures that guide development in the direction of an integral welfare.

The explicit recognition of these disciplines as members of **STKI** enriches the range of applicable knowledge required to promote a **balanced** development. They help in the assembling of a **holistic** view of community life and contribute to correct those aspects that **value creation** and **biosphere care** have neglected. Thus, the **welfare** and **progress** to which citizens aspire become compatible with the **ethical perspective** with which human beings judge their collective behavior. The development of these disciplines is therefore an integral part of this **Strategy**'s **Vision and Purpose**, thus introducing a commitment to the inclusion and dignity of people within a consistent ethical framework.

To conclude this chapter, **STKI**'s contribution to the country's development is based on its ability to **create value** for society through productive and organizational processes that do not abandon the **biosphere's preservation** and whose results are critically examined to improve the **inclusion**, **equity** and **social coexistence** of its inhabitants.

GLOBAL TRENDS

The accelerated process of change that humanity is undergoing, driven to a large extent by science and technology, can be summarized by stating that we are amidst a major **cross-cutting revolution** and simultaneously a pressing **global concern**. On the one hand, there is the **information revolution**, which is **transversal** and which occurs in two formats, **biological** and **digital**; on the other there is planet sustainability[2,3] which also occurs in two forms, **climate change** and concern for the **biosphere**, which require the joint action of all its inhabitants.

However, a distinction must be made between the two. The information revolution - digital and biological - is in itself a transformation driver. Then again, planetary sustainability - climate change and maintenance of biosphere balances - is a concern that arises from the acknowledgement of high **inertia** and **global scale** phenomena that unfold over extended time horizons and that are partly the consequence of human actions based on science and technology.[4] The digital and biological revolution is occurring with a planetary sustainability backdrop.

DIGITAL REVOLUTION

Mathematical theories have made it possible to **discretely represent** information in **digital format** and provide the required **architecture** for its **processing** in several computer platforms. This has given rise to the construction of a **digital universe** capable of representing objects of the **physical universe** and **simulating** different processes to make them more efficient or better suited to human needs, thus facilitating **communication**, **education**, and **entertainment**.

However, this revolution entails an important **discussion** regarding its **potentialities** and **risks**, among which are ownership and data use within the framework of people's **privacy**, manipulation of **individual autonomy** through **algorithms** that anticipate their expectations and preferences and the labor threat posed by **automation.**

BIOLOGICAL REVOLUTION

Modern biology explains the phenomenon of life as the physical expression of **complex organized and self-organized matter**. This has changed the contemporary **intellectual landscape** since it has allowed an understanding of the **interaction** of living organisms with their non-living environment and among each other with a **different perspective**.

In particular, it has led to the emergence of **synthetic biology**, which makes it possible to construct **artificial** vital components, different from those that naturally arise and to use them in different instances for the people's benefit. It has enabled the development of biotechnology which allows the **manipulation** of the **genetic basis** of organisms, and then combine both with other physical technologies, such as **nanotechnology**, thus opening up a fertile field of exploration for **human ingenuity** to generate value through **innovation** and **entrepreneurship**.

The **warning** for the digital revolution is even more **valid** in the case of a biological revolution since its use may endanger the **survival** of the species. The ability to genetically modify offspring by modifying the progenitors' **germ cells** by means of the **Crispr-Cas9** technique or to generate **artificial proteins** with yet unknown nucleotides require an exhaustive examination prior to their use.

Both revolutions are based on the concept of **information**: **bits** of discrete information, in the case of the former and discrete information contained in the **DNA** of living organisms in the case of the latter. For this reason, both tend to **converge** from a perspective of their understanding, expanding their mutual **combinations**, multiplying their **possibilities** of use, thereby opening up an enormous and fertile field of previously unavailable **experimenting**, **innovation** and **value creation**. This convergence also extends to **Physics**, **Chemistry**, and **Engineering**.

GLOBAL CONCERN

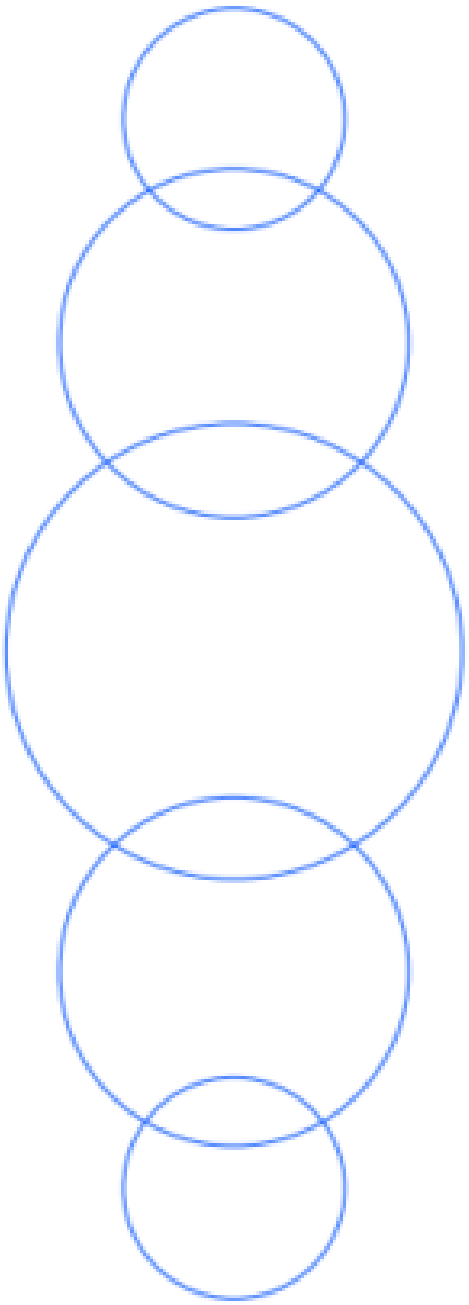
Human action, through the intensive use of **science** and **technology** and their applications in daily life, has interfered with the ecosystem services provided by the **biosphere**, which constitutes the **natural capital** on which human life is sustained. The most notorious is **climate change**, but so are the **degradation** of ecosystems and the loss of **biodiversity**, whose co-evolution must be understood in order to be able to correct its course when the sustainability of life on earth is threatened. This will require **more STKI** and not less but also a delicate and **thoughtful** use of it.

Establishing a proper interaction between both revolutions - digital and biological - as well as the need to preserve the sustainability of life will be the **scenario** under which humanity will unfold during the remainder of the century.

2. National Innovation Council for Development (2019). *Ciencia, Tecnología, Conocimiento e Innovación para Chile (Science, Technology, Knowledge, and Innovation for Chile).*
3. Álvarez, J. (2018). *Reportes de Futuro: Tres Preocupaciones Urgentes para Chile*. (*Future Reports: Three Urgent Concerns for Chile.)* National Innovation Council Innovation for Development.
4 National Innovation Council for Development (2021). *Base para la Estrategia Nacional de Ciencia, Tecnología, Conocimiento e Innovación*. *(Basis for the Science, Technology, Knowledge and Innovation National Strategy.)*

Photograph by Guy Wenborne, Imagen de Chile Foundation.

Carranza Lighthouse, Constitución. Maule Region, Chile



CHAPTER 2

STKI ECOSYSTEM

To achieve the stated **Vision** and the described **Purpose**, STKI components should be deployed individually and **intertwined**. This allows **knowledge production** - of **social** and **natural** phenomena, in addition to the critical thinking skills generated by exact and formal sciences such as mathematics, logics and computer sciences - and its **technological** application ought to be developed. From this starting point, value should be created in a broad sense and then all this be productively **implemented**. Furthermore, as already stated, it is STKI, properly oriented and encouraged, which, in today's sophisticated societies, plays a decisive role in **biosphere's equilibrium** preservation, both in its geophysical-chemical and biodiversity aspects. The social impact that all of the above entails is also to be considered. The critical reflection about the resulting society, provided mainly by Social **Sciences** and **research** in Arts and **Humanities** should contribute to tackle these challenges.

Photograph by Francisco Negroni,
Imagen de Chile Foundation.

Laguna Verde, Llaima Volcano,
Araucanía Region, Chile.

2.1. DESCRIPTION AND OPERATION OF THE ECOSYSTEM

The joint interaction of Science, Technology, Knowledge and Innovation form the **ecosystem** in which knowledge is generated and transferred to use it to the advantage of society. For this to happen it must be ensured that the actors participating in its different nodes are adequately inserted in the **social system**.

This **ecosystem** includes a set of **research institutions** and **promotion** of STKI activities, supporting **governmental** and **non-governmental** organizations, **local** and **national** knowledge systems, **companies** of varied sizes, **universities** and **educational** centres among many others. All of them constitute a complex network of **nodes** and **interactions**, whose activities, with different purposes and interests and intertwined among each other, enhance the **creation**, **exchange** and **transfer** of knowledge within them. It is in this interaction of ecosystem components that the relevant **value** for society as a whole is created and emerges.

This way the so-called **Knowledge Society** is created. Here the creation of **social value** occurs in multiple dimensions: **utilitarian**, **commercial**, **educational**, **cultural**, **sports**, **philosophical** or **artistic** thus, generating a positive impact on the population's welfare in its different areas.

As the Basis for the National STKI Strategy[5] emphasis was given on the sub-system of Science, Technology, Innovation and Entrepreneurship, the latter being science-technology based (**CTIE**), since it can productively implement what is generated in the others. Thus, the **knowledge** incorporated in the **goods** and **services** available to the population, through a **virtuous** interaction of these four pillars that **combine** and provide **feedback** in any order, generates the value that improves the population's living conditions.

In this Strategy, on the other hand, STKI is considered as a broader concept. It includes, besides **Science**, **Technology** and **Innovation**, the **Knowledge** from research in Arts and Humanities and a part of the **Social Sciences**[6], disciplines which describe, understand and interpret the human social behavior phenomena, trying to give them a **meaning** or reflect on how human life **should be** and how its **coexistence** should unfold.

5. National Innovation Council for Development (2021). *Base para la Estrategia Nacional de Ciencia, Tecnología, Conocimiento e Innovación*. (*Basis for a Science, Technology, Knowledge and Innovation National Strategy*.)

6. As explained in section 3.2.3 of chapter 3, there is a portion of the Social Sciences whose orientation is more normative than the rest, which are part of science as a whole.

2.1.1.
KNOWLEDGE FLOW

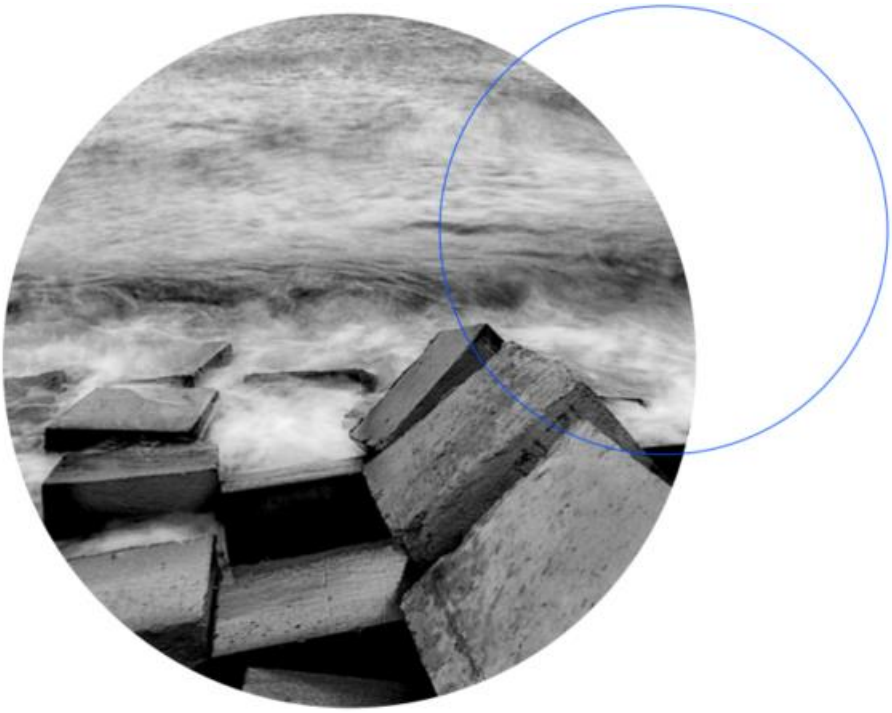
Essential in the Ecosystem is knowledge **flow**, **exchange** and **transfer** among its nodes based on its actors' different purposes and interests in the most diverse possible **combinations**, but within the **regulatory and ethical** framework established by society. Thus, knowledge can flow from those who **create** it to those who **apply** it, or from those who transform it into **innovations** that generate **value**, to **entrepreneurs**, or from all of them to those who create it, based on the new questions they pose.

Its operating logic is **non-linear**, so it is not obvious to **anticipate** how the knowledge that feeds one node is subsequently transferred into products, new questions, services or new frameworks of understanding in another node nor how these are then transformed into **tangible** and **intangible** results, let alone how all this **will impact** society and vice versa.

This characteristic means that the view of a traditional market of competitive goods and service exchange does not provide an accurate account of its operation since there are no well-established **property rights**[7], nor is there an absence of externalities, but rather there is an abundance of positive externalities[8]. For this reason and due to the positive impact that the ecosystem has on society, the **subsidies** granted are justified. Moreover, it is the existence of such subsidies that, in general, prevents the private appropriation of knowledge thus generated[9] and it is often the main reason why there are normally no **transaction prices** for such knowledge.

Photograph by Sernatur,
Imagen de Chile Foundation.

Nitrate Mine,
Tarapacá Region, Chile.



2.1.2.
CRITICAL MASSES

The ecosystem requires a **critical mass** of actors, both in terms of **quantity** and **diversity** of disciplines, **roles** and **skills levels**. This is what allows a **combined explosion** of connections and makes it possible to cover a greater variety of knowledge areas and action fields.

Additionally, to ensure that the combination of **quantity** and **diversity** does not lead to mutual antagonism, i.e. that the pursuit of diversity does not limit the development of disciplines where there is abundance and quality, a **minimum quality** threshold must be reached in new areas or disciplines to be incorporated, so that the diversity sought is combined with the required **disciplinary skill levels.** The **development** of diverse **capabilities** is important to take advantage of the territories' richness and to tackle the country's priorities.

The task of the agencies in charge of promoting the STKI Ecosystem is to ensure that resources be allocated observing the idiosyncrasy of each discipline and area of activity and the nature of the different actors ensuring the ecosystem's quality and performance as a whole. They must include mechanisms and criteria that provide flexibility to make the required modifications to close gaps, integrate improvements and adapt to new contexts.

Photograph by Rafael Chauquelaf,
Imagen de Chile Foundation.

San Antonio,
Valparaíso Region, Chile.

7. In fact, patents only appear in the later stages of the process and this is happening less frequently, their convenience being offset by the knowledge generation speed.

8. The enrichment of cultural heritage, the critical and reflective capacity of society, the capacity to anticipate scenarios, an innovative synergy based on public knowledge are all "externalities" of the STKI Ecosystem.

9. This is also supported in cases where knowledge is considered to be for the public good.

Photograph by Max Donoso,
Imagen de Chile Foundation.

Puclaro Dam, Vicuña.
Coquimbo Region, Chile.

2.1.3.
THE ROLE OF PUBLIC AND PRIVATE SECTORS

Hence, the State has the mission of promoting an ecosystem that facilitates **knowledge transfer**, which ensures **access** to knowledge as a common good and that fosters its **contribution** to the country's common good and development, even if their **positive** effects cannot be accurately anticipated. It plays a crucial role in the establishment of this ecosystem, being the main driver of **knowledge creation** and **promotion** of **technology**, **innovation** and **entrepreneurship**. Moreover, it is in the latter that the **private sector** is best positioned to participate in their deployment.

But the **State** has the additional responsibility of **providing direction** to this ecosystem so that it connects with the country's development needs and **articulates** the required abilities to achieve it.

Value creation on behalf of the **private world** depends, in turn, on the **depth**, **density** and **diversity** of the generation of knowledge and technological development promoted by the State. When this is achieved, there is a virtuous feedback between the two: the number of **science and technology-based** companies increases, which demand more public research, which then facilitates greater private participation in the ecosystem and in the long run tends to become **predominant.**

All this requires **long-term** policies that **persist** over time for which the State must have the firmly **convinced** about the value and importance of the **STKI Ecosystem** to promote the country's development. It must also provide an **institutional framework** that ensures the required **intertemporal consistency**. It is necessary as well to generate the **sociopolitical** conditions that allow this contribution to materialise, such as the rule of law, social peace, democratic institutions, political and social inclusion and institutional stability.

2.2. ECOSYSTEM ROBUSTNESS AND DENSITY

The STKI Ecosystem's robustness and density depends, among other attributes on: **diversity** within, **connection** between its nodes, **network** logic and **link** with the society in which it is inserted, proposing **societal challenges** that meet the needs of and make sense to the population. Said attributes are described below.

