"The INNA project: implications on the environmental governance and regulatory framework of renewable hydrogen in Chile"

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Diego García González

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Members of the Examining Committee:

Dr. Binyam Demena
Dr. Elissaios Papyrakis

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This document represents part of the author's study programme while at the International Institute of Social Studies. The views stated therein are those of the author and not necessarily those of the Institute.

Inquiries:
International Institute of Social Studies
P.O. Box 29776
2502 LT The Hague
The Netherlands

t: +31 70 426 0460
Fax: +31 70 426 0799
e: info@iss.nl
fb: https://www.facebook.com/iss.nl
X: @iss.nl

Location:
Kortenaerkade 12
2518 AX The Hague
The Netherlands

Abstract

This research examines Chile's environmental governance and regulatory framework on renewable energy regarding the "Integrated Infrastructure Project for the Generation of Hydrogen and Green Ammonia - INNA", a large-scale industrial energy complex planned to be developed in the Atacama Desert in northern Chile. It presents a literature review on the opportunities and environmental challenges of developing green hydrogen in Chile regarding INNA's environmental impact assessment. It focuses on the environmental impact of the project from increased light pollution in areas where astronomical observatories are located and illustrates how the environmental governance—regulatory framework and institutional dynamics—played a crucial role in the environmental evaluation process. By applying Bennett and Satterfield's framework, this study analyzes the relevant institutional and regulatory aspects of the INNA project to conclude that Chile's environmental governance dynamics contributed to the decision to withdraw the project.

Keywords

Renewable Hydrogen, INNA Project, Environmental Governance, Environmental Regulatory Framework, Environmental Impact, Light pollution.

Relevance to Development Studies

The study is relevant because it provides an analysis evidencing the complex interactions between environmental governance and economic development, addressing a case that reveals how sustainable development is pursued in the context of energy transition. However, it also illustrates that renewable energy projects, while contributing to global climate mitigation, may generate new environmental externalities and conflicts at the local level, such as light pollution and ecosystem disruption. Furthermore, it demonstrates that development processes are inherently multidimensional, involving trade-offs between economic growth, environmental protection, and social legitimacy, and particularly highlights challenges in reconciling economic development with environmental sustainability. Finally, by applying the environmental governance framework it explains how these processes consider relevant concerns in development studies such as power relations, participation, and multilevel governance, which shape governance dynamics, institutional arrangements, and stakeholder interactions, a combination of factors that collectively influence governance outcomes.

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List of Abbreviations and Acronyms

ALMA – Atacama Large Millimeter/submillimeter Array
CTAO – Cherenkov Telescope Array Observatory
EIA – Environmental Impact Assessment
EIS – Environmental Impact Statement
ELT – Extremely Large Telescope
ESO – European Southern Observatory
FDI – Foreign Direct Investment
GEG – Global Environmental Governance
GHG – Greenhouse Gas
IEA – International Energy Agency
INNA – Integrated Infrastructure Project for the Generation of Hydrogen and Green Ammonia
IREA – International Renewable Energy Agency
MLG – Multilevel Governance
MMA – Ministry of the Environment of Chile (Acronym in Spanish)
MPG – Max Planck Society (Max-Planck-Gesellschaft)
MW – Megawatt
SEA – Environmental Assessment Service (Acronym in Spanish)
SEIA – Environmental Impact Assessment System (Acronym in Spanish)
SMA – Environmental Superintendence (Acronym in Spanish)
VLT – Very Large Telescope

Chapter 1

Introduction

1.1 Research Background

Global temperatures are expected to continue increasing and reducing greenhouse gas (GHG) emissions is urgently needed to prevent even greater global warming (IPCC, 2021). Furthermore, the greenhouse effect alters the planet's atmosphere, rising average temperatures, and enabling more extreme climate events such as heatwaves and floods (European Parliament, 2023).

Economic activity from energy production and its GHG emissions has several implications for environmental quality. Through the energy transition, the world is shifting from fossil fuels to renewable energy sources to achieve climate neutrality, thereby reducing GHG emissions and combating the effects of climate change. This transition involves phasing out coal, oil, and gas, scaling up renewable energy such as wind and solar, improving energy efficiency, and developing new sustainable technologies, policies, and business models.

Hydrogen production is becoming increasingly important around the world due to increasing attention on clean and sustainable energy systems. As renewable or green hydrogen emits no carbon dioxide during the use phase, many countries have committed to adopting national strategies to produce green hydrogen. Among these nations, Chile launched its National Green Hydrogen Strategy in November 2020, aiming to reduce carbon emissions and become the world's most competitive green hydrogen producer (National Green Hydrogen Strategy, 2020).

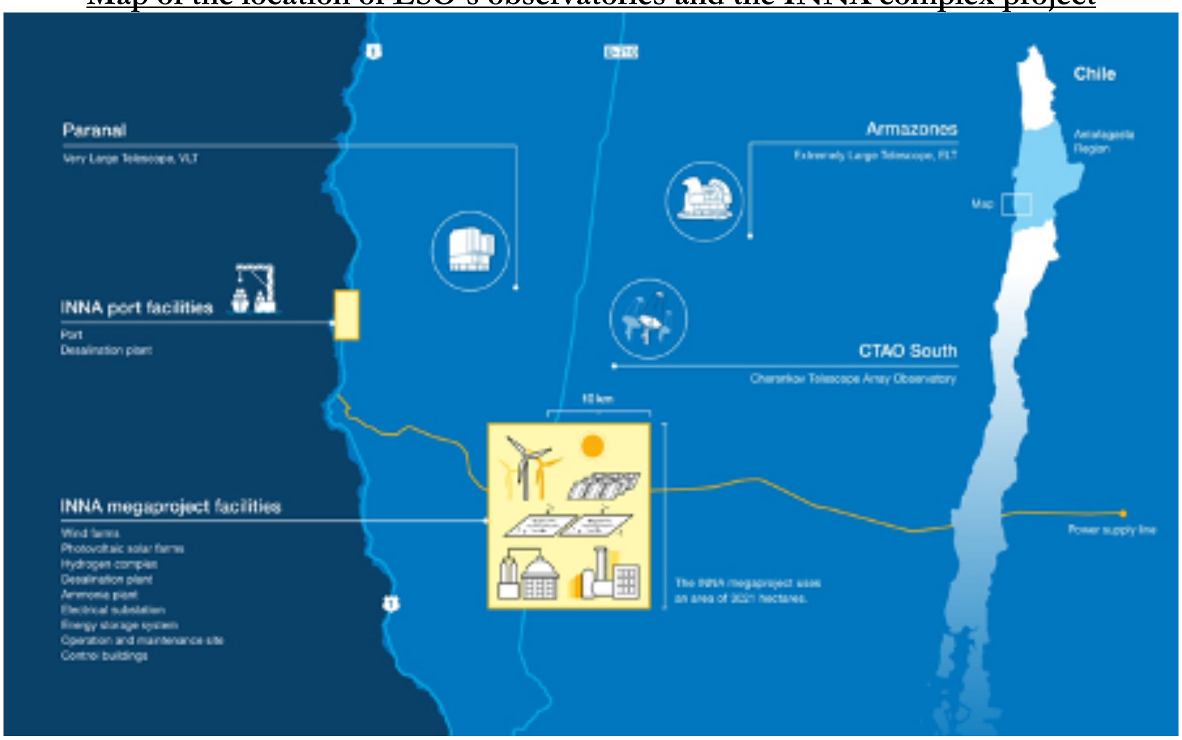
Chile is actively pursuing carbon reduction and energy transition with ambitious goals, aiming for 70% renewable electricity by 2030 and carbon neutrality by 2050 (World Economic Forum 2023). Currently, Chile has over 50 green hydrogen production projects strategically located to leverage energy resources, potential demand, and existing infrastructure (Invest Chile, 2024). Considering the quality and abundance of its renewable resources, Chile is enabling large-scale competitive production, which is a key tool to reduce greenhouse gas emissions. Numerous investment projects are underway, subject to an outlined environmental framework and relevant regulations.

One of these projects was the INNA complex, a massive green hydrogen and ammonia industrial facility proposed by AES Andes, a subsidiary of AES Energy, to be developed in the Atacama Desert in northern Chile. This project, a zero-carbon alternative aiming to help produce renewable energy and reduce greenhouse gas emissions to achieve carbon neutrality, was planned to include producing green hydrogen and ammonia, as well as deploying solar, wind, and battery storage to support the country's electricity needs (AES Andes, 2022, 2024).

The location where the INNA facility was intended to be developed has a unique characteristic: one of the clearest skies on the planet. Nearby are world-class observatories such as the European Southern Observatory´s (ESO) Very Large Telescope (VLT), the Extremely Large Telescope (ELT) which is under construction, and the Cherenkov Telescope Array Observatory (CTAO South), all critical for astronomical work and scientific research. In fact, the development of INNA presented several challenges, including environmental impacts on the ecosystem where it would be established, mainly due to light pollution.