2.2.1. DIVERSITY

A **diverse** ecosystem is more productive, resilient and capable of adapting to emerging and unforeseen conditions. A diversity of views and interpretations, disciplines and skills, roles and trajectories, allows for cross-**fertilization** that **enriches** its work.

To achieve said diversity, it is essential that the national **education system** allow access, without discrimination, to training oriented to the **skills** of the XXI century from the **earliest childhood**. Thus, the new generations will have the opportunity to access the provided disciplines and to develop the **critical**, **creative** and **reflective** thinking required to enable them to face the **uncertain** future and the constant **change,** a typical feature of contemporary societies. It should be one of the permanent guidelines of any **National Strategy** to value the diversity of interests, knowledge, trajectories and roles of the participants in the STKI Ecosystem. Another guideline is to recognise their relevance in **adapting** to emerging and unforeseen issues.

2.2.2. CONNECTION

Human intelligence is set to face unprecedented changes, in alliances that go beyond disciplinary, professional and local distances. In this sense, it is the **interaction** between the different institutional actors and people who participate in STKI that multiply the options for creating value and addressing uncertainty in an arena that is global. There are also diverse forms of **complex** and **sophisticated** interactions that need to be recognised, encouraging **multi/inter/cross-disciplinary** work. Connection places facilitate the exchange of tacit[10] and explicit domestic and global knowledge and foster **serendipity** and **randomness** so that there are more **improbable encounters** and more **virtuous convergences**.

10. Refers to the knowledge people have acquired through training or work experience. By its very nature it is a complex type of knowledge that is acquired through empirical interactions.

2.2.3.
NETWORK LOGIC

Robust systems have the capacity to withstand significant disturbances without losing functionality and become resilient. To achieve this, a **distributed** structure contextualized to its **territories** is required enabling several alternate "paths" from which the system can manage its processes, thus generating sustained skills over time (Illustration 1).

In this sense, the STKI Ecosystem's robustness depends, to a large extent, on the way in which its connection networks are structured.

2.2.4.
CONNECTING WITH SOCIETY

STKI is not developed in isolation. It is inserted in a **social**, **cultural** and **territorial** context that shapes it and on which it has an impact. Therefore, the **connection** that STKI achieves with society is **critical**. For society to socially and politically appreciate and **legitimise** the ecosystem's operation and activity, the issues it addresses must be relevant. In other words, for the relationship between the **STKI Ecosystem** and **Society** to be fruitful, it must be **bidirectional**.

Identifying and addressing **societal challenges**, the STKI community and society must act jointly within a **balance** that addresses the **urgent** needs with a long-term view. This implies recognising the voices of the different existing communities as **legitimate**: local, civil society, business world, art world and **indigenous people** as well, where we have a major gap. The contribution of STKI is **enriched** if it is integrated into a **dialogue** with the environment, which makes its **contributions** more relevant, and will therefore be perceived as closer to the environment's **needs**.

This holistic view is also required to address ethical dilemmas. Here the contribution of **Arts** and **Humanities** and **Social Sciences** is especially critical. This requires nurturing social interaction of **distinctive human acts** such as asking questions, exploring, seeking evidence, discovering and learning.

This does not mean that the STKI Ecosystem activity is governed by the circumstantial demands posed by **citizens.** What is rather being sought is that beyond its normal activities, the ecosystem maintains as its **ultimate purpose,** as a **vision of the future**, a close **connection** with society and its major **issues**, so that it understands and values its contribution, along with benefiting from it.

2.3.
THE STKI ECOSYSTEM AND HUMAN SKILLS

The **STKI Ecosystem** is not only a structure of nodes and connections in which these components interact but, above all, it is a vast network of **researchers**, **technicians**, **disseminators**, **innovators** and **entrepreneurs**, among others, that jointly constitute an important part of the country's **human skills**, whether they be **technical** or **advanced.**

For this reason, any effort made to **promote**, **improve** or **delve into** knowledge transfer in the ecosystem – on behalf of both **CTIE** and **STKI -** and thus boost the **generation of value** in the country and its regions, must necessarily be accompanied by the development of **human skills**. That talent increasingly requires better prepared actors, with **specialisation** and **master's degree** in their respective areas and disciplines. This goes for the cases when the areas are more academic or need to have **experience** in **innovative process** implementation, if we speak about companies of production or other types of organisations. This also requires cultivating, from an early age, a critical, creative and reflective mentality in such a manner that said processes can be fully integrated into the different areas of society.

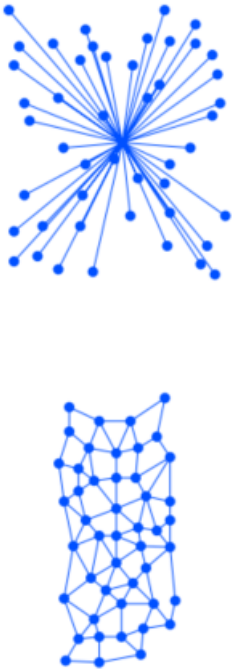
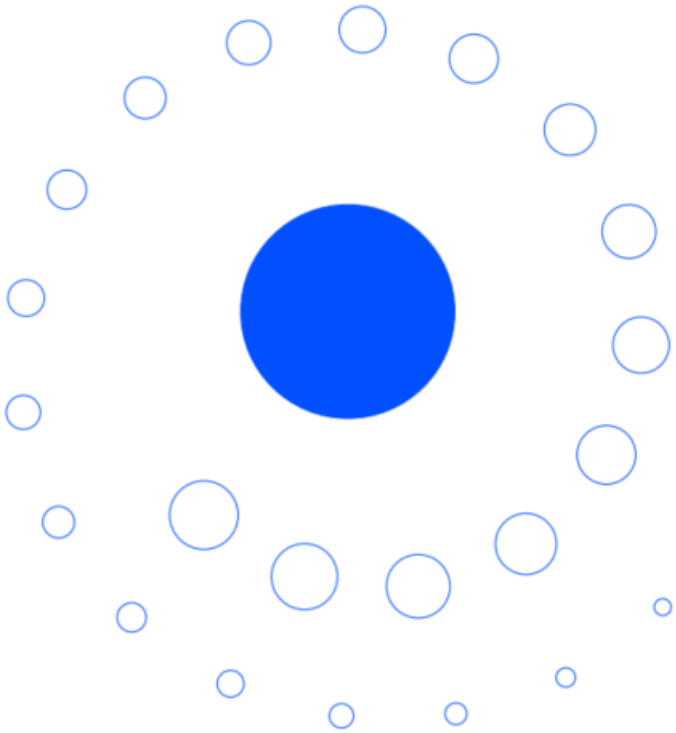


Illustration 1.
Centralised vs. distributed structure.
Source: NCID, 2017.

Photograph by María José Pedraza,
Imagen de Chile Foundation.

Santiago Aerial Tramway,
Santiago Metropolitan Region,
Chile.



CHAPTER 3

DIRECTIVES AND GUIDELINES TO STRENGTHEN THE STKI ECOSYSTEM

This third chapter presents **directives and guidelines** to advance in the **strengthening** and **deepening** of the STKI Ecosystem. These guidelines seek to strengthen the **connections of its nodes**, intensify its **knowledge transfer** processes, strengthen its **human skills** and add **new nodes** to broaden its scope. Thus, the creation of value arising from all this will accelerate the country's full development and increase its inhabitants' **welfare** and **life quality**.

Said directions are divided into two groups: those related to the **expansion** of transversal aspects of the STKI Ecosystem and those related to the **promotion** of its **components**.

Photograph by Carlos Roth,
Imagen de Chile Foundation.

Araucanía Region, Chile.

11. The White Paper "STKI para Chile" ("STKI para Chile") (2019) and "Base para la Estrategia de STKI" ("Basis for a STKI Strategy") (2021), - both documents written by the Council - highlight the relevance that STKI has had for the society over time.

12. Ministry of STKI (2021).
Política Nacional de Igualdad de Género en STKI. Ministerio de STKI de Chile. (National Policy on Gender Equality in STKI. Ministry of STKI of Chile.)

3.1. DELVING INTO THE STKI ECOSYSTEM's TRANSVERSAL ASPECTS

One of the major transversal issues that need to be addressed in greater depth is the link between the STKI Ecosystem and society so that the latter contributes decisively to its development and welfare. This requires, on one hand that citizens understand the **relevance** and impact that it has on their lives, and on the other hand that STKI be **integrated** in the **society**, recognizing its **diversity** and **heterogeneity**, contributing explicitly to its **social**, **economic** and **environmental** challenges. This generates a virtuous circle. The **value creation provided** by the STKI strengthens its understanding and **social adoption;** this increases the legitimacy of the country's investment into it. And it strengthens the ecosystem, driving in turn new value generation and **resetting** the cycle. All this needs to be accompanied by a **long-term political decision** to sustain this virtuous circle over time.[11]

In this context, it is essential that STKI be integrated in the educational training **throughout life**, influencing all its cycles. This contributes to the development of skills based on **critical** and reflective **thinking** in students, fostering their **curiosity** to understand the outside world with the **preciseness** that science leads to, and encouraging creative and innovative behavior paths throughout their professional lives.

Another relevant transversal aspect is to incorporate the demands of today's society into STKI's operation.

Mainly to address the gender gap by removing the barriers that have prevented **women** from participating under equal terms as this constitutes an ethical duty of inclusion which enriches the ecosystem with the talent of all people[12]. Subsequently, ensure the **working conditions** of those who work in these activities, which includes not only researchers in their different roles, but collaborators as well. Lastly, to have **ethical frameworks** to guide their conduct,[13] paying particular attention to those areas related to the **reconfiguration of life**, promoting the required ethical debates on the impact that these scientific-technological developments may have on the future of the human project.

Additionally, there are two other critical issues that cut across the entire STKI Ecosystem and which special attention should be given. The first is to have a **diverse** and **connected** STKI, both domestically and globally and the second is to contribute to the enhancement of the **territories**' value, highlighting their natural and cultural heritage and strengthening their identities.

13. They refer, among others, to research quality assurance; honesty in communicating research in a transparent, fair, full, and impartial manner; respect for colleagues, research participants, including animals, society, ecosystems, cultural heritage, and the environment; and research accountability from the initial concept to publication, and for its broader impacts on society. (ALLEA, 2017; Council on Governmental Relations, 2019).

Photograph by Max Donoso,
Chile Foundation Image.

City of Valdivia,
De Los Ríos Region, Chile.

3.1.1.
A DIVERSE STKI CONNECTED TO THE WORLD

Given the **complexity** of **today**'s challenges, diversity and interaction, properly connected domestically, globally and with the society, are fundamental.

Regarding diversity, as already stated, there must be a **multiplicity of disciplines** within the ecosystem, whose **cross-fertilization** enriches it as a whole.

Additionally, to overcome the rigid and pre-established ways in which the roles and career paths of the people domestically involved in STKI, have been understood, it is essential to expand and diversify them. Such diversity and the **multiple interactions** that it admits allow for a variety of options to integrate knowledge in different areas of society and thus provide the STKI Ecosystem with **adaptive capacity** and **resilience**.[14]

Regarding connection, it is important to highlight the link between **STKI** and the **State**. The latter is the main promoter of R&D, and its results should be an important source of evidence to generate **public policies** and **laws** in different areas. There are multiple ways of producing this link, both at domestic and international level, which should be expanded.[15],[16] All of them generate, as a desired consequence, the need to integrate people with **advanced degrees** in STKI in to the public sector.

14. Examples of integration are: the *Innovation Corps* (*I-Corps™*) program of the *National Science Foundation of the United States*, which trains researchers in innovation and entrepreneurship to connect with productive implementations; and the "Productivity Laboratory" of the Federation of Chilean Industry (SOFOFA in Spanish), transferring skills of people with business practices learned at STKI. There are also examples where artists work in a multidisciplinary way with people from the STKI world, blurring the division between these worlds and giving rise to common spaces where curiosity, creativity, and exploration unfold.

15. In the United Kingdom, for example, the role of the government's scientific advisor is crucial in the system. Universities have increased the generation of evidence needed to guide public policies, stimulated by specific funds and specialized departments.

16. In the National Innovation Strategy 2017, CNID, proposes the allocation of a percentage of the total expenditure of each Ministry to finance R&D&I for its long-term challenges.

Another aspect related to connections is the relevance of **international links** to achieve the required **critical masses** and reach the required **scale** in the ecosystem to ensure a significant impact for Society. Indeed, internationalisation is occurring with increasing frequency in the most diverse disciplines and in different interaction modes that boost the flow and generation of **knowledge.**

Currently, the global and complex challenges facing humanity has made **international collaboration** even more relevant. Migration, water challenges, legitimacy, and governance crises and definitely climate change and pandemics are at the genesis of global collaborative efforts in STKI.

Chile has also a great opportunity to generate value along with STKI based on its territorial and geographical singularities (see chapter 4). All this puts the country in a privileged condition to generate alliances at international level that enhance the impact of research, to allow the development of large-scale infrastructure and favor collaboration in training and development of people's careers.[17]

BOX 2_

SCIENTIFIC DIPLOMACY

One aspect of connecting with the world that also needs to be developed is **science diplomacy**, understood as: 'a set of practices that lie at the intersection of science and diplomacy.' These practices can help address **global challenges**, expand the understanding of **complex phenomena** and increase influence and **prosperity** of participating countries, among others. Science diplomacy can be categorized into three dimensions[18].

- **Science for diplomacy**: the use of science to promote diplomatic objectives.
- **Diplomacy for science**: the use of diplomacy to promote scientific and technological progress.
- **Science in diplomacy**: the direct involvement of science or scientific actors in diplomatic processes.

The initiatives and examples mentioned in this section fall within the second dimension. However, Chile could very well tackle the other two dimensions. In the case of Antarctica, the study of supranational governance processes and their empirical observations could shed light on how to improve the decision-making process at global level. This would not only contribute to the way in which several global challenges are addressed but would also help Chile to better position itself in the face of the changes that will most likely occur in that field . As for the first dimension, collaboration with neighbouring countries on common opportunities or challenges may add new aspects of relations that facilitate other diplomatic processes.

17. For example, double PhDs from prestigious universities worldwide, called "2+2", in which the PhD candidate spends two years at a foreign university and two years in doctoral programs at Chilean universities, under double degree agreements.

18. The Royal Society and AAAS (2010*). New frontiers in science diplomacy*.

Photograph by Amelia Ortúzar, Imagen de Chile Foundation.

Caleta Totoral, Atacama Region, Chile.

3.1.2. STKI TO HIGHLIGHT VALUE ADDITION OF TERRITORIES

The STKI **National Strategy** is designed to include **Chile** as a whole. Consequently it refers to including all **regions** of the country. The purpose is to integrate them to the stated postulate based on their own work, building an **integrated whole.**

Therefore, the **Vision** and **Purpose** expressed in Chapter 1 require that the **Regional Strategies**, intertwined with each other, contribute **harmoniously** to the National Strategy. Rather than individual strategies for each region, what is required is an integrated approach that creates synergy around a shared vision and purpose. Moreover, this implies that **local** STKI developments may impact not only on the regions in which they were generated, but also on others, and additionally, expand to a **national** and in some cases international **level.**

Having said this and recognizing the heterogeneity of the regions' skills, density and composition of the population, it is natural that the articulation of their Strategies with the National Strategy should be primarily based on the valorisation of their territories' **potential** and the **challenges** to face, profiting from STKI for this purpose. Indeed, it helps to better tackle local challenges, local manifestations of global challenges and to generate learning at local level to address said challenges on a larger global scale. It also contributes to the generation of value linked to the territories' **cultural** and **natural heritage** while contributing to the recognition of **diversity** and the strengthening of **regional** and **national identities.**

Within this context, the Council has understood that its contribution to the **Regional CTI Strategies** (the so-called Regional Strategy Component stated in the law) provides **conceptual elements** and **criteria** that contribute to a **strategic discussion** that lay the foundation for a dialogue process framed within a **common objective** of **sustainable**, **integral** and **harmonious development** of the country and its **regions.**

The value enhancement of the **territorial space** implies that it should not only be conceived as an asset, but as a **catalyst** that "activates", specifically the **value creation** processes highlighted in the National Strategy. Under this framework, the strengthening of a STKI ecosystem must ensure that the **specific geographic territory** is a space that, in addition to providing **roots** and a sense of **belonging**, provides robustness to its development via **networks distributed** throughout the **ecosystem.**

This requires collaborative frameworks among the **world of STKI**, the **public sector** and **local communities**, including **indigenous communities**. This could help to address and eventually unlock conflicts between modern and traditional productive activities, based on **ancestral knowledge**.