Figure 1

<u>Map of the location of ESO's observatories and the INNA complex project</u>



Source: European Southern Observatory (ESO) [*https://www.eso.org/public/unitedkingdom/images/INNA-map-EN/?lang*](https://www.eso.org/public/unitedkingdom/images/INNA-map-EN/?lang)

1.2 Research Problem: Environmental impact and the INNA Project

Research on energy´s environmental assessment has historically prioritized global externalities, particularly GHG emissions, due to their central role in climate change. At the same time, scholars affirm that focusing solely on carbon can obscure other important burdens. Hydrogen production, for example, is not impact-free, and entails meaningful environmental impacts primarily caused by emissions from the electricity supply (often quantified by GWP) (Kanz *et al.,* 2021). Specifically, emissions from hydrogen production and leakages of molecular hydrogen could indirectly affect atmospheric chemistry by increasing methane lifetimes and reducing stratospheric ozone. This happens when hydrogen is released into the atmosphere, since it participates in complex chemical reactions that increase the concentration of other greenhouse gases (van Ruijven *et al.,* 2011).

Green hydrogen is a promising but complex component of the global energy transition. It has its own environmental trade-offs. While it is extensively considered for its potential for decarbonization, it also incurs environmental costs. Its production requires large amounts of renewable electricity and water. The development of industrial-scale hydrogen infrastructure, which is often located in remote or undisturbed areas, requires large solar and wind installations, potentially affecting ecosystems and biodiversity (Younus et. al., 2025).

To illustrate further the trade-offs of this clean energy, life-cycle analyses reveal that its impacts include atmospheric effects and emerging externalities, such as light pollution and dust. In this regard, recent literature emphasizes that although green hydrogen contributes to climate mitigation, its environmental profile is highly sensitive to system boundaries, leakage rates, and infrastructure design, and thus it is still unclear how the hydrogen economy will evolve and which environmental impacts it will cause (Wei, et. al. 2024). Additionally, the promise of hydrogen as a clean fuel could be impeded if it is not produced with sufficient safeguards and oversight, and integrating life-cycle assessments, advanced safety protocols, and policy interventions to deploy cleaner hydrogen technologies (Dewangan *et. al.*, 2026).

Bará and Lima (2023) discloses that renewable energy systems give rise to significant local externalities, including light pollution, but this is still under-theorized and weakly operationalized. Their research recognizes the presence of wind farm lights as a source of light pollution, severely disrupting the aesthetic, cultural, and scientific values of the pristine starry skies in some places and suggests that the visual range of wind farms at night may be significantly larger than during the day, a factor that should be contemplated in environmental impact assessments.

Light pollution at astronomical observatories is a crucial factor for preserving their scientific productivity and useful lifetime; it is affirmed that to maintain the ability to carry out high-quality astronomical research, it is necessary to reduce the "artificial light at night" that affects the observatories as soon as possible (Falchi *et al.*, 2023).

For example, Jahn (2023) believes that the externalities concerning the atmosphere have been considered as "global commons" challenges and advocates environmental governance promoting collective responsibility for environmental protection. She argues that the law maintains a relationship of human domination over nature, considering the atmosphere as *res nullius* without legislative restrictions for GHGs, leading to massive global warming.

As part of AES Andes' strategy to develop green hydrogen in Chile, the INNA "Integrated Energy Infrastructure Project for the Generation of Hydrogen and Green Ammonia" complex was planned to be the largest industrial-scale green hydrogen and ammonia initiative in Chile. The estimated investment of US$10 billion would have covered an area of approximately 3,000 hectares, including industrial and logistics infrastructure for large solar and wind power generation facilities, electrolysis plants to produce green hydrogen and green ammonia, energy storage systems, transport connections, and potentially port facilities for international export (AES Andes, 2024). In terms of energy production, it would have incorporated a photovoltaic park with up to approximately 1,687 MW of installed capacity and a wind farm of up to 534 MW to produce hydrogen through water electrolysis and subsequently convert it into ammonia for storage and transportation (SEA Chile, 2025).

The INNA complex was planned in the Antofagasta region of northern Chile. This location is in an area characterized by some of the highest solar radiation levels in the world and strong wind resources. These conditions make that specific area highly attractive for renewable energy generation and hydrogen production. In contrast, this location is distinctive for having the clearest skies on the planet that are critical for astronomical work and scientific research. Thus, the future development of this industrial facility was expected to introduce environmental pressures that were not previously captured as a traditional atmospheric externality in that specific ecosystem. In fact, it was projected to bring artificial lighting into an ecosystem that is particularly sensitive to nocturnal disruption.

In December 2024, AES Chile submitted an Environmental Impact Assessment (EIA) for the proposed industrial-scale green hydrogen project INNA to Chile's Environmental Assessment Service (SEA), the relevant national permitting authority. During the early stage of the project's development, the EIA submission was crucial for determining whether it could obtain environmental permits for approval.

Over the months, the concern about the INNA project escalated internationally. On the 2nd of April 2025, 3,437 scientists worldwide signed a letter [1] addressed to Chilean President Gabriel Boric. They alleged that the INNA project would cause irreparable damage due to light pollution, posing a direct and severe threat to critical scientific endeavors, and requested the relocation of the project to a distance that would not endanger the darkest skies on Earth.

In May 2025, the public consultation process concluded, with the total participation composed of 4,094 observers and the submission of 724 comments [2], making it one of the most extensive in the history of the Chilean environmental assessment system and demonstrating widespread concern for the protection of dark skies (Fundación Cielos de Chile, 2026). Then, in September 2025 AES Andes requested an extension to respond to the public comments received in the participatory consultation process of the project´s EIA.

In the meantime, representatives of the scientific and astronomical community worldwide, particularly associated with the Max Planck Society, warned that the project could degrade the world-class dark skies of the Atacama Desert, because of its proximity of about 5 to11 km to the observatories. The main concerns raised pointed out that the industrial facilities of the INNA project would introduce light pollution, ground vibrations, dust affecting telescope mirrors, atmospheric disturbances, and threaten to destroy the pristine dark skies and potentially harm vital astronomical research, despite its alignment with Chile's clean energy goals (Max Planck Gesellschaft, 2025).

On the 14th of November 2025, a group of recognized researchers submitted an open letter to the authorities of the Chilean government urging them to protect the night sky over the Paranal Observatory. The argument presented was that the INNA industrial complex could increase light pollution by up to 35% above Cerro Paranal and cause disruptive microvibrations affecting telescope operations. They also requested the relocation of the INNA project and the protection of the delicate Paranal environment with stricter laws and updated regulations (Genzel *et al.*, 2025).

In December 2025, the protection of dark skies explicitly entered the national political agenda. The final presidential runoff debate directly addressed concerns regarding the impact of the INNA, thus making it a matter of national public interest. In response to the suggestion that the project's impacts could be mitigated, the Chilean Skies Foundation publicly reiterated that the INNA project is not subject to mitigation (Fundación Cielos de Chile, 2026).

The INNA project has been discontinued. On the 23rd of January 2026 AES Andes publicly revealed its determination to desist from the project. This decision was formalized in early February 2026 with the company's official notification of withdrawal (AES Andes, 2026)[1] to the SEA. Despite the company's announcement and the formal cancellation of the project, as of April 2026 AES Andes nor the SEA has reported any information regarding the final technical aspects of the project's environmental assessment.

From a development perspective the research problem addresses the fundamental challenge of reconciling economic development with environmental sustainability. Chile's ambition to become a global leader in green hydrogen production, a strategy closely linked to climate mitigation and economic modernization, interacts with localized environmental protection and governance dynamics.

From an economics perspective, in the context of energy transition, the study considers that despite the potential benefits from the production of renewable energy, such as the attraction of significant

[1]]https://infofirma.sea.gob.cl/DocumentosSEA/MostrarDocumento?docId=2026/02/06/2c40-d63d-4184-9861-93a178a657b4

foreign investment, the creation of job opportunities, and the prospective to reduce GHG emissions, can also generate negative local externalities, such as light pollution, producing environmental disruption.

The analysis of this challenge applied to the case of the INNA project can be interpreted as an outcome of institutional processes that mediate between private economic interests and public environmental concerns, emphasizing the importance of rules, norms, and governance structures in shaping economic behavior and outcomes.

1.3 Justification of Case Selection

The case study of the INNA project reflects a process that reveals whether existing environmental regulations in Chile can govern the environmental externalities of the renewable energy initiative or if they remain anchored in a paradigm designed for conventional extractive or industrial activities. This example provides the opportunity to examine the Chilean environmental law concerning a specific environmental externality such as light pollution *vis a vis* environmental benefits, such as the reduction of GHG emissions, which helps to advance towards carbon neutrality.

The research on this problem is important because the INNA project embodies a crucial challenge in contemporary environmental law: reconciling global climate change mitigation objectives with localized environmental and ecological protection. While green hydrogen projects contribute significantly to reducing greenhouse gas emissions and advancing Chile's commitment to carbon neutrality, they also generate new types of environmental impacts, such as light pollution. To illustrate this rationale, public opinion rather than acknowledging the benefits of renewable energy, pointed out its negative consequences due to light pollution which affects the ecosystem of dark skies important for astronomical research.

The evaluation of the Environmental Impact Assessment System (SEIA) to determine the feasibility of implementing the proposed INNA project considered the relevant provisions of Chile's Environmental Law. These regulations are crucial for understanding the relevant rules regarding the problem examined and its potential implications. The outcome of this process will certainly contribute to further academic and policy discussion on Chilean environmental governance and regulatory framework, specifically with regard to projects on renewable energy infrastructure and the importance of identifying novel risks or challenges.

From a public policy dimension, the technical environmental assessment of the INNA project and its related legal discussion addresses a dilemma, between developing clean and renewable energy infrastructure, which contributes to the energy transition and sustainable development, *vis-à-vis* protecting the darkest skies on the planet, a (inter)national heritage essential for astronomy, from the negative environmental effects. This research will review the key aspects, actors and regulations regarding the project, describing how the process took place, and providing input regarding the compliance of the environmental regulatory framework.

Overall, this research reflects on the implications of developing large-scale projects to produce renewable energy to reduce GHG emissions aiming to achieve carbon neutrality, and creating different types of local opportunities, versus the high costs of generating light pollution, which affects the atmosphere and interferes with scientific research. The analysis and discussion of these implications could contribute to further research in this area of work, and to potential investors interested in future development and implementation of renewable energy projects in Chile.

1.4 Research objectives and questions

This research examines the development of green hydrogen in Chile, and its environmental regulatory framework and administrative decision-making process, addressing the opposing arguments that hindered INNA´s approval. The announcement of AES Andes' decision to revoke INNA project´s proposal, brings relevant elements regarding the regulation of the environmental impact, from the increased light pollution in areas where international scientific-astronomical observatories are located, or even due to the pressure received from the scientific and astronomical community, amplified by numerous political actors. To understand the process that took place and the relevant regulations, this research will address the following main question and sub-questions:

- To what extent Chile's environmental governance dynamics and regulatory framework contributed to shape the decision by AES Andes to withdraw the INNA project?
- Sub-questions
- What legal and environmental regulatory provisions in Chile related to renewable hydrogen production governed the evaluation of the INNA project?
- Are there any provisions in Chilean environmental law regarding the prevention and mitigation of light pollution impacts in large-scale energy projects?

The answers to the questions presented are expected to provide elements sustaining the hypothesis that the environmental regulatory framework and the opposition from astronomical and scientific communities, as well as from environmental organizations, increased pressure on the proposed INNA project making its continuation difficult, which ultimately influenced the decision of AES Andes to withdraw it.

Moreover, the analysis of this specific case, by reviewing the relevant documentation and exploring how the institutional governance is structured, aims to explain how Chile's environmental regulatory framework and governance dynamics influence the development of large-scale green hydrogen projects´ environmental approval processes. This research will contribute to expanding the academic knowledge of environmental governance in Chile, eventually identifying challenges and proposing recommendations to improve the environmental governance and regulatory framework tailored specifically to evolving industries and emerging technologies, such as renewable energy.

1.5 Thesis structure

This research is structured into five chapters, progressing from contextualization and theoretical grounding to documentation analysis, normative evaluation, and recommendations.

Chapter one introduces this research, situating the study within the context of green hydrogen production Chile and its implications for environmental quality and presents the INNA project and its environmental externalities. Building on this contextual foundation, the chapter outlines the main research question and sub-questions, providing an overview of the thesis structure.

Chapter two develops the theoretical and conceptual framework. It describes the opportunities of producing green hydrogen in Chile; it elaborates on the environmental governance theory particularly focused on Chile´s relevant institutions for environmental decision-making, examining the relevant laws, strategies, and provisions regarding renewable hydrogen that are relevant to the process of the INNA project.

Chapter three explains the methodological approach. It outlines the research design based on a descriptive normative approach that examines official and academic documentation as primary data sources and clarifies the scope and limitations of the research.

Chapter four provides a comprehensive analysis of Chile's environmental governance in relation to the INNA project, using the analytical framework developed by Bennett and Satterfield (2018). It also offers an opportunity to examine environmental governance through the lens of institutional multi-level stakeholder engagement, including the political discussion on the implications of the INNA project, the national environmental regulations, and the decision-making processes.

Finally, chapter five concludes the research by summarizing the main findings, revisiting the research question and hypothesis, and offering recommendations for further investigation.

Chapter 2

Theoretical and Conceptual Framework

2.1 Understanding Green Hydrogen

Hydrogen is one of the most abundant elements on the planet. It is a colorless, odorless, tasteless, flammable gaseous substance, which, under ordinary conditions, forms a loose aggregation of hydrogen molecules, each consisting of a pair of atoms: a diatomic molecule H2. Although it is not a primary energy source, like coal or wind, it is considered an energy carrier because it can store energy [3]. Hydrogen can be produced from various sources and classified as grey, blue, or green hydrogen. "Grey" refers to the hydrogen that has been produced using fossil fuels through processes that release high amounts of CO2 into the atmosphere; "Blue" hydrogen, although produced similarly, relies on different carbon capture strategies aimed at reducing CO2 emissions to mitigate climate impact; and "Green", in contrast, is the term used to define when a source of energy has been produced using renewable energy sources (De Blasio, 2024).

According to De Blasio renewable or green hydrogen refers to hydrogen generated via water electrolysis powered by renewable energy sources like wind and solar. In this process, an electrolyzer uses clean electricity to split water (H_2O) into its components, producing hydrogen (H_2) at the cathode and oxygen (O_2) at the anode, with minimal carbon emissions. Currently, green hydrogen remains considerably more expensive than grey hydrogen and represents under 0.1% of worldwide hydrogen output (De Blasio, 2024). A major advantage of green hydrogen is its potential to reduce emissions in sectors that are difficult to electrify, including heavy industry, maritime transport, and aviation. Furthermore, it is a flexible energy carrier that can be utilized directly or transformed into other forms, such as ammonia or synthetic fuels [4].

Although hydrogen is defined as green when there are no CO2 emissions, Squadrito *et al.* (2023, p. 2) affirms that "the most suitable and well-developed technology is based on electrochemical water splitting (electrolysis), the common meaning of green hydrogen is as "Hydrogen made via electrolysis using renewable electricity". Furthermore, they believe that renewable hydrogen could reshape the geopolitics of global energy because many countries view hydrogen as the solution for future energy management and are increasingly supporting the introduction of hydrogen technologies aiming at a decarbonized economy.

According to the Global Hydrogen Review of the International Energy Agency (2025), in recent years the landscape of low-emission hydrogen production has expanded considerably. What began as a small number of pilot and demonstration initiatives has developed into more than 200 confirmed investment projects worldwide. Alongside the growing number of projects, their operational scale and investment levels have also increased, underscoring the strategic importance attributed to hydrogen in achieving long-term climate mitigation and decarbonization targets.

Fernández-Arias, *et al*. (2026) examined 1935 scientific articles on the evolution, trends, and knowledge gaps related to the sustainability of green hydrogen, to conclude that the scientific community envisions it as a key player in the future energy landscape, although identifies challenges related to efficiency, profitability, optimization, integration into sustainable energy systems, and emission reduction.

2.2 The production of renewable hydrogen in Chile

As it was pointed out in the introduction, Chile stands out for its exceptional climate, which makes it a country rich in renewable resources. It has pursued ambitious climate and energy policies aimed at reducing greenhouse gas emissions, diversifying the energy matrix, and attracting investment in renewable technologies such as solar, wind, and green hydrogen. Indeed, according to the latest report of the International Renewable Energy Agency in 2024, "renewable sources covered 63.4 % of the total electric-power demand of Chile" (IREA report 2024, in Baran et. Al, 2025).

Green hydrogen is a central component of Chile's strategy to reduce carbon emissions. This resource availability gives the nation clear advantages for hydrogen production, including strong wind gusts and the highest solar radiation in the world, and lower electricity production costs (Acosta *et al*., 2022). It has significant renewable energy potential, with over 1,800 GW of available power. This could even decarbonize sectors reliant on fossil fuels, addressing 76% of emissions, and aims to become a leading exporter of green hydrogen and its derivatives (Acosta *et al*., 2022).