Within this framework, it is important to distinguish between administration and **governance** in the decision-making process and the distribution of STKI **capabilities**. Thus, we can speak of an administrative **decentralisation**[19] of STKI's management and **de concentration** in generation and use of gained knowledge.

The first has to do with the **decision-making process** for resource allocations and the system's **governance**, so that this occurs preferably at local level. On the other hand, the second refers to the need for research and the development of knowledgeable **capabilities** to take place in various parts of the country, both as a way of **diversifying** its production, enriching visions and development options and to generate a **distributed**, not concentrated network of the same, providing resilience and **robustness** to the ecosystem.

Decentralised models bring **flexibility** and **heterogeneity** to public policies. This, together with the **de-concentration** of STKI **skills**, allows **closer relationships** among participating agents and favors research areas in which a **geographical proximity** to the currently being studied phenomenon is a determining factor. This also promotes the **local emergence** of **technological innovations** related to their own potential and capabilities.

The advantages of an administrative decentralization should not ignore the arguments in favor of **centralized approaches**: greater **efficiency** in the use of resources through central control of design, implementation, monitoring and evaluation of policies; risk **reduction** when **recruiting** actors in search of income or political and/or economic benefits, which leads to fragmentation and efficiency issues. And to avoid, above all, possible fragmentation of projects that benefit the country as a whole when defined at a central level.[20, 21]

19. It should be noted that, in terms of management, decentralisation refers to the transfer of power from a central level to the regions, and de concentration refers to the transfer of power and capabilities, while maintaining dependence on the central level.

20. Recent literature promotes governance based on more decentralised designs, with a multi-level approach, seeking greater degrees of horizontality and heterogeneity with actors at different levels (national, regional, municipal). But at the same time, it seeks to establish multi-level adjustments that preserve the unity of purpose to be assumed by the regions being part of the country.

21. Cancino, R., & García, M. (2022). *Elementos conceptuales para aportar a la discusión del Componente Regional de la Estrategia Nacional de Ciencia, Tecnología, Conocimiento e Innovación para el Desarrollo. (Conceptual elements to contribute to the discussion of the Regional Component of Science, Technology, Knowledge and Innovation for the Development National Strategy.)* National Council on Science, Technology, Knowledge and Innovation for Development.

Regarding the **de-concentration of skills**, a determining factor to achieve this is to have STKI people in the regions that are to sustain the local STKI Ecosystem. It is by investing in those skills that the development or **strengthening** of research lines and innovation areas can be sustained. They are to take advantage of their singularities and are to develop territorial vocations.

However, it must also be admitted that skill distribution should not jeopardize the generation of the **critical mass** required to generate an impact, nor allow their dilution through unnecessary **fragmentation.** Within this framework, the design of public policies must distinguish the various stages of STKI development and leverage strategies that, while ensuring access to knowledge for the entire population, define a distribution criterion that seek to strengthen STKI in the regions without affecting the ecosystem's overall performance. To this end it becomes interesting to expand the **development of nodes** that cluster STKI capabilities around territorial vocations, which go beyond the regions' political-administrative limits, generating synergy and complementarities, for instance, around macro zones.

The new Regional Governments and the Regional Committees for Science, Technology and Innovation now have at least three instruments at their disposal to add value to the uniqueness of their territorial diversities: the **Programming Agreements**, which make funding available for initiatives arising from agreements on national and regional level; the **Nodes for the Acceleration of STKI's Territorial Impact** (Macro zone Nodes), created in 2020, which have allowed the production of self-diagnoses that identify territorial specificities in several areas, as a basis for the construction of Roadmaps; and the **Natural Laboratories**, in which territorial specificities ease the **link** between **regional** and **national** levels and even **internationally**, which project territorial specificities into robust long-reaching agendas[22].

In conclusion, we must ensure that STKI contributions lead to a **harmonious** development that simultaneously combines the vision of the country as a whole and the vision of its **regions**. It is important that STKI in general, but especially the one generated at region level, be geared towards the **territories' enhancement**. They are to take advantage of and strengthen the distributed skills through virtuous alliances at regional and national levels - and internationally, when appropriate - using **governance mechanisms** that allow a systemic approach. The need for **decentralization** and **de-concentration** of skills, thus understood, transcends the regional political demand, rather arising as a **catalytic process** of **local STKI skills** when facing new local, national and global challenges.

This requires to take advantage of and to expand the platforms of dialogue and organisation of the Regional Governments with the different STKI agents and other social actors, including this Council, to develop the National Strategy and Regional Development and CTI Strategies.

BOX 3_

MAIN REGIONAL CHALLENGES

An analysis of regional innovation strategies - known as regional CTI strategies within the new institutional framework - shows that the main identified challenges are related to the need of strengthening decision-making capabilities; to the differences in human skills and CTI enabling conditions - including information, infrastructure and equipment -, that shape up the deployment of regional capabilities; and to the weaknesses in the production of collaboration and trust networks, as well as in the territorial articulation of the ecosystem's actors. The latter, in particular, is indicative of the regions' identity and cultural differences, which reveals the need to open up to tools and forms of management and governance capable of recognizing this heterogeneity.

This is complemented by the most recent diagnoses generated by the Macro zone Nodes,[23] which have identified areas in which decentralisation processes need to be expanded. These refer to enabling conditions that address territorial specificities and sub national priorities, such as: enabling infrastructure, accessibility to spaces and equipment; human capabilities -which appear as a transversal challenge in all regions, the integration of new requirements, such as gender identity, inter culture and social and territorial inclusion approaches; and financing, evaluation and development of research agenda logics that include the new needs that STKI must tackle, such as sustainability, climate change and strategic resources. Additionally, they highlight the relevance of developing a culture of innovation with a scientific-technological base at all levels, with access to information and support networks that make the supply of local knowledge visible to strategic productive and logistic sectors, as well as to transversal demands such as climate change and conservation.

On the other hand, the Macro zone Nodes show the need to recognize the territories' natural specificities and their scientific and technological potential (natural laboratories), which show challenges such as monitoring the impacts of global change and anthropogenic activities, environmental, scientific and citizen governance in the conservation and care of these ecosystems. Lastly, the need for an articulation between the private sector and academia is highlighted as a critical aspect to address productive transformations in strategic sectors defined at a macro regional level.[24]

22. Ibid

23. Consortia between universities and regional research centers created in the five macro zones under the umbrella of an ANID program in 2020.

24. Cancino, R., & García, M. (2022). *Elementos conceptuales para aportar a la discusión del Componente Regional de la Estrategia Nacional de Ciencia, Tecnología, Conocimiento e Innovación para el Desarrollo.* (*Conceptual elements as contribution to the discussion about the national strategy's regional component of Science, Technology, Knowledge and Innovation for Development* National Council of Science, Technology, Knowledge, & Innovation.

Photograph by Felipe Trueba,
Imagen de Chile Foundation.

Antarctica.
Magallanes and Chilean Antarctica
Region, Chile.

Photograph by Sernatur,
Imagen de Chile Foundation.

Morro in Arica.
Arica and Parinacota Region, Chile.

3.2.
BOOST REQUIRED BY THE DIFFERENT STKI ECOSYSTEM COMPONENTS

One of the main drivers, transversal to all the STKI Ecosystem components, is a robust financing system that is stable over time. In this area, the country has clear weaknesses. The central government budget for science, technology, knowledge and innovation represents about 0.36% of the GDP[25]. This figure has remained relatively stable during the present decade. Moreover, public spending on R&D,[26, 27] more restrictive than the previous one, has remained practically flat since 2011 at around 0.22% of the GDP[28], well below OECD countries.

Chile needs to break this trend and set an **ambitious goal**, significantly increasing investment in STKI in the coming years, which means reviewing the current R&D funding models and opening up to the fact that investments should not only be channeled through the current mechanisms to deliver funds.

In addition to the above, the main weaknesses affecting the different STKI components have been identified. They have emerged from the reflection, research and consultations carried out by the Council,[29] criteria and guidelines to tackle them are proposed below.

25. Balbontín, R., Roeschmann, J. A., & Zahler, A. (2018). *Ciencia, Tecnología e Innovación en Chile: Un Análisis Presupuestario*. (*Science, Technology and Innovation in Chile: A Budgetary Analysis*.) Chile: Directorate of Budgets, Ministry of Finance.

26. The difference between GBARD (Government budget allocations for R&D) and the STKI budget is that the latter includes all government expenditures to finance science, technology, knowledge and innovation activities.

27. The estimate for public R&D spending comes from an information survey based on budget items of the annual budget act through the study "Créditos presupuestarios públicos para la investigación y desarrollo" ("Public Budgetary Appropriations for Research and Development" [or GBARD]), periodically carried out by the Ministry of Science, Technology, & Innovation.

28. KRD y Asociados Ltda., Undersecretary of Science, Technology, & Innovation (2020). *Levantamiento y análisis de créditos presupuestarios públicos para investigación y desarrollo para Chile (I+D). (Survey and analysis of public research and development budget allocations for Chile [R&D]).* (Government budget allocations for R&D, GBARD).

29. Appendix: Participation, consultation and dialog process.

3.2.1. PERMANENT GENERATION OF KNOWLEDGE AND TECHNOLOGICAL DEVELOPMENT

A characteristic of knowledge generation, which sustains technological development, is that both are built on what has already been accumulated. To sustain this accumulation capacity, four focal points are identified: the need to care for and invest in the **national education** for people dedicated to STKI; the need to ensure a **permanent financing** system that combines the objectives of **continuity** and **excellence** in performance; the need to strengthen **associating capacities** in R&D activities; and the need to promote **technological development**, focused on its application.

Regarding the development of local STKI capabilities, the national **post graduate** education is fundamental. This regularly increases the number of more and new people at STKI, and is a **relevant support** for the research development in the country and moreover favours the development of **R&D capabilities** linked to the country's and regions' needs and opportunities.

Within this context, a balanced system of support is required for the **postgraduate program availability at national level**, as well as for **training overseas**, under a strategic alliance scheme.[30] This will allow the development of skills in the different knowledge areas, providing a broad and diverse base. This system should consider instruments to subsidise the demand - such as **scholarships** -, supplemented with subsidies to be allocated through financing **master programs**, particularly in emerging or loss making areas,[31] seeking a leveraged ecosystem strengthening to absorb these new **human skills**.

Diversifying the knowledge areas in national master's programs is also required, in addition to the currently dominant natural sciences.[32, 33] This diversification can be carried out based on demands associated with policy objectives such as: developing skills linked to the vocations of different territories;[34] strengthening the link with the **private sector** - business, education, social organizations among others - or enhancing the **public sector**'s modernisation and tackling challenges or State prioritised areas. In all these cases, it is necessary to advance in the consistency of the set of programs and instruments that have an impact on the formation of STKI human skills such as **accreditation** systems and **internationalisation** efforts.

Another basic aspect is to have, as part of the **financing system**, a balanced thrust between the **activities** that generate knowledge in general and the **skills or abilities** that sustain them in the **long term**. The former tends to be approached in a **competitive** logic, concerned with **performance** and the latter tend to receive institutional or basal funding, which ensures **continuity** and which may or may not incorporate performance criteria.[35]

As in the national system it is unclear how much of the **basal funding** to **universities** is assigned to sustain **research capacities**, the accumulated long term skills are permanently at risk. This also generates pressure on **competitive** funding that must be acknowledged and addressed.

There is also a weakness in financing research skills in the **Public Institutes of Technology** (ITP, for its acronym in Spanish), where the foundational contribution comes directly from the hosting ministries and agencies. This underfunding issue has sought to be supplemented with the sale of services but in many cases this has not been sufficient. In the scientific-technological centres[36] there is a long-standing concern to avoid the loss of accumulated skills, for which the Council proposed the generation of a long-term renewable subsidy scheme that operates under performance criteria.

30. For instance, through agreements that grant shared degrees with prestigious foreign universities.

31. Santiago Consultores (2007). *Estudio referido al reordenamiento del Sistema Nacional de Becas de Postgrados. (Study on the reorganization of the National System of Graduate Scholarships)*. Innovation Council for Competitiveness.

32. Ibid

33. Ministry of Science, Technology, Knowledge, & Innovation (2021). *Plan de Desarrollo de Talentos: Ideas y Acciones para el Futuro. (Talent Development Plan: Ideas and Actions for the Future.)*

34. For instance, by encouraging interregional collaborative doctorate programs.

35. In Chile, institutional funding for universities which support a large part of the research capacity is provided through the sub-secretariat of Higher Education of the Ministry of Education. Research funding, which covers most of the research activities financed by the State, is the responsibility of ANID, which reports to the Ministry of STKI where the logic of competition and demand subsidies predominates.

Since it has not been possible to establish a clear **base funding** policy for universities and other knowledge-generating institutions, the objectives and **motivations of the agents** are distorted. It is difficult to establish the extent to which funds are allocated to support and develop R&D within the institutions - such as access to and maintenance of R&D **infrastructure and equipment**, and **working conditions** of researchers, technologists and support teams - and even less to evaluate the spending evolution and effectiveness of each one.

It is therefore crucial, on the one hand, to **align** the policies of the different ministries and agencies so as to ensure the **continuity** and **performance** of the different ecosystem nodes and, on the other hand, to move towards a **balanced** and **supplemental** funding system (foundational and competitive) that ensures the enabling conditions for STKI.[38]

The State must ensure the coherence of public policies and instruments, supporting both demand and supply, and ensure consistency between **incentives**, **recognition criteria** and **evaluation systems** of the different ministries and agencies, recognizing the diversity of roles, actors and career paths.

Another critical aspect to strengthen the ecosystem is to foster **associative research** and the resulting **technological development**. This has become particularly necessary due to the **complexity** of the great challenges that humanity is facing - such as climate change, migration, aging, automation among others - which has fostered associative global **knowledge network** systems that transcend disciplinary and geographic limits. These include **multi disciplinarity**, **inter disciplinarity** and **trans disciplinarity**.

Multi discipline procedure is a research approach that, under a common framework problem, includes several disciplines to tackle it. Each one proposes its own differentiated objectives and analysis. The interdisciplinary approach researches problems via several disciplines, but this time identifying a problem and common objective, assuming research as a whole and achieving reciprocity of exchanges that can create novel solutions, new knowledge, new areas of activities, disciplines and approaches. Finally, transdiscipline[39] is an approach in which the fusion of knowledge within and outside of Academia is emphasized. It is a mode of scientific research that studies the organised entirety systematically.

36. Those financed by Basal Financing, Millennium, Fondap and Regional Centers programs.

37. National Innovation Council for Development (2016). *Lineamientos para una Política Nacional de centros de investigación.* (*Guidelines for a National Policy of research centres*.)

38 A starting point would be that the logic of instrument design and management, as well as the budget discussion itself, be approached jointly, promoting the adequate articulation of the scarce existing efforts in these areas.

39. Piaget, J., W.F.M., M., Paul, L. et al. (1979). *Tendencias de la investigación en ciencias sociales* (4a ed.). (*Trends in social science research* [4th ed.]).

In Chile, during the recent years, the centres have played a decisive role, not only in the production of knowledge, but also in promoting the attributes that are key to an ecosystem (diversity, connection, network logic and linkage with society). Through **centres of excellence** for basic and applied Research and Development in various areas - such as scientific, technological and innovation centres and ITPs, operating at national and regional levels - the country has provided itself an adequate mechanism for the **progressive growth** of skills, a specialized infrastructure and **advanced human capabilities** in areas of interest for scientific and technological Research and Development. This has, based on an associative logic, facilitated the link with society.

These nodes act in different ecosystem areas, some more towards the generation of **basic knowledge** while others focus on applied research with skills and options for the development and incorporation of **technologies** in society.[40]

On the one hand, taking better advantage of their potential, requires promoting the **use of the generated knowledge results** and, on the other hand, improving national scientific and technological **competitiveness** under a global competition approach.[41]

The use of the knowledge generated in these centres -by the different social actors, economic agents and the State itself - requires new and deeper cooperation frameworks. This would allow the emergence of the reaped contributions and their incorporation into increased **economic value** and into productivity in the **productive sectors**, for instance. Conversely, the State is the key element to create an active public demand based on the results provided by national centres, which can be relevant for the continuous improvement of **public policies**.

The improvement of national scientific and technological competitiveness requires recognizing that, with the exception of some areas of knowledge, new conditions are required to promote the development of **more complex** research agendas and the international positioning of domestic R&D. This is driven by the contribution to **national and regional challenges**, as well as by the **interests of researchers** with more **complex** research agendas. The quality of national scientists and researchers and the lessons obtained through the collaborative work achieved by the centres, offer great possibilities for a greater integration into international networks and circuits in cutting-edge scientific areas.

To promote all of the above, a better **organisation of public programs** is required. Both **scale** and **global connection** of the different centres must be considered. These are determining factors of the impact that R&D will have.[42] It is also necessary to introduce **prioritisation** criteria that, among other things, allow opening spaces for new areas so that previously existing capabilities do not dictate the path to be followed.