The production of green hydrogen has a high valued potential. According to Chile's National Green Hydrogen Strategy (2020, p. 10-11), it will "achieve the lowest levelized cost of production on the planet by 2030. The reductions in costs "will lead to highly competitive green hydrogen production for domestic use and export. If timely and effective action is taken, the use of green hydrogen in domestic applications will generate an industry capable of competing in international export markets. Investment in green hydrogen will lead to significant national capabilities and to the creation of dynamic economic ecosystems throughout the country".

The National Green Hydrogen Strategy (2020) of Chile indicates that the country possesses more than 1,800 GW of renewable energy potential, including 1,200 GW from solar and 550 GW from wind. In light of the above, García and Oliva affirms that green hydrogen can be produced at competitive prices. "To achieve this goal, Chile has launched a series of policies and initiatives aimed at promoting the use of clean energy and increasing energy efficiency. Among them, the government expects to reduce more than 10 million tons of CO2 emissions by producing 5.4 GW of hydrogen by 2050" (2023, p. 8).

The International Energy Agency (Global Hydrogen Review, 2025) notes that low-cost electricity is crucial for hydrogen production, with countries like Chile benefiting from inexpensive renewable energy sources. The IEA Review estimates that by 2030 the levelized cost of electricity for solar and wind in Chile is expected to decrease significantly, enhancing its competitiveness in hydrogen production. Additionally, according to the Team Europe Renewable Hydrogen Funding Platform for Chile, implemented by the Chilean Production Development Corporation (CORFO), the country has confirmed committed loans of EUR 100 million, targeting at least 150 MW of new electrolyze capacity from export credit agencies (2025, p. 182-183).

Barra (2024) analyzes the role of green hydrogen in Chile's energy transition and affirms that due to the current increasing share of renewable energies and projects, the country has the potential to become a leading exporter of green hydrogen globally. Pottstock (2024) study of the environmental impact of the production of green hydrogen in the country sustains that regardless of how hydrogen is produced, minimizing metal and energy consumption can significantly reduce its environmental impacts. Moreover, although recognizes Chile's National Strategy as a starting point for transiting to a low emission country, her research notes that "hydrogen production methods are not emission-free, as the infrastructure required to produce and transport hydrogen generates emissions during its construction, operation, maintenance, and dismantling". Thus, recommends the strategy to consider the entire life cycle of the process to contribute reducing environmental impacts (2024, p. 24).

In view of the high potential of the renewable hydrogen industry, Cereceda (2024) argues that a regulatory gap exists in Chile regarding the green hydrogen production. He identifies legal, regulatory, and state gaps in all areas of the national institutional framework and advises the establishment a solid regulatory framework defining standards and requirements, as well as regulatory measures to control and supervise new projects in the green hydrogen industry. Additionally, Raihan (2023) analyses variables that contribute to carbon emission reduction in Chile and recommends preventing environmental degradation though the establishment of robust regulatory policy instruments.

2.3 Environmental Governance

The theory of environmental governance provides a normative context for the analysis of the withdrawal of the INNA Project because it considers the concerns regarding the environmental impact not only from a technical perspective, but also from an institutional dimension: how governance arrangements and dynamics shape the environmental policies that are formulated, negotiated, and implemented, such as the role that plays the environmental governance framework, the regulatory provisions and the relevant stakeholders in the policy decision-making process.

Environmental governance refers to the set of regulatory processes, mechanisms and organizations through which political actors influence environmental actions and outcomes (Lemos & Agrawal, 2006), managing and steering the relationship between society and the environment in order to address environmental problems and achieve sustainability (Evans & Thomas, 2024). Unlike traditional environmental government, which relies mainly on hierarchical state regulation, environmental governance recognizes that authority is distributed among diverse actors, including governments, private firms, NGOs, communities, and international organizations. Benson & Jordan affirm that there is no single theory of environmental governance, because "most accounts of how the environment and sustainable development has been governed make little or no reference to what currently passes for governance theory, it has undeniably become a normative strategy" (2017, p. 7).

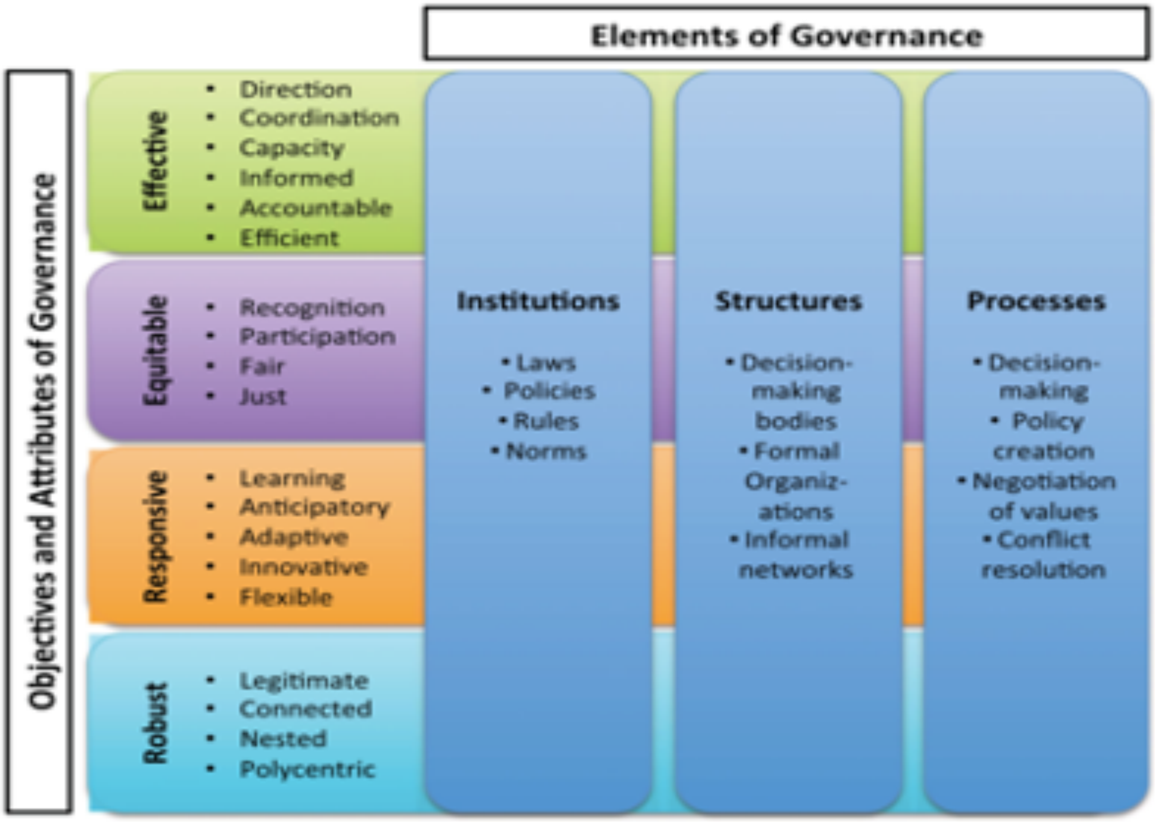
In their pursuit to frame the evaluation, design, and analysis of systems of environmental governance, Bennett and Satterfield (2018) provide a comprehensive framework that can be applied to this endeavor in different social and political contexts, to diverse environmental problems and modes of governance. In this framework they consider that environmental governance must aim for four objectives: to be effective, equitable, responsive, and robust.

These objectives have a set of attributes that are evaluated across three analytical dimensions: capacity, functioning, and performance. All are considered simultaneously across the institutional, structural, and procedural aspects of environmental governance. *Effectiveness* refers to the extent to which governance systems achieve their intended environmental outcomes; *Equity* to fairness in the distribution of costs, benefits, and participation; *Responsiveness* to the ability of governance systems to adapt to new information and stakeholder concerns; and *Robustness* to the resilience and stability of governance systems under pressure (Bennett & Satterfield, 2018, p. 3-6).

The concepts of institutions, structures and processes are based on the definitions stipulated by Douglas North (1990). *Institutions* are the formal and informal rules that shape human interactions that guide, support, or constrain human or management actions; *Structures* are formal bodies, organizations, and informal networks of actors that embody governance capacities and perform different functions; and *Processes* are the means for realizing the functions and the performance of governance. Environmental governance structures and processes can come together in many ways, driven by diverse actors, at different level. "Moreover, the institutional, structural, and procedural elements of governance can occur at various scales from local to global, to interact across scales, and to have an effect on the capacity, performance, and outcomes of environmental governance" (North, 1990, in Bennett and Satterfield 2018, p. 6).