40. Sierra, P. (2021). *Centros de Investigación y Desarrollo e Institutos Tecnológicos Públicos. Principales características y desafíos. (Research and Development Centers and Public Technological Institutes. Main characteristics and challenges.)* National Council on Science, Technology, Knowledge, & Innovation for Development.

41. Ibid

42. The small scale compared to more developed countries, added to the national diversity in size and resources, also requires an articulated action to allow certain centers to at least grow in size, once they reach a certain performance level, so that their potential can be effectively developed. This need for a greater scale can be addressed with more funding, as well as with the advocacy of national and international alliances. The definition of which nodes to promote should consider both their development level and the consideration of strategic criteria for the country (Sierra, P., 2021).

This requires guidance from the public sector with respect to the **critical needs** in which it is necessary to develop skills that currently are non-existent or insufficient in scale.

We must reiterate that **technological development** is a critical competency. Many of the **country's challenges** cannot wait for solutions from the market alone but require local or national developments that address **specific needs**, for example, those posed by the **future mining industry**, or technologies to characterize and address the **water cycles** in the country's different basins.

Likewise, when producing knowledge and technological development it is not sufficient to continue to build on **existing capabilities** alone; rather, schemes are required to develop technological paths that do not depend exclusively on what is already in place. To this end, there are several options.

One option is to advocate **multi disciplinary projects** aimed at bringing supply and demand closer together, with the joint participation of different actors, particularly from the private sector and academia, generating interaction spaces for this purpose, starting with master's training.[43]

Another approach is to consider the **country's** major **challenges**, in addition to **specific missions**,[44] combining the need to strengthen local technological development capabilities with the permanent requirement for the countries to address the society's requirements[45]. The challenges far exceed the **electoral periods** of any government and therefore to line up around them helps to generate and maintain **long-term** initiatives. **Missions**, on the other hand, are more limited projects, selected by the authorities due to the advantages of tackling them, or because the **expertise** to do so already exists. They receive limited resources and are required to meet **milestones** and **deadlines** to deliver.

A third option, which at the same time can feed the two previous ones, consists of investing in transformative **enabling technologies**, i.e. technologies with a high impact at macro level that affect - often synergistically - different areas and sectors, thus generating **positive transformations** for the country. These include information and sensing platforms, communications infrastructure, big data, artificial intelligence, quality internet access throughout the territory,[46] among others.

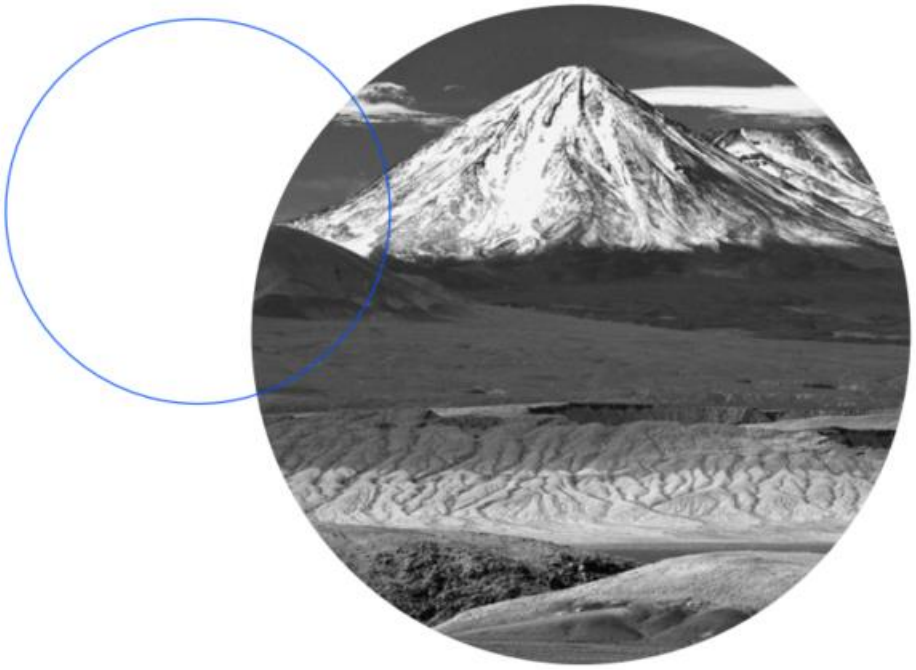
Promoting technological development will require new incentives and tools.

43. Finland for example proposes a series of initiatives to favor a link between the private sector and academia, without prioritising specific disciplines or sectors, but with the desired effect of aligning and focusing efforts on industrial development. Ministry of Economic Affairs and Employment of Finland (2020).

44. OECD (2021). *The design and implementation of mission-oriented innovation policies: A new systemic policy approach to address societal challenges*.

45. The country challenges correspond to major problems identified as relevant, such as climate change and its derivatives, healthy eating, issues with the elderly or with water supply.

46. This was proposed as one of the five transformative measures in the 2017 CNID, Strategy, under the name "Broadband from Visviri to Cape Horn".



BOX 4_
NEW INCENTIVE LOGIC AND TOOLS FOR TECHNOLOGICAL DEVELOPMENT

One obstacle faced by **technological development** is the lack of adequate incentives. In the case of universities, the current indicators of the National Accreditation Commission give great relevance to the publication of academic papers[47] in detriment of the development of **innovation** projects or **patenting** technologies, thus determining the academic evaluation criteria.

The ITPs also lack incentives that lead them to include policy priorities and/or industry needs which weakens their ability to provide scientific-technological "**intelligence services**"[48] linked to **private sector** demand and **government** priorities.

In the private sector, the R&D **tax incentive**, in spite of the efforts made, has still produced only scarce **results**. It is required to analyse how to encourage those companies that are in a better position to allocate more resources to R&D to use it more intensively, thus generating more innovations and to achieve that their success stories encourage the **hiring of scientists and technologists**. Specifically, maximum amounts and other obstacles that could affect their full utilisation are to be analysed. The eventual success of these companies would induce a powerful impact on the rest, thus initiating the required virtuous circle.

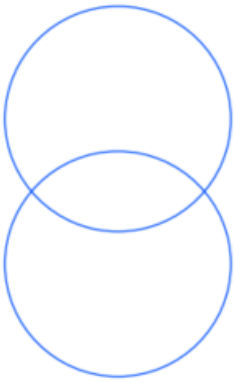
Regarding the instrumental logic for development and technology transfer, Chile must move "from a project-oriented culture to a long-term sustained effort"[49] since the logic of the former is insufficient to generate critical masses that ensure continuity. To this end, a **portfolio logic** is useful, since having a diversified set of projects makes the re-use of skills developed in unsuccessful projects easier. Thus to service new initiatives, diversifying the risks of exploring different options. Under such a scheme, the evaluation focus is on the **add on** that projects introduce to the ecosystem, for instance, the new skills that would be generated.

The knowledge exchange approach[50] is consistent with this logic, since **technological development**, **dissemination** and **transfer of knowledge** as a whole require a permanent connection between research and users. This process approach allows a visualisation of other impacts, such as a gain in know-how, development and research contracts, induced investment,[51, 52] the generation of networks and the creation of jobs in institutions and companies.

Photograph by Gerhard Hüdepohl.
https://atacamaphoto.com

Licancabur Volcano,
Antofagasta Region, Chile.

47. The Commission issued new accreditation criteria for PHD programs, which will explicitly incorporate other dimensions such as innovation and technology transfer. These criteria, which come into effect in October 2023, are a step in the right direction to tackle the incentive issues raised.
48. World Bank (2009). *Chile: Fostering Technology Transfer and Commercialization*. Washington, DC.
49. Ibid
50. Brinca y HubTec (2020). *Estudio de resultados de proceso de transferencia del conocimiento. (Knowledge transfer process results analysis.)*
51. Ibid
52. Induced investment refers to the public and private investment that takes place in a project during its development stage.



53. Hornidge, A.-K. (2011). 'Knowledge Society' as Academic Concept and Stage of Development- A Conceptual and Historical Review. In *Beyond the Knowledge Trap*. World Scientific.

54. Lane, R. E. (1966). The Decline of Politics and Ideology in a Knowledgeable Society. *American Sociological Review*.

3.2.2.
SCIENCE AND TECHNOLOGY-BASED INNOVATION AND ENTREPRENEURSHIP AS AN ECONOMIC DEVELOPMENT DRIVER

Innovation and **entrepreneurship** are the activities that are most directly connected to the creation of tangible value for individuals. While innovation is expressed by the introduction of **new combinations** of product elements and of production processes, entrepreneurship contributes with new economic activities that generate value for society.

Many entrepreneurs have the ability to look closely at the markets and identify opportunities for novel ideas and innovative businesses. In the case of **technological ventures**, these are associated with the creation of new economic activities, based on the exploitation of results from **Research and Development** activities, and which also have the capacity for rapid growth in the markets where they operate.

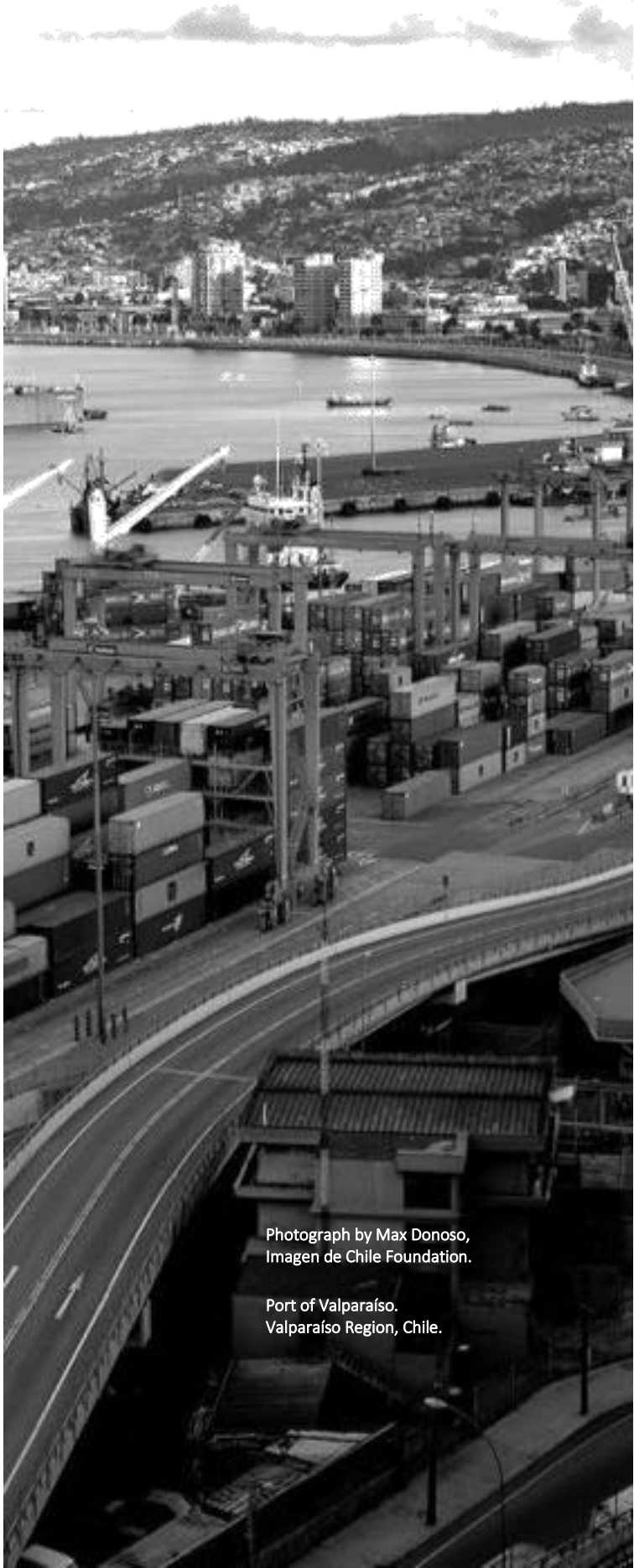
Innovation processes are fed by multiple inputs, including Research and Development activities, the acquisition of licenses, equipment procurement and human capital training among others. The different **sources of innovation** should be fostered because of their contribution to development in different dimensions and timeframes. For instance, innovation based on people's creativity usually requires less capital and can have short-term effects. On the other hand, those based on **science and technology** require greater investment and time and they generally support deeper or structural transformations.

In the case of technological innovations, they are the result of a **technological progress** that makes possible or enables their emergence: **new materials**, more resilient, more flexible or more durable; new ways of long-distance **communication** based on the instantaneous transmission of information associated with the **digitalisation** of contemporary life, with multiple and growing applications; also new ways of taking advantage of **biological molecules**, or discoveries for human use, such as vaccines based on **mRNA** or the **Crispr Cas9** method for genetic modifications and fight against disease, among many others.

Innovations only materialise their potential value once they have been **implemented** and their benefits have been made available to the public in the form of goods or services delivered through markets. Companies do this when they have the required technical skills or the resources to outsource them to specialised entities and centres, but it is also conducted by **entrepreneurs**, in many cases from universities and Research and Development centres, who form specialized companies to that end.

The intricate link that exists between the **knowledge** generated by **science**, the **technology** that obtains applications from it, the **innovation** that creates value with it, and the **entrepreneurship** that productively implements this whole chain for the benefit of society is what needs to be strongly linked through a **robust, interconnected, and fluid STKI Ecosystem**. This is why it is so important for the ecosystem to develop through all its nodes and for a National STKI Strategy to be deployed amidst such an ecosystem.

Chile has the great opportunity to take advantage of innovation and scientific-technological entrepreneurship as an engine for economic development, moving towards a knowledge economy, where knowledge -mostly of scientific, philosophical, and cultural origin - allows for a greater efficiency in the use of physical capital and human skills available, leading to an increase in productivity that elevates the level of national income.[53] [54]



Photograph by Max Donoso, Imagen de Chile Foundation.

Port of Valparaíso.
Valparaíso Region, Chile.

The challenges faced by the country are played out at least at three relevant levels: contributing to the process of **sustainable** productive transformations; generating **new value options** based fundamentally on knowledge; and enabling **productivity leaps** through technological implementations.

A sustainable productive transformation opens up as a great demand for innovation to solve **sector challenges**, such as the appearance of new pests, due to the impact of climate change in the forestry and agriculture sector, or the impact of water scarcity in the mining sector, among many others.

Additionally, there is the opportunity of developing new economic activities with significant value potential based on science and technology, which connect us globally. This is the concept behind the notion of natural laboratories: **astronomy** can give rise to data mining services and **state-of-the-art technologies**; Chile's proximity to Antarctica can be exploited to create a supply of sophisticated **scientific** and **technological services** worldwide; resilience to **natural disasters**, in addition to contributing to the welfare of society when faced to these catastrophic events, can assign an offer of high value to the world.

On the other hand, to increase productivity by adopting existing technologies or innovations has a great impact potential at smaller companies' level. To achieve this impact, however, efforts are required to promote mass adoption, where it is not enough to have the technology, but also that access to technologies be facilitated, such as the digitisation of organisations and the development of skills and capabilities to take advantage of them over time.

Lastly, the production of goods and services with a **high scientific-technological component** allows for a better use of people's talent and demands more sophisticated **skills**, which can lead to **higher quality jobs**, directly affecting people's welfare and life quality.

BOX 5_

PROMOTING INNOVATION AND ENTREPRENEURSHIP

The promotion of innovation and entrepreneurship has traditionally been CORFO's responsibility; through its agency INNOVA and other areas of this organisation, which has provided funds to support multiple programs for business innovation, prototyping, early entrepreneurship, venture capital funds and others that can be accessed by entrepreneurs, companies, funds and investors, universities and research institutes. Although the innovative performance of companies and productive sectors has not yet achieved significant results at an aggregate level, this effort must continue and increase. Once again, only with conviction, perseverance, persistence and without giving up, making permanent adjustments to the programs to better respond to the needs of the country and of those who use them, will produce the desired results. Moreover, this will allow reaching the critical masses that will virtuously provide feedback throughout the cycle.

An interesting example of success of the above has been the case of Startups. The program to support entrepreneurs began step by step in the 2000s by Corfo; later, in 2010, the Startup Chile program was launched, aimed at attracting entrepreneurs, including international entrepreneurs. Currently, after 20 years of decisive efforts, in which for a long time it seemed that the results were not reaches, the country has a significant contingent of science-technology based startups that venture internationally; among which three stand out, valued at more than US$ 1 billion dollars by investors. All this illustrates the need to persist in well-directed efforts to reinforce promising programs and not to dismantle them; mobilising groups of innovators and entrepreneurs to continue on the path they have chosen. Hence, they create value, contribute to providing quality jobs and more taxes are collected which allows the Treasury to carry out the tasks that citizens demand.

Photograph by María José Pedraza,
Imagen de Chile Foundation.