To understand the application of the evaluation framework is also crucial to integrate aspects of multilevel governance (MLG) theory, which considers the analysis of how authority and decision-making are distributed across different scales and actors (Saito-Jensen, 2015). Moreover, the analysis of Pattberg and Widerberg (2015, p. 686-687) on Global Environmental Governance (GEG) considers the proliferation of actors and the intensified interaction of governance levels among the key trends of GEG. They indicate that traditional state actors and intergovernmental organizations are no longer the sole or even dominant agents in environmental governance. Instead, a wide range of non-state actors, including non-governmental organizations, multinational corporations, scientific networks, and city-level governments, now exercise authority and influence across borders. Therefore, in light of the above, this research recognizes the analysis of environmental governance as distributed and networked, involving state and non-state actors that operate at different levels.

Figure 2: "Evaluation framework for environmental governance"



Source: Bennett & Satterfield (2018, p. 8)

Lemos & Agrawal (2006, p. 319) believe that effective environmental governance requires the incorporation of knowledge about limits on aggregate levels of human activities that contribute to pollutant emissions. They sustain that for designing and assessing strategies of environmental governance it is critical to consider nature´s concerns and long-term sustainability. In relation with environmental impact on the atmosphere, Jahn (2023) addresses how international obligations for climate change mitigation may be transformed into domestic legal duties that facilitate local co-governance of the atmosphere, drawing on new legal approaches that focus on humanity's responsibility towards nature.

Although the energy transition and renewable technologies have contributed to climate mitigation, they also generate environmental externalities at different levels, particularly in the most vulnerable environments, introducing new governance challenges. Therefore, institutions need to adjust their structure, mechanisms, or frameworks. Currently, the governance of renewable energy projects requires integration with local ecosystems and communities, taking into account different multidimensional variables, to ensure, for example, compliance with land use, infrastructure development, or the addressing of any conflicts between global climate objectives and local environmental concerns (Mamat *et al.*, 2025).

De la Mora (2022) considers that the concepts related to environmental governance and analytical frameworks in Latin America are unclear and polysemic. Her critical perspective on the effectiveness of institutional components and social organizations of environmental governance distinguishes the main challenge presented by environmental governance as "the lack of a democratic tradition that favors relations between state and society based on the recognition of the latter as subject of rights; therefore, the lack of respect for the rule of law has repercussions for local communities and ecosystems" (2022, p. 862-863).

Regarding Environmental Impact Assessments, Nita *et al.* (2022) argue that the quality of implementation varies depending on the country or even the project. The analysis observes that issues interfering EIA's proper implementation are common, such as specific regulations, low quality of assessment reports, insufficient equipment and trained staff, inadequate institutional framework, lack of public participation, and low levels of cooperation between policymakers, researchers, and stakeholders.

2.4 Environmental Governance in Chile

In Chile, environmental governance is structured around a set of regulatory institutions and legal frameworks that govern environmental protection and resource management and plays a critical role in mediating these processes. Since the 1990s, environmental governance has evolved significantly, with the creation of environmental institutions, policies, regulations, and participatory mechanisms designed to evaluate and mitigate environmental impacts, responsible for addressing environmental externalities, including those associated with large-scale energy projects.

Although academic research suggests that socioenvironmental conflicts often arise from policy incoherence across sectors, these conflicts are explained by a systematic problem, rather than being attributed to a particular industry, since in many cases, legal environmental rights have not been fulfilled (Berasaluce *et al.,* 2021). Additionally, it has been found that the relationship between transparency and public accountability is triggered by the agenda setting and linked to the policy outcome through formulation, institutional change and a government's implementation style (Fontaine *et al.*, 2022).

Flores-Fernández (2020) believes that the socio-technical process of the Chilean energy transition has given rise to a post-political energy condition, enabling the perpetuation of power relations and structures of capitalist appropriation and management of energy resources. One of his main arguments is that the transition "has not implied progress towards democratic and decentralized energy systems that promote local development and the effective participation of communities in energy decision-making". He affirms that "energy decisions continue in the hands of private monopolistic and oligopolistic actors, who with the permission of the State define the location of projects without effective processes of citizen participation beyond the -often testimonial- instances of environmental qualification (2020, p. 186).

Eterovic Martí (2023) affirms that Chile faces several governance challenges related to green hydrogen development, including regulatory uncertainty, infrastructure development, and environmental permitting processes. She specifies that "there are various aspects of the green hydrogen industry that need to be regulated throughout the entire value chain, such as safety, environmental, and tax benefits. While she explains that "Law 21.305 allowed the Ministry of Energy to regulate green hydrogen and implement its regulatory agenda regarding safety aspects", she also argues that the "definition of the quality and sustainability attributes to be certified must align with the implementation of the Strategy, the carbon-neutrality goals, and the just energy transition" (Eterovic Martí, 2023, p. 39-40).

Moreover, Skewes et. Al., (2025, p. 7) examine the regulatory challenges and trends in Chile's energy law in the context of energy transition, and indicate that "emerging technologies, such as green hydrogen, require new regulatory adaptations", explaining that "a comprehensive framework for hydrogen and further development in energy storage regulations are critical to unlocking their potential".

Bergamini and Pérez (2022) analysis on Chile's EIA process revealed that despite positive improvements, there remain significant weaknesses in almost all stages, identifying "above all in matters related to communication and citizens' engagement, a key element that has been putting into question the whole system of environmental impact assessment in Chile. In the same vein, one relevant upgrade that still needs to be developed is the processes of early citizen engagement" (2022, p. 434). Additionally, Rodríguez-Luna *et al.* (2021, p.8) compared the Chilean EIA system with those in Brazil, Spain, and Canada, and propose that the "main options for improving the Chilean EIA system are related to criteria Alternatives for design, Adoption of decisions, EIA decentralization at the national level, Scoping, Baseline information, and Public information process and post-evaluation".

Furthermore, Jiliberto (2021, p. 377) states that SEA is a process led by the sectoral decision-maker, where the environmental authority takes on an observational role. He argues that how SEA functions in Chile is shaped by a tension between its strategic purpose and the way it is carried out in practice, resulting in a distortion of its strategic character, because it was implemented "on the basis of a rigid and standardized procedural verification model that collides with the ambiguity and openness of complex decision-making processes inherent in the formulation of policies and plans. This has had consequences not only administratively, but also substantively, as it has tended to encourage a formalization of the evaluation process and its departure from the final decision" (2021, p. 374).

Conversely, the study by Irarrazaval *et al.* (2023) examines instances of social protest linked to investment projects within the EIA framework, finding that while such protests can slow down the process, they do not affect the nature of the environmental decision issued. The research also finds that energy projects encountering social opposition are more prone to rejection than those in mining or other sectors. Furthermore, Silva (2023) analyzed the politics of policy implementation and efforts to reform the Chilean SEIA, to conclude that their role does not ensure policy impacts. However, his research identified that "an insider strategy of working with political institutions was warranted since the immediate arena was a parliamentary committee. From there, activating a policy network that included politicians was an effective for generating mediated impacts under favorable conditions and indirect impacts under unfavorable conditions" (Silva, 2023, p. 8).

2.5 Environmental governance of the INNA Project:

2.5.1 Project proponent AES Andes:

AES Andes is an electricity generation and energy infrastructure firm based in Santiago, Chile. It operates as a subsidiary of AES Corporation, a global energy company headquartered in the United States. In South America, it has an installed capacity of 5,657 MW and maintains a wide pipeline of renewable energy projects under development. The company is among the leading power generators in the region, with a diversified portfolio that includes hydroelectric, wind, solar, energy storage, natural gas, and coal-based facilities.

In Chile, this energy business, formerly known as Chilectra Generacion, was first incorporated via public deed by the federal government in 1981. In 1987, it was divided into three different companies, with Chilgener remaining as the main generator and distributor. In 2000, AES acquired Chilgener and changed its name to AES Gener. In April 2021 the company changed its name to AES Andes (Bolsa de Santiago, 2021) [6].

Currently AES Andes and its subsidiaries own and operate 3,885 MW, comprising 1,645 MW of thermal power, 771 MW of hydroelectric power, 431 MW of wind power, 667 MW of photovoltaic solar power, and 371 MW of battery energy storage systems, in addition to seawater desalination plants and transmission lines. It has 572 MW of renewable capacity under construction and a contracted project pipeline exceeding 1,620 MW, with investments exceeding USD 2 billion between 2024 and 2027 (AES Andes, 2024).

AES Andes has increasingly focused on renewable energy and energy storage as part of the global transition toward low-carbon power systems (AES Andes, 2024). A key milestone in the company's transformation occurred in 2018 with the launch of its sustainability strategy Greentegra [7], which focuses on decarbonizing the company's energy matrix; making their customers' supply more sustainable; and strengthening their investment grade to accelerate portfolio transformation.

In 2022, AES Andes affirmed that Greentegra's transformational strategy continued to consolidate, demonstrating solid operational and financial performance and commercial resilience. In that report, the CEO Javier Dib highlighted that "the financial results show the resilience of the Company in the execution of Greentegra, which is a reflection of the strategic discipline of our entire team to honor the commitment that we have with the decarbonization of the energy matrix and the contribution of new 100% renewable solutions" (AES Andes, 2022). Overall, since Greentegra was launched, AES Andes has made significant strides in reducing the emissions intensity of its portfolio, investing over USD 1.9 billion to incorporate 1,504 MW of wind, solar, and battery capacity (AES Andes, 2024).

AES Andes´ industrial-scale INNA complex was planned as one of the most prominent energy infrastructure projects. In December 2024 AES Chile submitted INNA´s Environmental Impact Assessment (EIA) to the Environmental Assessment Service (SEA) for its review. In January 2026, still under the EIA process, AES Andes announced the withdrawal of the implementation of the INNA project, explaining that the decision was in line with the guidelines of its parent company in the United States (AES Andes, 2026).

2.5.2 The Ministry of the Environment of Chile:

The Law 19.300 [8] on the General Bases of the Environment, from 1994, is the legislation that established the foundation for Chile's national institutional environmental framework. This law created the National Environmental Commission as the main institution responsible for environmental oversight and environmental policy development. Subsequently, following institutional reforms further strengthened the environmental governance framework.

The Ministry of the Environment (MMA) [9] was created in 2010 under Law 20,417, as the country´s central institution to articulate the environmental governance architecture, it is responsible for shaping and developing environmental policies and regulations, safeguarding biodiversity, and ensuring sustainable development within the framework of national law. A fundamental pillar of the MMA is the Environmental Impact Assessment System [10] (SEIA), an environmental management tool of a preventive nature managed by the Environmental Assessment Service, which, based on an Environmental Impact Study or Declaration, determines whether the environmental impact of an activity or project complies with current regulations. SEIA plays a crucial role particularly in regulating large-scale infrastructure projects through policy design, coordination, and oversight of environmental instruments, especially those with significant impacts.

The MMA agencies are (i) the Environmental Assessment Service (SEA), (ii) the Environmental Superintendence (SMA), and (iii) Environmental tribunals. These institutions were designed to separate environmental policymaking, project evaluation, and enforcement functions. The SEA is the public agency responsible for managing and coordinating the environmental impact evaluations of the SEIA, while the SMA oversees compliance with environmental regulations and enforces sanctions for violations.

On February 19, 2025, the MMA, through its Regional Secretariat–SEREMI of Antofagasta, submitted an official document[2] with several observations to the EIA submitted by AES Andes, particularly requesting clarification on why the proposed INNA project was not located within the polygons defined by the electric generation development poles (PDGE); requested presentation of a feasibility analysis of the project's location, indicating the alternatives studied for its location; and a re-evaluation of the project's location.

2.5.3 Central Government and Presidential Office:

As previously specified, the MMA was primarily responsible for technical evaluation and regulatory compliance. Therefore, this subsection explains the role of the Central Government of Chile, focusing on the executive branch led by the Presidential Office, and other ministerial authorities that played a secondary role in the examined case.

During the period when the EIA process was being carried out, President Gabriel Boric Font led the Executive branch of the Government of Chile, whose mandate extended from 11 March 2022 to 10 March 2026. Despite several formal communications from different stakeholders, specifically the international scientific community and the Senate of Chile, alerting it to the potential negative consequences if the project was developed, no public references or direct evidence were found regarding adopted decisions or official statements delivered by the executive branch or the President himself.

The Central Government's position is considered non-interventionist. Rather than issuing a related directive or decision, the government played a strictly coordinating role, allowing the environmental legal process to be undertaken through institutional channels. The position is also ambivalent because, instead of promoting or rejecting the project, the Government endorsed the idea of coexistence between renewable energy development and astronomical research. Overall, the Executive branch did not become involved in the EIA system, which is interpreted as a means to strengthen the legitimacy of the decision-making mechanism.

Moreover, the environmental review process also involved indirectly the Ministry of Science and the Ministry of Foreign Affairs. Both ministries reported concerns regarding the preservation of the astronomical ecosystem and international agreements related to the observatories, respectively. The Ministry of Science advocated for protecting Chile's astronomical infrastructure, highlighting the global importance of the observatories located in the north of the country, and contributed scientific expertise to the evaluation process. Meanwhile, the Ministry of Foreign Affairs played an important

[2]https://infofirma.sea.gob.cl/DocumentosSEA/MostrarDocumento?docId=2025/02/20/66af-9ddc-41ba-aefa-4c142b8f548e

role by raising alarms about potential violations of international agreements governing astronomical facilities.

Following the project's cancellation, government authorities adopted a validating stance, emphasizing the importance of protecting Chile's scientific and environmental heritage. The decision was widely interpreted as aligning with national interests, particularly in preserving the unique conditions of the Atacama Desert for astronomical research and the need for stronger regulatory frameworks.

2.5.4 Congress: Senate and Chamber of Deputies:

The Senate is composed of 50 members who participate in numerous commissions, permanent, mixed topic or even ad-hoc committees, responsible for studying and reporting to the Senate plenary on bills and constitutional reform proposals submitted for their consideration. The initiatives are distributed among the committees according to specific themes, and as exemplified in this case, often act as key venues for integrating specific topics or technical knowledge into political processes.

With regard to the INNA case, Senate commissions, particularly those involved with environment, energy, and science-related issues organized hearings that included the participation and testimonies from astronomers, international scientific organizations, and environmental experts to examine the project's implications. The statements given by some representatives of the Senate also contributed to the discursive framing of the INNA project in different aspects, such as the protection of Chile's scientific infrastructure; defense of national heritage; environmental sustainability; economic development; energy transition; and local employment.

Furthermore, in accordance with the commitment made within the commissions on Environment, Climate Change and National Assets; Mining and Energy; and Foreign Affairs, the Plenary of the Senate unanimously approved the draft agreement, that requested the Executive branch to set a mandatory critical radius of protection in those strategic sites for optical and infrared astronomical observation and to establish exclusion zones [11].

Additionally, the Chamber of Deputies, which is composed of 155 deputies, also played an active role in the discussions regarding the INNA project, particularly from representatives of the Antofagasta region in northern Chile by posing questions to government officials, issuing public statements, and, in some specific cases, supporting environmental advocacy. Numerous statements by deputies were widely circulated in national media. Individual members, including presidential candidates, also referred to the AES Andes project, advocating for the protection of the skies and opposing it by demanding its relocation or cancellation.

Overall, the stance and role adopted by the Legislative branch of Chile reflected regional and political dynamics. Both corporations channeled diverse interests and conveyed important messages from relevant stakeholders, such as environmental NGOs, the scientific community, and local actors. This dynamic contributed to influence congressional agendas and mobilize public opinion, transforming the project into a national political issue, amplifying environmental concerns and increasing public scrutiny.

2.5.5 The Chilean Astronomical Society (SOCHIAS):

SOCHIAS[3] is a non-profit organization that represents the community of astronomers in Chile before various national and international bodies. Its purpose is to promote the development of astronomy by fostering research, teaching, and outreach, as well as safeguarding the interests and rights of astronomers in Chile. The position of SOCHIAS regarding the INNA project is clearly articulated as one of strong resistance to its development, advocating for the early termination of the environmental evaluation process. It performed a significant role in alerting the public and the scientific community, amplifying the message through social networks and collecting signatures to protest the project.

Through a public statement[4] in February 2025, SOCHIAS requested an early termination of the INNA project, indicating that the observations issued by the MMA revealed significant technical deficiencies and inaccuracies in the project's Environmental Impact Study, particularly regarding its potential impacts on astronomical observation, due to (i) the project's location, noting that it was not planned to be situated within officially designated energy development zones; (ii) serious deficiencies in the evaluation of light pollution, including insufficient data and uncertainty regarding mitigation measures; and (iii) the definition of the project's area of influence, emphasizing the inadequate consideration of impacts on nearby observatories and the omission of critical scientific parameters in the analysis.

Furthermore, on the 10th of March, SOCHIAS issued a public call[5] to Chilean citizens and organizations encouraging them to actively engage in the citizen participation process (PAC) by submitting their observations in support of the relocation of the INNA project. Notwithstanding this outreach action, on the 31st of March SOCHIAS formally petitioned the SEA for an early rejection of the project, arguing that the information provided by AES Andes´ EIA was insufficient and inaccurate, and lacked essential information, anticipating that the presented project was not meeting the necessary criteria to guarantee the protection of Chile's dark skies, and that the projected impacts were too severe to be mitigated[6].