National Library.
Santiago Metropolitan Region,
Chile.

3.2.3.
SOCIAL SCIENCES, ARTS & HUMANITIES AND THEIR ROLE IN STKI

In following the mandate tasked by the law that created it, the **Council** has incorporated into its Strategy the promotion of and research in, Arts **and Humanities**, as well as that portion of **Social Sciences** closely related to the above and has undertaken the task of describing the important **role** they play in this scenario.

To this end, it is important to **distinguish** between the **knowledge** arising from **science,** associated with **STEM** (*Science, Technology, Engineering, & Mathematics*) and from the **Arts**, **Humanities** and part of the **Social Sciences**, usually known as **SSH** (Social Sciences and Humanities).

In general terms, science seeks to describe the consistencies of environmental **phenomena**, whether **natural** or **social**. To do this, researchers make **observations**, and conduct **experiments and/or systematic studies.** Then they formulate explaining **causal hypotheses**, which are subsequently **validated or refuted** by empirical evidence, to finally be submitted to the scrutiny of **peers.**

Those who observe reality especially **human phenomena** with a **different perspective**, reflecting on the **"must be**" of human beings and their societies with a normative lens, or who place an emphasis on the interpretation of human phenomena, or who investigate their **expressive** or **artistic** manifestations, or who reflect on how **relationships** between people should be organized and what the **ultimate meaning** of existence should be, fall under the SSH mantle.

The above distinction allows us to affirm that the social sciences are partially in both groups. There are those who adopt a **scientific** view on human behavior, as phenomena whose **consistencies** can be investigated despite the enormous difficulty of doing so, develop disciplines that are part of the first group. Then there are those who characterise, understand and interpret the **human social behavior** phenomena, trying to give them **meaning** or who reflect on how human life and its **coexistence should be**, who tend to belong to the second group.

On the other hand, the distinction between **STEM** and **SSH** is the product of the different intentional stance of their activities, the difference in the **methodologies** they use, and the diverse ways in which they **impact** the population. The **scientific method** establishes a way to **validate** the one explanation that best interprets the phenomenon under study, by contrasting hypotheses with **empirical evidence**, among the different explanations proposed. Then again, at **SSH** in general and at **Arts and Humanities** research in particular, there is almost always an **interpretative** or **creative** space that does not necessarily admit a **univocal** validation accepted by the community at large. This **epistemological** difference has led to an intellectual **division** or **tension** between them. This generates, in the field of **public policies**, a **competition** for resources that the State allocates to promote their development, without having been able to establish clear **criteria** for said allocation.

The most **tangible** impact of STEM versus the more **intangible** impact of **SSH** in the productive world has contributed to this, which should invite to think about the implications that their different **nature** has when allocating resources for their **assignment.**

One way to address this problem may be to differentiate the project selection **criteria** and allocation of **public resources.** Additionally they should respond to different analysis **categories**. In this case, despite the efforts made, it is still required to ensure that the evaluation mechanisms and criteria take into account the different nature of the **disciplines** under scrutiny. It does not seem convenient to promote activities with such a **diversity of intentions, methods, results and impacts**[55] and subject them to similar schemes to **assign awardings**. This only leads to a **zero-sum** game and deepens tensions between disciplines that should be considered as **complementary** as they are **important** for the development of societies in the XXI century.

To advance towards a diverse, **free-flowing and interconnected** STKI ecosystem, it is not sufficient to ensure the permanent production of knowledge if the different areas that generate knowledge are not also considered under **equal terms**. This implies **recognising and valuing** research in **Arts and Humanities**, as well as in the **social**, **natural** and **exact sciences**, ensuring rules that acknowledge their distinctive nature and encourage their multidisciplinary integration.

In addition to the recently mentioned **SSH** characteristics, chapter 1 on the Vision and Purpose of this Strategy stated the **crucial role** that they would play in this area.

The SSH orient their activities precisely to the analysis of the **ways of coexistence** and relationships that exist between people in society, trying to specify how they "**should be**", what would be the **deep meaning** of "**human**" and in what direction they should be pointing. To this end, it uses **normative, creative, expressive or artistic** approaches.

Obviously, in these matters there will be a **multitude of points of view**, without necessarily agreeing among them. But it will be the democratic deliberation, that arises from the disquisitions that the SSH have made of society, which will help to find the paths of **agreement** in the permanent reflection on the goals that **open and free societies** seek to achieve to augment their individual and collective welfare.

That is why it is so important to promote and **encourage** the development of **SSH**, interconnected with **CTIE**, forming together the **STKI Ecosystem**, since they play a critical role of constituting the society's "**conscience**".

Given that this topic had not been addressed in previous Strategies and that its role holds the relevance just stated, it will be a task for future Strategies to continue to delve into the concepts and distinctions presented herein, so that the SSH will have the endurance and dynamism that the country's development requires.

55. Research in the Arts and Humanities materialises through different channels that have an impact on society. It has an impact on the training of most of the country's professionals through several aspects that go beyond university careers (generation of projects, communication, general training, linguistics, etc.). It also does so through publications, exhibitions, films, documentaries, social, technological and innovation projects; through advisory services for decision makers and politicians, guild development, multidisciplinary collaboration networks, and participation in the media, among others.

CRITERIA TO EVALUATE AND MONITOR STKI ECOSYSTEM'S PERFORMANCE

Measuring the performance of the STKI Ecosystem is an essential task, both to establish the degree of compliance of the policies being implemented including those applied from this Strategy. But also evaluate the efficient use of the allocated resources, to make comparisons with other countries, between regions, or within the country in general and to build a set of parameters, performance indicators or otherwise to characterise and monitor the ecosystem over time.

A better performance of the STKI Ecosystem implies a greater node density and diversity, with multiple interactions among them, with skills distributed under network logic and closely connected. For this reason, the ecosystem logic proposed in this Strategy poses the additional challenge of incorporating indicators to examine this particular complexity.

A comprehensive evaluation system has, as a basic condition, the generation of integrated information that accounts for changes at an aggregate level, to monitor and evaluate the impact in a global and not segmented manner, as is mostly the case under the current system.

Evaluation processes should consider methodologies that move from output or product level measurements to process, final results and impact indicators. This requires achieving the interoperability of the different domestic information systems - still in an incipient stage of development - ensuring the transparency of public data and coordinating the evaluation of instruments to support STKI.

In turn, this requires more complex models of representation, characterisation and measurement of the Ecosystem, both at national and regional level, which integrate the greater dynamism and interaction that this notion recognises and that, at the same time, have a dialogue and complement the models already used.[56]

Within this framework, a first challenge is to integrate new impact dimensions, such as social and environmental impact, in addition to economic impact, with indicators such as the contribution of STKI to the country's cultural repertoire or to environmental conservation, among many others.

Measuring the economic impact through process input indicators, such as R&D expenditure, does not capture the complexity of the processes involved. In turn, restricting the impact that STKI has on the growth of total factor productivity or TFP is insufficient and it is essential to develop methodologies that complement the previous ones with novel approaches.

A second challenge is to estimate the influence that the social and cultural context has on the STKI Ecosystem, and that influences the actors' behavior. Hence, indicators are required to estimate the quality and quantity of interactions and links between the Ecosystem nodes, their local, regional, national and global connection, and the connection of their work with societal challenges. Additionally, indicators referring to trust the institutions directly and indirectly linked to the Ecosystem, such as those of the National Survey on Science and Technology Social Perceptions.

A third challenge is related to the distributed structure that the STKI Ecosystem presents when operating under a network logic, measuring the de-concentration of capabilities as well as the strength of its nodes and their interactions, particularly in the comparison between regions or macro regions.

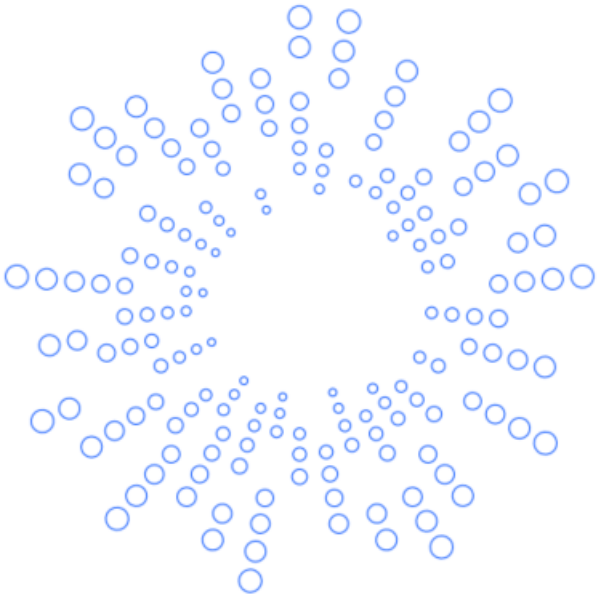
A fourth and final challenge consists of developing graded indicators of social insertion into the STKI Ecosystem, i.e. its integration and contribution to different social spaces and territorial levels. Among them, those that reflect the connection of STKI policies and actions consistent with National and Regional Strategies, the existence and preponderance of STKI oriented by challenges and missions. More graded indicators for the quality of the links and contribution of the nodes to the private sector at a productive, social, or environmental level, among others. This can also be measured through how much STKI related institutions are being trusted as to their ability to generate collaborative projects and to attract funding from actors other than the public sector.

To address these challenges, moving forward gradually, establishing short, medium and long-term goals is required. A short term proposal is to redesign the monitoring and evaluation system, developing new indicators that will make it possible to account for the logic of an STKI Ecosystem. In the medium term, this novel approach can be applied to specific areas of STKI contribution, such as whole country challenges. And lastly in the long term, the proposal is to expand this new framework to all STKI programs and instruments, as well as to the measurement of STKI's aggregate impact at both national and regional levels.

56 Alvial, C. & Menéndez, M. J. (2018). *Desafíos de monitorear la contribución de la STKI a grandes retos: Aplicación al desafío país de sostenibilidad del recurso hídrico en Chile*. *(Challenges of monitoring STKI's contribution to major challenges: Application to the whole country challenge of water resource sustainability in Chile*.) National Council on Innovation for Development.

Photograph by Los Contra,
Imagen de Chile Foundation.

Biobío River,
Biobío Region, Chile.



CHAPTER 4

VISION CATALYSTS

To achieve the **Vision** that this **Strategy** conceives and the **Purpose** it sets forth, the STKI Ecosystem must be **strengthened.** The previous chapter stated the different areas and directions in which this needs to be done. In addition to strengthening, it will require a **mobilisation** of the country's **research**, **technology**, **innovation** and **entrepreneurship** towards the desired direction.

This requires the integration of STKI into society and that citizens' understand and highlight its relevance, supported by a **national narrative** in which STKI is established as a pillar of the **Knowledge Society** and summons different actors to become part of it. It is also essential to consider other **drivers** that, by collaborating with this effort, will **accelerate** the progress along the required path.

We call this narrative and drivers **catalysts**, because their purpose is to **accelerate** the achievement of the objectives set out by this Strategy. They correspond to **mobilising concepts**, which materialise the framework of the proposed vision, providing **direction** to action in different areas of society and **articulating** different actors.

Their role is therefore to **trigger** processes that, when approached coordinately, can have a major impact on the **country's development**. These directions seek to take advantage of the **convergence** of technological capabilities and rely on the **political consensus** that STKI is capable of generating.

Photograph by Sernatur,
Imagen de Chile Foundation.

Southern Ice Fields.
Aysén del General Carlos Ibáñez
del Campo Region, Chile.

On the other hand, they **go beyond the scope** of STKI policies and although they do infer, their impact extends to **different ministries**, **agencies** and **regional governments**, seeking to involve other social actors in different spheres and territorial spaces. Given that these are **mobilising ideas** and driving guidelines, it is essential that they have an broad general character. It is also important that they be deployed in the short term, so that as time goes by, they can drive the **structural transformations** required in the medium and long term.

Rather than aiming at a specific future, these initiatives seek to open spaces from which **various potential futures** can emerge, in all of which the Vision of this Strategy can materialise with the participation of different actors: a State that articulates and guides, a STKI committed to the country and a private sector and civil society that are involved and proactive.

There are five proposed catalytic initiatives, all of which are **mobilising** , the first of which is motivational and inclusive.

- **STKI** as part of a **Chilean narrative** that makes sense to its people and strengthens its internal identity and its international identity.
- STKI at the service of the **country's challenges** and its inhabitants' needs.
- STKI decisively contributing to ecosystem sustainability and biodiversity preservation.
- Public-private complementing to enhance STKI's transforming role.
- **Education in STKI** and **STKI in education** that contributes to creativity and critical as well as reflective thinking about the integral formation of people.

4.1.
STKI INSERTED IN A CHILEAN NARRATIVE THAT MAKES SENSE TO ITS PEOPLE AND STRENGTHENS ITS IDENTITY BOTH DOMESTICALLY AND INTERNATIONALLY.

The greatest ambition of this **Strategy** is that STKI becomes part of the **identity** of the country and its people, becoming a source of pride and **international positioning**, joining different social spaces, contributing **understanding**, **reflection** and innovative ways of improving life quality by addressing the challenges of a sustainable and inclusive development to which we aspire.

Thus, knowledge can contribute to the **value** of Chile's **cultural and natural heritage**, contributing to a better understanding of the country's own conditions and the opportunities generated by its **specific features**.

A society that understands STKI's **critical role**, which seeks to push forward its deployment with the required **conviction** and **perseverance**, which incorporates this heritage into the country's **culture,** integrating it into its **collective imagination**, such a society will be equipped with the required tools to achieve this Strategy's goals.

A non inclusion of STKI in the country's narrative is shown, among other things, in the **low priority** given by the political world over time. It is not seen as a key pillar of development. If this was the case, the citizenry itself would demand its promotion, the political world would have it among its priorities and efforts would be persistent over time. In that case, its ability to create value and generate better living conditions for the population would legitimise it, allowing virtuous feedback that would positively impact the country's development.

Photograph by Sernatur,
Imagen de Chile Foundation.

Pingüino de Humbold National Reserve
Coquimbo Region, Chile.

Thus, a first major Vision catalyst is to incorporate STKI into the **national self image**, thus becoming an integral part of the **identity of the country** and its people, and, additionally, to turn it into a **new image** that projects the country abroad, becoming a source of national pride and **international positioning**. This requires building and giving life to a **country narrative** congruent with this proposal.

Both in the **STKI White Paper** and in the **Basis of the Strategy**, narrative elements are proposed to help build this image based on the unique and unrepeatable conditions offered by the Chilean territory's diversity which can well be a source of **sustainable value creation**. Additionally, the characteristics of an **extreme nature**, constantly exposed to natural disasters, provide its inhabitants with a **resilient character**, transversal to the country's cultural diversity. This character is also expressed in its political history, particularly during democratic transition processes.

Thus, the STKI world joins society, forming part of an **inspiring dream** that allows Chilean men and women to recognise themselves as a creative, resilient and innovative people. This allows us to rescue our history, integrating our condition as an extreme country and to project our culture and territory as a **great coexistence and sustainability laboratory** for the world.

BOX 6_.

A NARRATIVE THAT HIGHLIGHTS OUR NATURAL UNIQUENESS

In **northern Chile**'s **Atacama Desert**, the best skies on the planet for **astronomical observation** are found and one of the best **mining-energy districts** in the world to generate photovoltaic solar energy and green hydrogen, as well as green copper and lithium, all of which is becoming crucial in ending the use of fossil fuels and replacing them with **electric energy generation and storage.**

In the **very South** there are the most important **maritime-terrestrial ecosystems** of the southern hemisphere and a **privileged location** to access **Antarctica**, a continent destined only for research, for which Punta Arenas has all the conditions to become the **scientific capital** of that pursuit. It is a territory whose study will allow a better understanding of the formation of **ocean currents** and **sea temperatures**, all of which affect the **planet's climate**.

Additionally, the country's **vast coastline** and the **ocean** facing that coastline is a vast space open to scientific research of crucial importance for the future of humanity, since the **oceans** are the planet's least studied and understood areas.

This **privileged geographical location**, along with the existing **world-class tourist** attractions in Chile's extremes - both the Atacama Desert and the Chilean Patagonia and sub-Antarctic area - and the **symbolic-scientific** infrastructure that is being developed with **iconic buildings** such as the **International Antarctic Centre** to be built in Punta Arenas, the **Cape Horn Sub-Antarctic Centre** located in Puerto Williams. Furthermore there are more iconic buildings to be installed in the future -the **Chajnantor Astronomical Interpretation Centre** in ANID's Atacama Astronomical Park and the one to be built by the **Corporation for Research and Advancement of Paleontology and Natural History of Atacama**, in Los Dedos Park, near Caldera - constitute a set of assets in the context of the narrative to which this Strategy alludes.