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3 https://sochias.cl/
4 https://sochias.cl/wp-content/uploads/2025/02/Early_Termination_Statement_SOCHIAS_English_20250221.pdf
5 https://sochias.cl/instructivo-pac-por-proyecto-inna/
6 https://sochias.cl/proceso-de-participacion-ciudadana-en-relacion-a-inna

2.5.6 The European Organization for Astronomical Research in the Southern Hemisphere (ESO):

ESO is an intergovernmental organization founded in 1962, with headquarters in Germany. Supported by multiple European member states, ESO is one of the world's leading organizations for astronomical research, whose mission is to design, build, and operate world-class astronomical observatories and to enable international scientific collaboration. Over the decades, ESO has played a pivotal role in astronomical discoveries, including innovative observations of distant galaxies and stellar evolution (ESO, 2025).

In 1963, ESO and Chile signed a visionary agreement that paved the way for the construction of La Silla Observatory, in the region of Coquimbo. This original intention, based on the spirit of trust and cooperation, led ESO to generate a unique synergy with society in the country, reflected in the fact that it currently operates all of its observatories in Chile, including Paranal, and the Atacama Large Millimeter/submillimeter Array (ALMA) in partnership with international collaborators [12].

The Paranal Observatory is particularly significant because it hosts the Very Large Telescope (VLT), the most productive astronomical ground-based facility in the world, which has made an undisputed impact on observational astronomy [13]. In addition, the nearby Cerro Armazones site will host the Extremely Large Telescope (ELT), which is expected to begin scientific observations later this decade. These facilities require extremely dark and stable skies to perform high-precision observations of faint cosmic objects. As a result, the preservation of environmental conditions around these sites has become a major concern for the scientific community.

On March 17, 2025, the European Southern Observatory released a press statement presenting findings from an analysis indicating that the INNA project would raise light pollution over the Very Large Telescope by at least 35%, and by more than 50% over the southern site of the Cherenkov Telescope Array Observatory South. Overall, the project would contribute to higher levels of light pollution, atmospheric turbulence, and airborne dust in the region, thereby worsening conditions for astronomical observation, while project-related vibrations could significantly disrupt the operation of these facilities.

In addition, the analysis concluded that the INNA project would substantially decrease the performance of all the telescopes (VLT and VLTI in Paranal, ELT in Armazones and the CTAO-South), indicating that "as all mitigating actions have already been taken, these negative and unacceptable impacts cannot be avoided or mitigated, unless the INNA project moves away. Should the INNA project be approved, the value of the telescopes installed or planned by ESO would substantially decrease. These losses are manyfold and not recoverable worldwide" (ESO, 2025).

2.5.7 The Max Planck Society for the Advancement of Science (MPG):

Founded in 1948 as the successor to the Kaiser Wilhelm Society, MPG is Germany's most successful research organization. With 31 Nobel Laureates among its scientists, and more than 15,000 publications each year in international scientific journals, MPG is renowned for its contributions to important research across multiple disciplines, such as natural sciences, social sciences, and humanities. [14]

MPG is funded primarily by the German federal and state government. It operates a decentralized network of specialized research institutes covering disciplines globally, from astrophysics to comparative law and social anthropology, engaging in research, policy debates, and advisory roles focused on environmental governance, climate law, and sustainability transitions, often combining legal analysis with empirical scientific data [15]. Its research activities have had a profound influence on international scientific discourse and policymaking, including emerging debates in environmental governance and environmental law.

With an interdisciplinary approach, MPG actively engages in research related to environmental governance, climate law, and sustainability. It addresses complex ecological challenges, such as climate change, biodiversity loss, and ecosystem degradation. Regarding the INNA project, MPG adopted a clear and coordinated position, emphasizing both support for renewable energy and concern for the protection of the scientific infrastructure. Through the open letter submitted in November 2025, a group from MPG urged the Government of Chile requesting to relocate the industrial complex and to protect the delicate Paranal environment with stricter laws and updated regulations.

2.5.8 Fundación Cielos de Chile:

Fundación Cielos de Chile [16] was established in 2019 as a private, non-profit organization with the core mission of promoting, protecting, and preserving the extraordinary value of Chile's skies as a natural laboratory for science and research, and as an element of cultural and recreational importance for its citizens and tourists from around the world. The foundation also aims to be a leading institution, on a national and international level, in the fight against light pollution, and in its evaluation, regulation, and mitigation, to recover the natural levels of darkness in the night sky.

The organization frames dark skies as a scientific asset and as an environmental and cultural resource that is increasingly threatened by artificial lighting and industrial development. It is closely linked to the astronomical community, including major observatories such as those supported by the European Southern Observatory, reflecting a strong science-based orientation.

Fundación Cielos de Chile played a role in the environmental governance of the INNA project by articulating concerns related to light pollution and its broader implications. Through institutional participation, scientific advocacy, and public communication, the foundation actively participated in the public debate of the INNA project, with media interventions, public statements, and communication strategies that contributed to bringing the issue of light pollution into national and international attention. The foundation also engaged with formal governance mechanisms, including the EIA process. However detailed records of these submissions are not publicly available.

2.5.9 DarkSky International:

DarkSky International is a global nonprofit organization dedicated to protecting the night environment and preserving dark skies. It was founded in 1988 and is widely recognized as a leading authority on light pollution and night-sky conservation. It is based in the United States, with headquarters in Tucson, Arizona, but operates internationally through chapters, delegates, and partnerships. DarkSky's general position and key concerns are framed under the "*Five Principles for Responsible Outdoor Lighting*". These guidelines to prevent or minimize light pollution outline that responsible outdoor lighting must be (i) *useful*, (ii) *targeted*, at *low level*, *controlled,* and *warm-colored* (Dark Sky, 2020).

On March 25, 2025, DarkSky published a position briefing paper on project INNA and its impact on Chile's dark skies. The organization opposed INNA's location because it affirmed that the project's impact on light pollution and atmospheric conditions will threaten world-class dark skies and astronomical research. It advocated for the protection of these skies, calling for the establishment of a 50 km buffer zone in the national law, ensuring that light pollution within this zone does not exceed 1% above natural background levels, and for the project's relocation outside this buffer zone to safeguard Chile's leadership in astronomy while allowing for sustainable development in a more compatible location (Dark Sky, 2025).

2.6 Environmental Regulatory Framework in Chile

This section illustrates the major institutional developments and current relevant regulations.

2.6.1 Environmental Framework Law (Law 19.300) & SEIA:

The Environmental Framework Law 19.300, adopted in 1994, is the overall regulation establishing the national institutional framework, principles and procedures for environmental protection in Chile. Its general provisions indicate that it will regulate the right to live in a pollution-free environment, the protection of the environment, the preservation of nature, and the conservation of environmental heritage. Among its main objectives, it considers environmental management, the liability for environmental damage, and the operation of the instruments for environmental management, including quality standards, prevention plans, and remediation plans. It determines the liability of individuals for damage caused to the environment and requires their remediation.

As described in the institutional framework of environmental governance, the structure of state agencies responsible for these matters is led by the MMA, but the most relevant institution for the purpose of this research is the Environmental Impact Assessment System [17] (SEIA), responsible for regulating the obligation to submit investment projects for assessment to prevent negative impacts. The SEIA assesses projects or activities that generate significant impacts; each initiative that generates significant impacts is submitted as Environmental Impact Assessments (EIAs), while all other projects are presented as Environmental Impact Statements (EISs). The procedure is conducted by the regional offices of the Environmental Assessment Service (SEA), or by the Executive Directorate in the case of interregional projects. EIAs always include at least one period of Public Participation (PAC); and when applicable, a Consultation Process with Indigenous Peoples (PCPI) is also considered.

The classification of a project, whether it is approved, approved with conditions, or rejected, are determined by the Environmental Assessment Commissions in the case of regional initiatives, and by the Executive Directorate of the Environmental Assessment Service (SEA) for projects that span multiple regions. The process concludes with the issuance of an Environmental Qualification Resolution (RCA). When the RCA is favorable, it confirms that the project meets all relevant environmental requirements, including any mitigation, compensation, and remediation measures, as well as the standards for ongoing monitoring and supervision by the Superintendencia del Medio Ambiente (SMA). No public authority may refuse the environmental permits required.

Along with the SEIA procedures, it is worth highlighting the importance of the SEA technical guidelines and evaluation criteria (under Article 11 of Law Nº 19.300), which provide benchmarks regarding the information necessary to predict and assess the environmental impacts of a project or modification of an activity. These documents not only contain the crucial criteria for determining whether the identified impacts are significant and whether an impact assessment is required (either qualitative or quantitative, depending on the available information) but also specify technical information for preparing an Environmental Impact Statement (EIS) or an Environmental Impact Assessment (EIA) before projects are submitted to the SEIA, contributing to reduce the level of discretion in the decision-making process.