This image of Chile must be **promoted at all levels**, by the State and private sector, incorporated into the work conducted by the Imagen de Chile Foundation and become part of the **national daily language** so that Chileans internalise it as their own and that, from overseas, the country is increasingly perceived this way. An **image** built this way will naturally contribute to **catalyse** the proposed **Vision** and will be the basis for the other visions presented below.[57]

BOX 7_.

A NARRATIVE THAT HIGHLIGHTS THE RESILIENCE OF CHILE's INHABITANTS

According to Charles Darwin, who witnessed the ruin of Concepción in 1835, this unstable condition should have been enough to destroy the prosperity of any country, predicting that the country would fall into bankruptcy, disorder and total chaos. However, if Darwin had stayed in Concepción long enough, he would have discovered that this is not what happened in 1835, nor during any other major catastrophe that our country has suffered. On the contrary, after the Concepción earthquake, order was only momentarily interrupted; the Authority quickly organised the city from a tent pitched at the Main Square and the Central Government was concerned with organising the reconstruction of the affected towns. In 2010, Chile neither collapsed nor was unable to maintain fiscal finances and institutional order, as Darwin predicted. On the contrary, like in 1835, after a few days of initial disorder, it managed to regain control of the situation and then organised its reconstruction and economic recovery.[58]

57. National Innovation Council for Development (2019). *Ciencia, Tecnología, Conocimiento e Innovación para Chile. (Science, Technology, Knowledge, and Innovation for Chile.)*

58. National Innovation Council for Development (2016). *Hacia un Chile Resiliente Frente a Desastres: Una Oportunidad. (Towards a Chile Resilient to Disasters: An Opportunity.)*

Photograph by Gerhard Hüdepohl.
https://atacamaphoto.com

Pia Fjord,
Magallanes and Chilean Antarctica Region, Chile.

4.2. STKI AT THE SERVICE OF THE COUNTRY'S CHALLENGES AND ITS INHABITANTS' NEEDS

Another important **Vision catalyst** is the search for and implementation of **solutions** to our society's major concerns in those areas where STKI has much to contribute. Defining and addressing major **National Challenges** allows Chile to strengthen the capabilities of the STKI ecosystem and become a relevant global actor in these matters. This conviction has been at the core of the Council's reflection and proposals for over a decade.[59] [60]

These challenges **mobilise resources**, focus **attention**, drive creativity and stimulate the **imagination** of the STKI Ecosystem. They are challenges that, due to their **interdisciplinary and multidisciplinary** nature, connect different areas, bring together diverse actors and promote **cooperation** among all of them in pursuit of the same goal. Consequently, this approach would make it possible to connect the greater needs of society with the results of STKI activity,[61] and thus seeks to change the trajectory of national STKI development.

In some cases, said challenges may have a general character, and in others a more specific one, but the common aspect they should share is that they answer to major national needs, where STKI is **critical** for its resolution and in which **technological convergences** can be used,[62] so that in certain cases they can become an offer of value to the world. These are **ambitious proposals** that have an impact on development, which address the **population**'s major concerns and whose solution involves the deployment of the different capabilities of the **STKI Ecosystem**.

There have been several efforts that have attempted to orient STKI towards these major challenges in Chile. However, it has not been possible to generate the **institutional capabilities** that allow this approach to address public policies through a **consistent effort** over time. This implies a great challenge for the **State's organisational** logic, which demands a guiding and articulating role that overcomes the sectoral and compartmentalised logic that dominates its ministries and agencies.[63]

59. National Innovation Council for Competitiveness (*2013). Surfeando hacia el futuro. Chile en el Horizonte 2025. (Surfing towards the future. Chile in the 2025 Horizon.)*

58. National Innovation Council for Development (2017). *Ciencias, Tecnologías e Innovación para un nuevo Pacto de Desarrollo Sostenible e Inclusivo.* (*Science, Technologies and Innovation for a new Sustainable and Inclusive Development Pact*.)

61. UCL Commission for Mission-Oriented Innovation and Industrial Strategy (2019). *A Mission-Oriented UK Industrial Strategy*.

62. This implies implementing mechanisms to identify such convergences based on an interdisciplinary approach focused on the development of new technologies, particularly those that are highly complex and challenging, which will make it possible in the medium and long term to advance through discoveries that transform into high value for society. The observation of exponential technological trajectories by Stanford professor Tony Seba is an interesting reference to identify emerging technologies.

Currently, the stage is ripe for establishing the required mechanisms to overcome this issue. On the one hand, there is a global and national consensus on the need to tackle these major challenges and also on the conceptual frameworks for this policy approach.

It is therefore necessary to create the institutional capacity to define, prioritise and address the long-term challenges that will organise STKI's contribution. These **institutional mechanisms** should base their priorities on major social concerns, in addition to the economic ones. Likewise, for their implementation, there must be an instance that, based on these challenges, defines in certain cases specific **missions**, measurable through milestones and of limited duration, to be addressed multi disciplinarily by different sectors. This body should report directly to the Presidency and involve a diversity of public, private and civil society organisations.[64]

However, addressing these challenges will often require to connect with STKI ecosystems of other countries, either because they have complementary capabilities that are appropriate to the specific challenge or because the challenge also exists in those countries and **cooperation** seems an appropriate strategy to address it.

It is particularly important that these challenges resonate with what the **citizens need**, or if this connection does not initially exist, that it can be **communicated** and transmitted to the population so that the emerging projects are legitimised and incorporated into the country's **collective imagination**, thus contributing to the narrative stated in the previous point.

Today there is a general consensus on the **major concerns** that we share as a society - such as water scarcity, care for the environment, inclusion of indigenous peoples, migration and aging - which can become whole country challenges. There are also local challenges or specific expressions of these country challenges in different relevant **territorial and social contexts.**

The purpose of this proposal, rather than classifying them or pretending to be all-embracing, is the call to produce institutional mechanisms to define them and materialise the contribution of STKI to address them.

63. As an example, in the case of water, there are more than 40 public sector institutions, in different ministries and agencies, which have an impact on water management.

64. UCL Commission for Mission-Oriented Innovation and Industrial Strategy (2019). *A Mission-Oriented UK Industrial Strategy*.

BOX 8_

SOME EXAMPLES OF CHALLENGES

1. COMPREHENSIVE USE OF ASTRONOMY

It is fact that Chile concentrates with the already existing telescopes and the ones to be installed **two thirds of the planet's astronomical** data collection capacity. This is due to its skies' quality and the seriousness of the institutional framework that has been built in this field thus an **advantage** that the country should know how to use. Among the challenges that can be tackled are joining the supply chains of the necessary **precision instruments** , the developing **high-performance computing** given the enormous amount of **data** that astronomy generates, the **storing and processing** of said data and developing **data centres** and an associated **data science.**

2. SOLAR ENERGY

Solar energy will probably be the most important source of **energy** production **on the planet** during the XXI century. The **Atacama Desert** is one of the best areas in the world to capture and use it. For this reason, it is also an excellent **attractor** for future research and technological development in this area.

3. GREEN HYDROGEN AND CLEAN ENERGY

Added to the above challenge is the production of **green hydrogen**, generated from solar or wind power, as another energy source to replace fossil fuels; for instance, to haul **heavy loads** on highways and sea routes and, in the future by air. Solar power generation and green hydrogen, in turn, give rise to the challenge of developing technologies to **store** energy cost-effectively when it is not being used instantaneously.

4. ENERGY FROM THE SEA

Chile has between **14,000** and **18,000 MW** of potential power in the first narrows of the Strait of Magellan that can be used due to the ocean currents that flow from the Atlantic to the Pacific and vice versa, twice a day, with speeds of up to seven knots. Perfecting the technology to do so allows us to have **solutions that can be exported** to other latitudes.

5. SANTIAGO500 WITHOUT SMOG

The challenge of transforming Santiago into a smog-free city by 2041 - the 500th anniversary of its foundation- is a multidisciplinary effort, requiring **hard** and **soft technologies**, which can be achieved by collaborating with other cities facing similar issues, such as Beijing and Mexico City.

6. NATIONAL ARTIFICIAL INTELLIGENCE STRATEGY

The relevance that artificial intelligence is acquiring in the world makes it essential to adopt a national strategy in this regard, which the Ministry of STKI is already addressing.

7. OCEAN-TERRESTRIAL MONITORING AND CLIMATE CHANGE

The relevance that **climate change** has acquired, the need to better understand the formation of ocean temperature and the production of its currents, are all issues that can be preferentially addressed in the southernmost part of our country. There are concentrated **ocean-terrestrial ecosystems** in which the ratio of water to land is the inverse of that of the northern hemisphere. The **interdisciplinary challenge** that this implies is a gigantic **attractor of world-class scientific research** and state-of-the-art technology to the country.

8. QUANTUM SOFTWARE

The incipient but promising development of **quantum computing**, needed to solve certain kind of problems that would take too long on standard computers, requires **software** development. This is an area in which no country has made noteworthy progress and Chile could address this challenge in collaboration with others.

9. NATURAL DISASTERS

Chile has suffered, throughout its history, major natural disasters, such as earthquakes and tsunamis and has acquired great experience in their mitigation and in the **resilient** collateral efforts. That advantage can be leveraged by expanding the technologies required to **mitigate** the damage in these and other types of disasters and exporting those solutions to the world.

Photo by GettyImages.

Solar plant.
Antofagasta Region, Chile.

10. WATER

Water is an essential element for human life. Its geographic distribution is uneven and **climate change** is modifying that distribution. Addressing this problem is **unavoidable**. The problem is scientific and technological, as well as economic and social. Chile's geography, which stretches from the Atacama Desert to Cape Horn, emphasizes this challenge and encourages the search for different solutions that will also serve other countries.

11. PANDEMIC

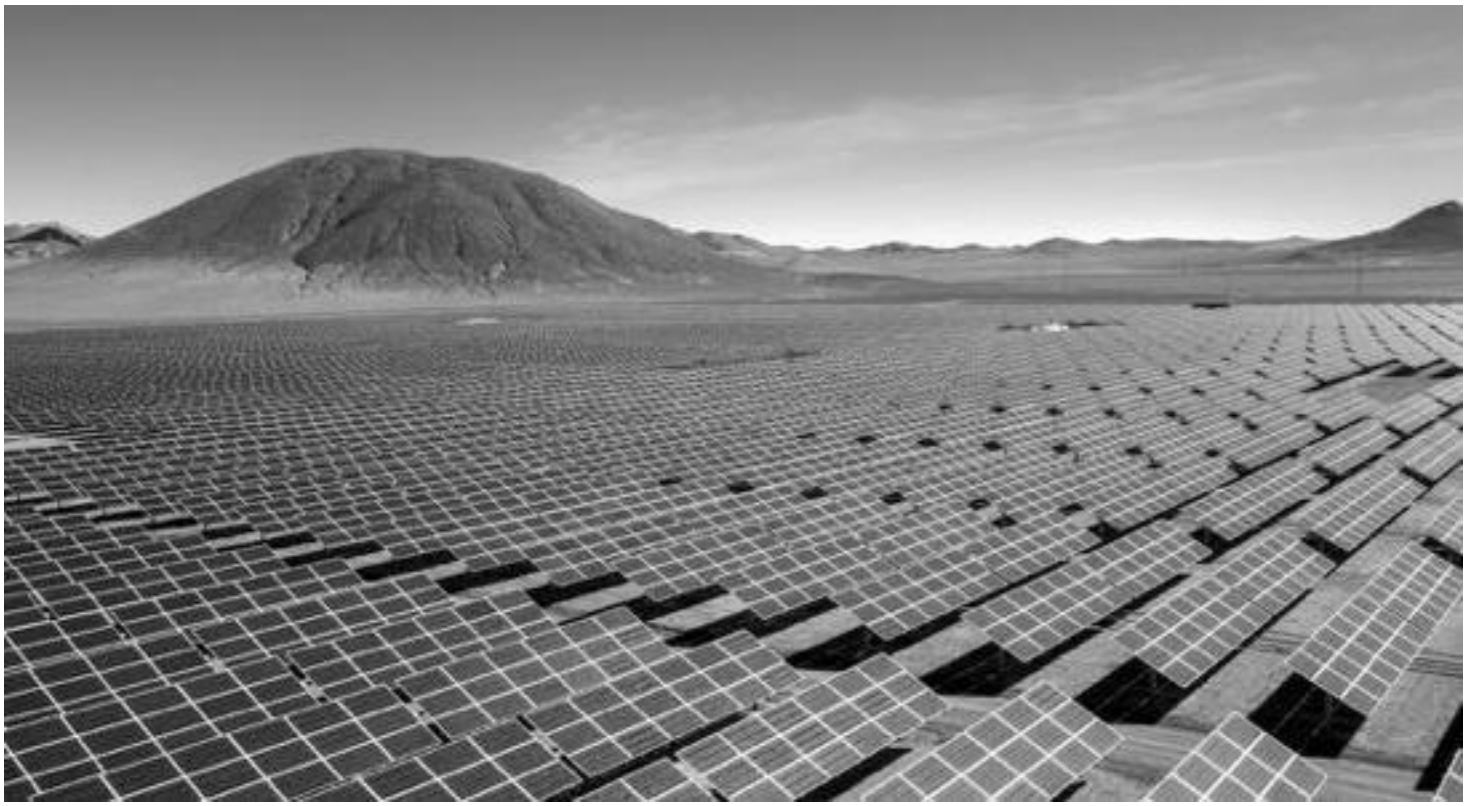
The experience that the country has obtained under the COVID-19 pandemic, both in the treatment of the most serious cases, as well as in the massive testing of people to check their infectious status and in the population vaccination, in addition to the capacity to develop new ones and produce them in the country, has vast repercussions in different areas of the health sciences. Continuing with this momentum generates many multidisciplinary options for scientific-technological advances.

12. HEALTHY EATING

The need to modify the population's **eating** habits, as well as the supply of healthy foods, which also take care of the increasingly criticised systems of protein production in animal factories, is a research area that concentrates efforts in many countries of the world. Chile, one of the countries providing a quality Mediterranean diet and the possibility to become an **agri-food** power, has a major national challenge with a global impact in this area.

13. SENIOR CITIZENS

An enormous national challenge, shared with many other nations, is to provide adequate living conditions for the elderly, a proportion of the population that will grow over time, and whose requirements differ from those of the rest of the population in many areas. Facing them, from pension financing to their physical activity financing ,to the supply of jobs that make them feel useful to society, is a challenge that needs to be addressed as soon as possible with a long-term, multidisciplinary approach.



Photograph by Sernatur,
Imagen de Chile Foundation.

Ancud.
Los Lagos Region, Chile.

Photograph by Sernatur,
Imagen de Chile Foundation.

Torres del Paine Park,
Magallanes Region
and Chilean Antarctica, Chile.

65. Dasgupta, P. (2021). The Economics of Biodiversity: *The Dasgupta Review*. London: HM Treasury.

4.3.

STKI DECISIVELY CONTRIBUTING TO THE SUSTAINABILITY OF ECOSYSTEMS AND BIODIVERSITY PRESERVATION

At the beginning of the third decade of this century, humanity must take on the **greatest challenge** the species faces: the **sustainability** of the **physical and biological** substrate that allows its existence. To meet this challenge, it will be essential to generate new knowledge, based on research and to explain the phenomena involved with greater precision. From this, it will be possible to introduce **innovative technologies** that **mitigate** the damage to the substrate and recover **degraded ecosystems.** They are to re-use the waste generated in new productive processes, in what has been called **circular economy** as well as to innovate in new forms of organisation of social life and in the sustaining socio-technological systems.

In other words, STKI will be a major player in this effort.

It does not seem possible to return to **previous technological stages** given the increase of the world's population - even if it was to stabilise during the second half of this century - and the growing aspirations of each of its members to improve their **standards of living**. It is therefore unavoidable to involve STKI into this effort.

Gearing STKI efforts towards **sustainability** of ecosystems and **preservation** of biodiversity, which is the **third catalyst** proposed by this Strategy, not only implies **combating** the threats to the environment such as climate change, rise of the Earth's average temperature, degraded ecosystems, among many others. But also, and simultaneously, it encourages the introduction of **new technologies** and the wish that the implementing industries be a source of **new value creation**, necessary to improve people's life quality. Thus, the redesign of **cities** and **human settlements** and the rearrangement of **distribution chains** to make them sustainable will generate new demands for STKI; the **substitution of fossil fuels** made feasible by **electro mobility** and others, implies changes in the entire associated production chain and will be a source of new **technological opportunities**; the introduction of **dry tailings** in mining will be a tremendous step forward in making this industry more environmentally friendly; developing processes that make the **circular economy** a reality will generate new resources to satisfy human needs; taking advantage of **biotechnology** to create proteins for human consumption without needing animal factories will be fundamental in facing

the immense challenge of healthy eating. But all this, and the rest of the multiple examples that can be invoked in this regard, requires STKI in vast amounts and at all levels.

Hence, directing the national **productive transformation** in this direction is a top-priority **strategic objective**, which incidentally will impulse **STKI development** heavily. Additionally, it will contribute to build a **Knowledge Society**, which along with satisfying the population's ambitions and aspirations will be in a better position to face the **existential threat** to which humanity is exposed.

This is the responsible way of directing STKI's contribution. In his influential report "**The Economics of Biodiversity**",[65] the British economist **Partha Dasgupta** and his team responded to a request from the UK Treasury to lay the foundations for an economy that could address the threat. The report uses a **conceptual framework** that seems to be the most appropriate to achieve this goal.

This consists of recognising that the entire **human civilising effort** - the supply of materials and energy required to meet the current life standards along with all the **technological sophistication** and social **organisation** that has been accumulated throughout this process - is based on **ecosystem service**, or nature contributions, provided by the biosphere: among them water, carbon and nitrogen cycles. Additionally there is the influence of ocean currents on the climate given by the distribution of land masses and ocean temperatures at different levels. These services make available the **natural and energy resources** we use every day. They are supported by the **existing biodiversity** due to its permanent interaction with the geophysical-chemical phenomena involved in these cycles through processes such as **photosynthesis** or the different **trophic chains** in which they participate plus many others. These processes do sustain the health of the planet and the health of people.

This entire **base layer,** on which the development of species and societies has been founded, constitutes in the language of the Dasgupta report, the "**natural capital**". In economic terms, this corresponds to the **basic wealth** used to generate the **creation of value** that humans have deployed throughout their history by accumulating knowledge. As this capital **wears** and **degrades** due to human action, the report states that it is necessary to invest resources to correct these phenomena, **mitigating** the impact caused by productive activities and **preventing** their occurrence in the future.

To address this major challenge, it is crucial to have information, models and methodologies available that allow us to include these dimensions into the decisions that define our actions.

It is also necessary to measure **natural capital** and estimate its **degradation,** but also to estimate the **investments required** to recover it, develop the appropriate **technologies** to do so and **envisage the time** required to achieve it. In other words, we must combine the **Natural Sciences,** which study the phenomena that support natural capital and explain both its preservation and its depletion, with the **discipline of economics.** We must be capable of making careful **cost-benefit** analyses of human action, both to satisfy its needs and to preserve the **biosphere** and thus the substrate upon which life is sustained, balancing both with the best measuring tools to make this possible.

The application of this **conceptual framework**, described in the Basis of the Strategy, has been taken up by the **Ministry of the Environment**, **the Ministry of Finance** and the **Central Bank**, forming a Committee, in which this **Council** also participates, that will promote the measurement of natural capital and its insertion into the decision making process, thus constituting a first and important step to implement this third **Vision Catalyst**.

Photograph by Max Donoso,
Imagen de Chile Foundation.

Rano Raraku Volcano, Rapa Nui.
Valparaíso Region, Chile.

4.4.
PUBLIC-PRIVATE COMPLEMENTATION THAT HARNESSES STKI's TRANSFORMATIVE POTENTIAL

The documents prepared by this Council, including this Strategy, have insisted on the relevance of the **STKI Ecosystem** in order to achieve a smooth transfer of knowledge. For this transfer to happen as required, connectivity between its nodes is essential. The joint interweaving of **Science-Technology-Innovation-Entrepreneurship** with knowledge - gained from **research in Arts and Humanities** along with part of **Social Sciences** - so that the **generation and application** of all this knowledge lead to the **virtuous circle** that justifies all this effort. This interweaving comprises the **innovations** that create value and the **enterprises** that implement these innovations productively be permanently articulated. It is a process that is not linear, but rather a **feedback loop**, in which scientific knowledge can be bundled into **productive ventures**. The latter can generate **questions** and opportunities that require research and technology for their solution, as well as a series of other possible intermediate combinations.

The traditional **division** between components, as if they were distinct and separate activities, is **inadequate** to represent the phenomena expected to occur in the ecosystem. They are better interpreted by the **arpeggio** metaphor in which the different notes sound harmoniously in whatever order they are played. Thus, the **permanent interaction** between them generates a richness of content, **cross-fertilization** of "metaphors" and concepts and **enhances** the capabilities of each one in directions that cannot be anticipated *ex-ante*.

The efforts made by the **State** - allocating resources to **Research and Development** in universities, research centres and institutes as well as expanding **innovation, prototyping and the different instruments for financing entrepreneurship** – referring to generate value, whose impact will benefit the population, must be complemented by the **dynamism** that the private sector can deploy to take advantage of all of the above. This development **will also require** more R&D based on the success of some of these ventures.

The permanent interaction between the two, with **public investment** making the country's **STKI Ecosystem** more robust and the private sector promoting the creation of more **science and technology-based companies**, is what will lead to **better jobs** and better salaries. Additionally, it will increase **private investment** and this sector's participation in the ecosystem. This mutual reinforcement is what will eventually lead to greater **private participation** in **R&D** investments compared to the one made by the public sector, as it happens in **developed countries**.

In Chile, however, none of these sectors has been able to **articulate** its activities with the required strength: sometimes due to **distrust**, sometimes due to lack of competition in the markets, sometimes due to the insufficient **critical mass** to facilitate this connection. But also, despite the progress made, it has not been possible to install institutional mechanisms from public policies to ensure the **articulation, continuity and depth** of the incentives that this connection requires.

This is a particularly appropriate moment to propel **public-private-academic complementation**. The complexity of the **economic situation** in which the country is after the pandemic, the **institutional change** implied by the constitutional process, as well as the need to **make the country's productive matrix more complex** by incorporating **more STKI**, require that this **complementation** take place in different spaces and at different levels: while tackling the **National Challenges**, through **tax instruments that favor the use of STKI in the productive world** (enhanced R&D laws, Romer tax or others); during the quest for **Sustainable Development Goals**, through the demands of new environmental standards and circular economy; or during the development of **clean energy**, the promotion of **green production** and healthy food, the challenge of **water scarcity** among many others.

The implicit "**production leap**" in all of the above will only be possible if **academia**, the **public sector**, and the **private sector** articulate their creative energies, direct their resources and allocate their human talent towards such a leap.

If this is done with conviction, perseverance and persistence over time, it will become the powerful **Vision catalyst** that this Strategy has set forth and, incidentally, will contribute to **ironing out the differences** that have accumulated between the private and public spheres during the previous political cycle.

This complementation is a fundamental pillar of the country's future development.

The other three catalysts - the Proposed Narrative, the National Challenges to be chosen and STKI's orientation to create sustainable ecosystems and preserve a biodiversity - will decisively assist this **fourth catalyst** to take hold with the adequate force.

4.5.
EDUCATION IN STKI AND STKI IN EDUCATION, CONTRIBUTING TO CREATIVITY AND CRITICAL THINKING IN THE INTEGRAL FORMATION OF PEOPLE.[66]

Education plays a **transversal** role at all levels, especially in the country's ability to deploy its inhabitants' potential and certainly in the appreciation and vocation to participate in **STKI**. It is a key factor in advancing towards a Knowledge Society and to sustain and build an Ecosystem that delivers fruitful results to this **Strategy**.

From an **early age**, when **stimulation** is particularly important and later in **elementary and secondary education**, when habits are formed and more specific interests of young people are awakened, it is important that the educational effort promote the role of **imagination**, **curiosity** and **critical thinking**. Within this framework, it is relevant to consider that, as the current generations are "**digital natives**", **new strategies** are required[67] that also help them to critically discern among multiple sources of information.

It is on this basis that a more reflective and innovative society is being built, in which STKI is valued and in which more people choose to lead their lives in this direction. This constitutes a great challenge given that there are still many shortcomings in this educational stage and many disparities between the country's different schools.

Subsequently, in higher education and particularly in **specialisation** and **graduate** education, when people make more specific decisions regarding their professional options, the **STKI** trainining they receive becomes critical.

Although **education** is not formally part of the areas that this **Strategy** addresses, it is essential for the **Vision** to properly crystallise and therefore it is unavoidable to mention its relevance.

It is also true that education has a different impact on the development of STKI than the other four catalysts, since the improvements that can be made to the educational process only have long-term effects. However, **mobilising** State resources to make this happen without further hesitation is a **strategic** task that cannot be postponed. Therefore fostering an alliance of the **STKI Ecosystem** along with the world of **Education** at all levels is crucial, expanding and deepening the different initiatives that have sought to promote this link from a **public**, **private** and **academic** point of view.

66. National Innovation Council of Development (2015). *Informe subcomisión de cultura de ciencia, tecnología e innovación en Un sueño compartido para el futuro de Chile: Informe de la Comisión Presidencial Ciencia Para el Desarrollo de Chile. (Report of science, technology and innovation subcommittee in A Shared Dream for the Future of Chile: Report of Presidential Commission Science for the Development of Chile.)*

67. Matamala, C. (2021). Digital capital in higher education: Digital strengths and shortcomings to face distance learning. International Journal of Sociology of Education.

With the presentation of these Vision Catalysts, we complete the content of this Strategy. It is intended to serve as a long-term guide for the decisions that governments will make on these matters in the future. Its content, as well as the conceptual frameworks on which it is based, should be reviewed and updated by the upcoming Councils so that, adapted to the ever-changing circumstances generated by historical drift, they will continue to serve as a guide to achieve a similar purpose.

Photograph by Juan Ernesto Jaeger,
Imagen de Chile Foundation.

Curaco de Vélez.
Los Lagos Region, Chile.

Photograph by Max Donoso.
Imagen de Chile Foundation.

Aysén del General Carlos Ibáñez del Campo Region, Chile.

APPENDIX

PARTICIPATION, CONSULTATION AND DIALOGUE PROCESS

To prepare this Strategy, numerous discussions have been held and countless contributions have been received from individuals and institutions that allowed us to expand the reflection and enrich the proposals generated by the Council. The STKI National Council on Development is deeply grateful to all of them.

This dialogue was organised through three participation mechanisms. The first was holding technical roundtables or meetings with experts on global and specific issues. The second was a massive online consultation aimed at gathering general suggestions from several stakeholders and the third was a key stakeholder consultation, as defined by the Council members, which allowed us to expand our understanding of the Strategy's priorities.

TECHNICAL ROUNDTABLES AND MEETINGS

Considering that the discussions among the STKI Ecosystem's actors are a permanent process of the Council, from 2019 to date, meetings have been held with multiple and diverse STKI Ecosystem actors on several topics, which were fundamental for the Strategy development These are:

- **Strategy's conceptual framework based on the document prepared by the Council: "Ciencia, tecnología, conocimiento e innovación para Chile" ("Science, technology, knowledge and innovation for Chile"), 2019.** Meetings were held with the following institutions:
  - Chilean Academy of Sciences.
  - Desafíos del Futuro Senate Committee.
  - Vice Rectors for Research and R&D, Council of Rectors of Chilean Universities (CRUCH in Spanish).
  - Corporation of Private Universities (CUP in Spanish).
  - Technological Division of the Chilean Navy.
- **Natural Capital and proposals for its measurement and institutionalisation in Chile.** A series of meetings were held with representatives of the Ministry of the Environment, Juan José Donoso; Ministry of Finance, Cristóbal Gamboni and Daniela Buchuk; Central Bank, Elías Albagli and Francisco Ruiz; and the very Council: advisor Bárbara Saavedra. Additionally, a technical meeting was held with specialists from the Natural Capital Committee of the United Kingdom: Julian Harlow, Maniv Pathak, Alastair Johnson, Rocky Harris, Colin Smith and Adam Dutton.
- **Challenges for the new STKI regional institutional framework**. Discussions with Margarita Lay, Regional Ministerial Secretary (Seremi) of STKI Northern Macro zone; María José Escobar, Seremi STKI Central Macro zone; Paulina Assmann, Seremi STKI Southern Central Macro zone; Olga Barbosa, Seremi STKI Southern Macro zone, and Pamela Santibáñez, Seremi STKI Southern Macro zone.

- **Technology Transfer Challenges**, with the Technology Managers Network, represented by Silvana Becerra, Fernando Venegas, and Magali Maida.

- **Current status of the new institutional framework for university higher education**, with Camila Cortez, head of the University Education Division, Ministry of Education.

- **Ethics in science**, with Dr. Fernando Zegers, specialist in ethics and public policies in human reproduction.

- **R&D financing in the university sector**, with María José Bravo, head of the Office of Studies and Statistics of the Ministry of STKI.

- **Identification of basic conceptual elements for the design of the Strategy's Regional Component**, with researchers Ronald Cancino and Mauricio García, who prepared the study and with the experts that were part of the study's technical support team: Nadia Albis, Miguel Atienza, Etienne Choupay, Daniel Goya, Cecilia Ibarra, Cristian Ortega.

- **STKI's economic impact**. Two meetings were held with economists and specialists on this topic: Bernardita Araya, José Miguel Benavente, Hernán Cheyre, Jorge Katz, Jocelyn Olivari, and Andrés Zahler.

- **Transformative Innovation**, with Matías Ramírez, Senior Lecturer, Science Policy Research Unit, University of Sussex, United Kingdom.

- **Institutionality and STKI Policy Challenges**, with Undersecretary Carolina Torrealba, Senior Advisor to the undersecretary of STKI, Virginia Garretón and ANID Director, Aisén Etcheverry.

- **STKI as source of quality jobs**, with Carlos Álvarez, former CNID, (for its acronym in Spanish) advisor.

- **Natural Laboratories as an opportunity for Chile**, with José Miguel Aguilera and Felipe Larraín, authors of the book Natural Laboratories for Chile.

- **Opportunities for STKI in the new Constitution**, with constitutional lawyers Gastón Gómez and José Francisco García.

- **Innovation Policies**, with José Miguel Benavente, former vice-president of CNIC, Eduardo Bitrán, former president of CNIC, Alfonso Gómez, former CNIC advisor, Gonzalo Rivas, former president of CNID, (for its acronym in Spanish).

- **Talent Policy and Advanced Human Capital**, with Soledad Ugarte and Matías Caamaño, advisors to the cabinet of the Minister of STKI.

- **Role of Social Sciences, Arts and Humanities**. Two meetings were held to analyse the relationship between research in Arts and Humanities and the natural and Social Sciences, with a presentation by José Joaquín Brunner and the participation of Roberto Torretti, Adriana Valdés, Sonia Montecino, Carlos Peña, Sol Serrano, and Fernando Flores. Additionally a meeting was held with the Chilean Association of Researchers in Arts and Humanities, represented by Carolina Gainza, Matías Ayala, and Andrés Grumann.

- **Use of data**, with Elías Albagli, Monetary Policy Division manager, Central Bank.

MASSIVE ONLINE CONSULTATION[68]

During October 2021, a survey of quality perceptions of the members of the STKI Ecosystem, Regional Governments, civil society associations and citizens was conducted regarding the country's challenges in terms of STKI and its contribution, with the objective of incorporating their visions as input in the process of building the National STKI Strategy for Development.

This query was online for three weeks via dissemination through social networks and distribution via allies and over 600 elaborated responses were obtained.

The results were analysed by an interdisciplinary team with data science, social sciences and design expertise. Through a text analysis process, computer extraction and systematization strategies were combined with qualitative analysis of the responses.

The systematisation strategy contemplated two types of analysis. On one hand there was descriptive analysis, where the opinions are organised by means of extraction techniques and direct word counting or phrase elements. This was done to show directly what had

been discussed and to build visualizations such as word clouds and word trees. On the other hand, probabilistic and inferential analyses were performed, where topic modeling, dictionary construction and logistic regressions were presented to identify latent themes and to raise comparative hypotheses among the different types of participants.

As for the identified obstacles, three major overlapping axes of conversation were found. First, the government-state tension reflected in the aspiration for state policies that exceed current governments and in multidimensional criticisms of the current design of public policies. Second, the lack of funding, which emerged as a cross-cutting and dominant issue during the conversations. This is mentioned with particular emphasis referring to STKI application, to the researchers' working conditions and to research budgets. Third, the STKI-society tension, which is formulated as a lack of STKI social appreciation and of a citizenry lack of interest in and appreciation of expert knowledge.

In terms of opportunities, four axes of conversation can be recognised. In the first place, the look from crisis to opportunity, in which the current health, political, environmental and social crises are seen as opportunities for action and development for STKI. Second, Chile's natural environment that is positioned as an opportunity for research, production and leverage towards sustainability. Third, the advanced human capital in Chile, seen as the main strength to create economic and social value. Fourth, there is an opportunity to link actors and achieve decentralisation.

The findings showed three major challenges for Chile and the world. First, the environment, which appears transversally in all the query questions. It is concluded that it can operate as a consensus target and a mobilising challenge for the STKI Ecosystem. Second, life quality, which is reflected in challenges of social complexity such as education and inequality. Third, productive transformation, from commodities to the incorporation of "added value".

68. DILAB- School of Engineering UC (2021). *Reporte Final Sistematización y Análisis Consulta STKI. (Final Report, Systematization and Analysis of STKI Query).* National Council of Science, Technology, Knowledge and Innovation for Development. Link: https://docs.consejoSTKI.cl/documento/reporte-final-sistematizacion-y-analisis-consulta-ctci -2021/

The following institutions were invited to participate in this process:

REGIONAL GOVERNMENTS:

Gobierno Regional de Arica y Parinacota
Gobierno Regional de Tarapacá
Gobierno Regional de Antofagasta
Gobierno Regional de Coquimbo
Gobierno Regional de Valparaíso
Gobierno Regional de Santiago
Gobierno Regional del Libertador Gral. Bernardo O'Higgins
Gobierno Regional del Maule
Gobierno Regional de Ñuble
Gobierno Regional de Biobío
Gobierno Regional de La Araucanía
Gobierno Regional de Los Ríos
Gobierno Regional de Los Lagos
Gobierno Regional de Aysén del Gral. Carlos Ibáñez del Campo
Gobierno Regional de Magallanes y de la Antártica Chilena

TECHNICAL TRAINING CENTRES AND PROFESSIONAL INSTITUTES:

Centro de Formación Técnica e Instituto Profesional Santo Tomás
Centro de Formación Técnica Enac
Centro de Formación Técnica San Agustín
Centro de Formación Técnica Teodoro Wickel
Centro de Formación Técnica de la Universidad Católica del Norte
Duoc-UC
Inacap
Instituto Profesional Chile
Instituto Profesional CIISA
Instituto Profesional IPLACEX
Instituto Profesional Virginio Gómez

UNIVERSITIES:

Pontificia Universidad Católica de Chile
Pontificia Universidad Católica de Valparaíso
Pontificia Universidad Católica del Norte
Universidad Academia de Humanismo Cristiano
Universidad Adolfo Ibáñez
Universidad Adventista de Chile
Universidad Alberto Hurtado
Universidad Andrés Bello
Universidad Arturo Prat
Universidad Austral de Chile
Universidad Autónoma de Chile
Universidad Bernardo O'Higgins
Universidad Bolivariana
Universidad Católica de la Santísima Concepción
Universidad Católica de Temuco
Universidad Católica del Maule
Universidad Católica Cardenal Raúl Silva Henríquez
Universidad Central de Chile
Universidad de Aconcagua
Universidad de Antofagasta
Universidad de Atacama
Universidad de Aysén
Universidad de Chile
Universidad de Concepción
Universidad de la Frontera
Universidad de la República
Universidad de La Serena
Universidad de Las Américas
Universidad de Los Andes
Universidad de Los Lagos
Universidad de Magallanes
Universidad de Playa Ancha de Ciencias de la Educación
Universidad de Santiago
Universidad de Talca
Universidad de Tarapacá
Universidad de Valparaíso
Universidad del Alba
Universidad del Biobío
Universidad del Desarrollo
Universidad Diego Portales
Universidad Finis Terrae
Universidad Internacional SEK
Universidad Mayor
Universidad Metropolitana de Ciencias de la Educación UMCE

Universidad Miguel de Cervantes

Universidad San Sebastián

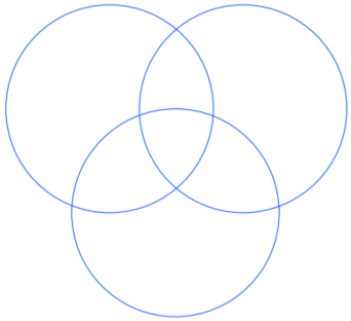
Universidad Santo Tomás

Universidad Técnica Federico Santa María

Universidad Tecnológica Metropolitana UTEM

Universidad UNIACC

Universidad Viña del Mar



INSTITUTIONS:

Agencia Nacional de Investigación y Desarrollo, ANID

Asociación Nacional de Investigadores de Postgrado, ANIP

Asociación de Investigadores en Artes y Humanidades

Consejo de Estudiantes e Investigadores de Postgrado de Chile

Comisión de Comisión de Futuro, Ciencias,
Tecnología, Conocimiento e Innovación de la
Cámara de Diputados

Comisión Desafíos del Futuro del Senado

Comisión Sistemas de Conocimientos, Culturas,
Ciencia, Tecnología, Artes y Patrimonios de la Convención Constitucional

Corporación de Fomento de la Producción, CORFO

Fundación Encuentros de Futuro

Fundación para la Innovación Agraria

Nodos Macro regionales de Aceleración Territorial de la Ciencia, la Tecnología, el Conocimiento y la Innovación

Red Innovación Chile

Red de Gestores Tecnológicos

Red de Investigadoras

Red de Sociedades Científicas de Chile

Redes Chilenas de Investigación, ReCh

Secretarías Regionales Ministeriales de STKI

STAKEHOLDER CONSULTATION

During January 2022, query emails were sent to several participants of the STKI Ecosystem and civil society organisations who had been suggested by the Council's members. The replies received revealed the visions and identified the priorities of these actors, and were answered by:

Ximena Báez, President ANIP (National Association of Postgraduate Researchers).

María Angélica Barroso, Director of Research and Doctoral Programs, Patagonia Campus, San Sebastián University.

Pedro Bouchon, Vice Rector of Research, Pontifical Catholic University of Chile.

Bernardita Cádiz, PhD in Neuroscience.

Cristian Campomanes, General Director, Incubatec de la Frontera University.

María José Escobar, former SEREMI of the Ministry of Science and Technology.

Juan Pablo Henríquez, Chilean Scientific Societies Network.

Sergio Hernández, Vice Rector, Research and Doctoral Programs, del Desarrollo University.

María Cecilia Hidalgo, National Science Award 2006.

Galvarino Jofré, dbs, Rector, Cardenal Raúl Silva Henríquez Catholic University.

Andreas Kaufer, Director of Operations, La Silla Paranal Observatory, European Southern Observatory.

Luis Lillo, Vice Rector, Research and Postgraduate Studies, del Biobío University.

Cristhian Mellado, Rector, Santísima Concepción Catholic University.

Rodrigo Mujica, Director of Public Policy, Federation of Chilean Industry, Sofofa.

Carolina Navarrete, Research Director, de la Frontera University.

Rodrigo Navia, Vice Rector, Research and Postgraduate Studies, de la Frontera University.

Ricardo Nicolau, President, Chilean Institute of Engineers.

Soledad Quiroz, Vice President of Policy, International Network for Government Science Advice (INGSA).

Colonel Lautaro Rivas, Director, Military Geographic Institute.

Claudia Rodríguez, CranChile Company.

María Cristina Rojas, Rector, Pontifical Catholic University of Valparaíso.

Claudio Ruff, Rector, Bernardo O'Higgins University.

Eligio Salamanca, Teacher, Multigrade Primary School, town of Quelhue.

Paula Solar, Research Director, SEK University Chile.

Nicolás Trujillo, Doctor of Philosophy.

Nadia Valenzuela, Teacher, Best Teacher Prize.

David Viera, Education Principal LATAM, Anglo American.

Juan Manuel Zolezzi, Rector, University of Santiago de Chile.

REFERENCES

ALLEA (2017). *The European Code of Conduct for Research Integrity*.

Alvarez, J. (2018). *Reportes de Futuro: Tres Preocupaciones Urgentes para Chile. (Future Reports: Three Urgent Concerns for Chile*.) National Innovation Council for Development.

Alvial, C., & Menéndez, M. J. (2018). *Desafíos de monitorear a contribución de la STKI a grandes retos: Aplicación al desafío país de sostenibilidad del recurso hídrico en Chile. (Challenges of monitoring STKI's contribution to major challenges: Application to the country challenge of water resource sustainability in Chile*.) National Innovation Council for Development.

Balbontín, R., Roeschmann, J. A., & Zahler, A. (2018). *Ciencia, Tecnología e Innovación en Chile: Un Análisis Presupuestario. (Science, Technology and Innovation in Chile: A Budgetary Analysis.)* Chile: Budget Directorate, Ministry of Finance.

Brinca and HubTec (2020). *Estudio de resultados de proceso de transferencia del conocimiento. (Study of the knowledge transfer process results.)*

Cancino, R., & García, M. (2022). *Elementos conceptuales para aportar a la discusión del Componente Regional de la Estrategia Nacional de Ciencia, Tecnología, Conocimiento e Innovación para el Desarrollo. (Conceptual elements to contribute to the discussion of the Regional Component of the National Strategy for Science, Technology, Knowledge and Innovation for Development.)* National Council of Science, Technology and Innovation for Development.

National Competitiveness Innovation Council (2013). *Surfeando hacia el futuro. Chile en el Horizonte 2025. (Surfing towards the Future. Chile in the Horizon 2025.)*

National Innovation Council for Development (2015). *Un sueño compartido para el futuro de Chile: Informe de la Comisión Presidencial Ciencia Para el Desarrollo de Chile. (A shared dream for the future of Chile: Report of the Presidential Commission Science for the Development of Chile.)*

National Innovation Council for Development (2016). *Hacia un Chile Resiliente Frente a Desastres: Una Oportunidad. (Towards a Resilient Chile When Faced With Disasters: An Opportunity.) Lineamientos para una Política Nacional de centros de investigación. (Guidelines for a National Policy on research centres*.)

National Innovation Council for Development (2017). *Ciencias, Tecnologías e Innovación para un nuevo Pacto de Desarrollo Sostenible e Inclusivo. (Science, Technologies and Innovation for a new Sustainable and Inclusive Development Pact*.)

National Innovation Council Development (2019). *Ciencia, Tecnología, Conocimiento e Innovación para Chile. (Science, Technology, Knowledge and Innovation for Chile.)*

National Innovation Council for Development (2021). *Base para la Estrategia Nacional de Ciencia, Tecnología, Conocimiento e Innovación. (Basis for a National Strategy for Science, Technology, Knowledge and Innovation.)*

Council On Governmental Relations (2019). *Excellence in Research: The Funding Model, F&A Reimbursement, and Why the System Works*.

Dasgupta, P. (2021). *The Economics of Biodiversity: The Dasgupta Review*. London: HM Treasury.

DILAB- School of Engineering UC (2021). Reporte Final Sistematización y Análisis Consulta STKI. (*Final Report Systematization and Analysis STKI Consultation.)* National Council on Science, Technology, Knowledge and Innovation for Development.

Hornidge, A.-K. (2011). 'Knowledge Society' as Academic Concept and Stage of Development-A Conceptual and Historical Review. In *Beyond the Knowledge Trap. World Scientific*.

KRD y Asociados Ltda., Undersecretariat of Science, Technology, Knowledge and Innovation (2020). Levantamiento y análisis de créditos presupuestarios públicos para investigación y desarrollo para Chile (I+D). (*Survey and analysis of public budget allocations for Research and Development for Chile [R&D]) (Government budget allocations for R&D, GBARD)*.

Lane, R. E. (1966). The Decline of Politics and Ideology in a Knowledgeable Society. *American Sociological Review*.

Matamala, C. (2021). Capital digital en educación superior: Fortalezas y carencias digitales para enfrentar la educación a distancia. (Digital capital in higher education: Digital strengths and shortcomings to face distance learning) *International Journal of Sociology of Education*.

Ministry of Science, Technology, Knowledge and Innovation (2021). *Plan de Desarrollo de Talentos: Ideas y Acciones para el Futuro. (Talent Development Plan: Ideas and Actions for the Future.)*

Ministry of Science, Technology, Knowledge and Innovation (2021). *Política Nacional de Igualdad de Género en Ciencia, Tecnología, Conocimiento e Innovación. (National Policy on Gender Equality in Science, Technology, Knowledge and Innovation.)*

Ministry of Economic Affairs and Employment of Finland (2020). *National Roadmap for Research, Development and Innovation*.

OECD (2021). *The design and implementation of mission-oriented innovation policies: A new systemic policy approach to address societal challenges*.

Piaget, J., W.F.M., M., Paul, L., & et al. (1979). *Tendencias de la investigación en ciencias sociales (4a ed.). (Trends in social science research* [4th ed.].)

Santiago Consultores (2007). *Estudio referido al reordenamiento del Sistema Nacional de Becas de Postgrados. (Analysis of the reorganization of the National System of Graduate Scholarships.)* National Council of Innovation for Competitiveness.

Sierra, P. (2021). *Centros de Investigación y Desarrollo e Institutos Tecnológicos Públicos. Principales características y desafíos.* (*Research and Development Centres and Public Technological Institutes. Main characteristics and challenges.)* National Council on Science, Technology, Knowledge and Innovation for Development.

The Royal Society and AAAS (2010). *New frontiers in science diplomacy*.

UCL Commission for Mission-Oriented Innovation and Industrial Strategy (2019). *A Mission-Oriented UK Industrial Strategy*.

World Bank (2009). *Chile: Fostering Technology Transfer and Commercialization*. Washington, DC.

This publication has been developed by the National Council for Science, Technology, Knowledge and Innovation for Development and its Executive Secretariat.

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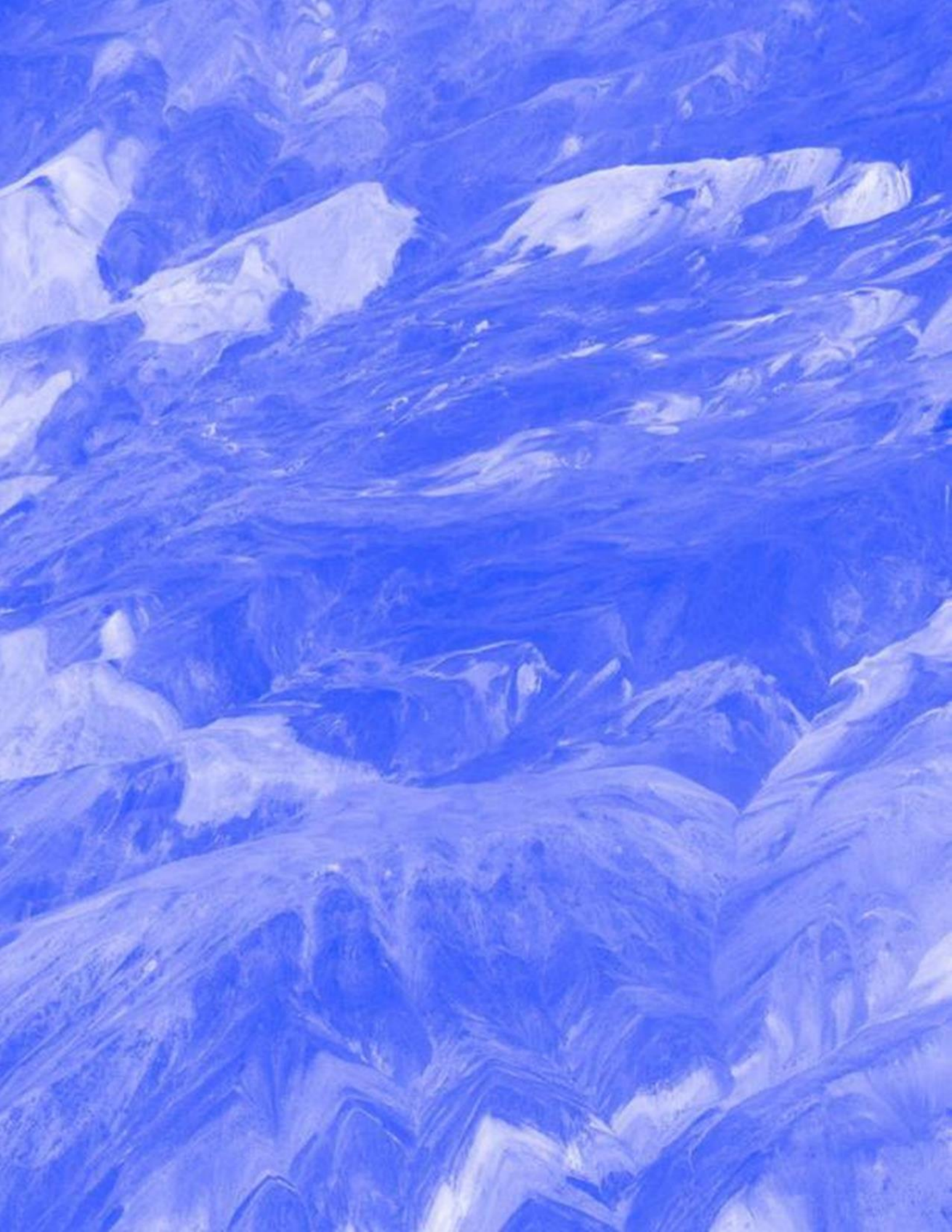
Gerhard Hüdepohl - atacamaphoto.com
Imagen de Chile Foundation

Printing and binding
Cuadernos Blancos

Aktiv Grotesk and Aktiv Grotesk Extended typefaces were used in this book.

Santiago de Chile, May 2022. First edition.



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