Particularly, for the EIA of the INNA project, the SEA based its evaluation on accordance with the "Evaluation criteria for determining the susceptibility of astronomical areas to impact" (SEA, 2024). Under this standard, the criteria to determine if a project presents the effects, characteristics or circumstances described in article 11 letter d) of Law No. 19,300 are to meet two conditions: first, the project must be located in or close to an astronomical area; and second, its artificial luminosity emissions must be likely to affect the astronomical area (2024, p. 18). Additionally, the minimum background information to be submitted must include a description of the artificial light emissions resulting from the use of outdoor lighting generated by the project or activity during its construction, operation, or closure phases (2024, p. 24-25).

In addition to the astronomical impact, the SEA applied the standard criteria of the SEIA, which included the evaluation of the atmospheric emissions and dust, noise and vibrations, impacts on biodiversity (flora and fauna), effects on communities and the surrounding area, climate and environmental risks associated with the infrastructure.

2.6.2 Framework Law on Climate Change (Law 21.455):

Ley Marco de Cambio Climático 21.455, enacted in June 2022, establishes a framework to confront the challenges of climate change by promoting a shift toward low GHG and climate-forcing emissions. Its goals include reaching and sustaining carbon neutrality by 2050, strengthening adaptation by lowering vulnerability and enhancing resilience to climate impacts, and fulfilling the international commitments undertaken by the Chilean State in this area.

Overall, the law institutionalizes climate governance in Chile by integrating climate considerations into national development planning, strengthening accountability, and ensuring long-term continuity of climate policies. It also refers to the institutional framework, climate change management instruments, greenhouse gas emissions standards and emissions-reduction certificates, financial mechanisms and guidelines, access to information and citizenship participation, among other provisions.

The most relevant provisions of Law 21.455 are those particularly referring to the standards for and compliance with greenhouse gas emissions. Under its article 14 the law determines that the Ministry of Environment will develop rules to establish the maximum amount of a greenhouse gas and/or a short-lived climate-forcing agent that an establishment, emitting source or group thereof may emit, based on a reference emissions standard by technology, sector and/or activity, in order to meet the objectives of the Long-Term Climate Strategy and the Nationally Determined Contribution. To define the emissions standard, the Ministry of Environment will consider the best available techniques by applying criteria focused on cost-effectiveness, equity, responsibility and economic, social and environmental impacts.

In terms of compliance with the standards of the GHG emission, under its Article 15 the law indicates that projects in Chile must submit documentation to prove the reduction or absorption of greenhouse gas emissions. The Ministry of Environment is the entity that establishes, through regulations, the criteria for determining the maximum number of certificates allowed to be used, in a given period of time, to comply with the standard, as well as the requirements for the eligibility; the procedure for their processing; the background information that must be included; the criteria and methodologies for verifying the reductions or absorptions of emissions; and any other complementary methodologies that may be necessary. It stipulates that within the framework of the international cooperation established in Article 6 of the Paris Agreement, the Ministry of the Environment will regulate emission reduction or offset certificates, promoting sustainable development, environmental integrity, transparency, and the application of robust accounting.

Although Law 21.455 does not directly refer to green hydrogen or its specific environmental impacts, it complements the climate and environmental policy framework within which green hydrogen projects must be evaluated. In this regard, it is worth highlighting that the law establishes that project developers must submit documentation indicating the assessment of climate impacts, mitigation measures, and compatibility with climate policies. The law includes the most important provisions related to GHG emission and incorporates climate change variables and relevant environmental components.

2.6.3 National Green Hydrogen Strategy:

In November 2020 the Government of Chile launched its "National Green Hydrogen Strategy" (2020). This roadmap, strongly grounded in the country´s commitment to climate action, defines different areas or work in line with the commitment of achieving net-zero emissions by 2050. The strategy positions green hydrogen as a key tool to reduce greenhouse gas (GHG) emissions, complementing electrification and energy efficiency, and promotes green hydrogen as a replacement of fossil fuels in various sectors like mining transportation, industry, power generation, and chemical production, among others. The strategy indicates that green hydrogen will contribute significantly to emissions reduction, both domestically and globally, since it is produced through electrolysis powered by renewable energy, and therefore acts as an energy carrier that does not generate greenhouse gas emissions during its use (Ministry of Energy, 2020, p. 7).

Regarding the regulatory framework, it is essential to ensure safe and sustainable deployment of hydrogen technologies. The strategy notes that early regulatory development will help protect operators, the public, infrastructure, and the environment while enabling the scale-up of hydrogen production and use. To achieve this, Chile plans to develop technical standards and regulatory mechanisms across the hydrogen value chain, including production, storage, transport, and final consumption. These regulations are intended to align with international standards and provide certainty for investors and project developers (Ministry of Energy, 2020, p. 26).

In relation to environmental externalities, the strategy expresses its commitment to a balanced use of resources and land, indicating that industrial development must be coherent with its socioenvironmental context and that Chilean institutions will work to safeguard the environment while maintaining active dialogue with local communities. Moreover, its Action Plan includes a goal to communicate with the general public regarding environmental and safety opportunities and challenges to generate trust in hydrogen use (Ministry of Energy, 2020, p. 22-29).

2.6.4 Green Hydrogen Action Plan 2023-2030:

The Green Hydrogen Action Plan 2023–2030 (2023) in Chile is a government policy roadmap designed to guide the development of a national green hydrogen industry during the referred period. It outlines the strategic actions, regulations, investments, and institutional measures needed to scale up the production and use of green hydrogen produced from renewable energy sources, aiming to operationalize the national hydrogen strategy by setting concrete measures, timelines, and responsible institutions to develop the green hydrogen sector.

It also includes several elements addressing environmental impacts and externalities associated with the production and deployment of green hydrogen. It refers to an environmental governance framework to support the sustainable development of the green hydrogen industry, recommending the creation of a robust regulatory system for permitting, environmental assessment, and project monitoring to address the emerging challenges associated with large-scale hydrogen production. Specifically, the plan proposes strengthening the Environmental Impact Assessment System (SEIA), developing technical criteria for evaluating hydrogen-related projects, and increasing institutional capacity within the Environmental Assessment Service to improve the evaluation of complex projects in the hydrogen value chain (Ministry of Energy, 2023, p. 113-119).

In addition, the plan aims to consolidate the existing reference information of the SEIA, by compiling and standardizing existing environmental reference information and valuing information from conducted environmental impact studies, which will serve as a reference for future processes. It also promotes the adoption of international environmental standards where national regulations are insufficient or not regulated, considering them relevant to the industry's construction, operation, and sustainable management, and applying them until they are replaced by national regulations (Ministry of Energy, 2023, p. 96-97).

With regard to environmental impact, the plan recognizes that the large-scale deployment of hydrogen infrastructure may generate externalities that must be carefully assessed and deem measures to ensure that the growth of the hydrogen industry does not undermine ecosystem integrity and biodiversity conservation while enabling the sector to contribute to climate mitigation objectives. It particularly highlights potential impacts on biodiversity, ecosystems, and environmental services from the expansion of renewable energy facilities, industrial infrastructure, desalination plants, and transport networks across the hydrogen value chain. To address these risks, the plan establishes sustainability criteria requiring hydrogen projects to apply precautionary and preventive principles, emphasizing the need to consider cumulative and synergistic environmental effects on air, water, soil, and biodiversity, especially in regions expected to host large hydrogen projects (Ministry of Energy, 2023, p. 42-44).

2.6.5 Chilean Regulation on Light Pollution: Supreme Decree Nº 1/2022:

Since 1998 Chile has had an Emission Standard for the Regulation of Light Pollution. Supreme Decree No. 686 of 1998 was the first regulation, focused on protecting the astronomical quality of the night skies of the country's northern regions of Antofagasta, Atacama, and Coquimbo.

The current regulation is the Supreme Decree No. 1 of 2022, the *Norma de Emisión de Luminosidad Artificial Generada por Alumbrados de Exteriores,* which aims to control outdoor lighting emissions to protect astronomical quality, health, and biodiversity, and to establish emission standards for artificial luminosity generated by outdoor lighting systems, indicating technical limits and operational restrictions according to the lighting category. This regulation aims to reduce light pollution and its associated environmental impacts, particularly in sensitive ecological areas and regions hosting astronomical observatories.

The decree explicitly recognizes the preservation of dark skies as a matter of scientific and environmental importance. In relation to the impacts associated with the use of the sky for astronomical observation, acknowledges that light pollution reduces the capacity of telescopes, thus affecting the development of scientific astronomy based in the country and tourism activities associated with astronomy (MMA, 2023, p. 2-3).

In addition, the regulatory framework introduces, under Article 3 (j) of its general provisions, the concept of *Astronomical Areas*: as areas with scientific and research value for astronomical observation, and under 3 (k) the *Special Protection Areas*: astronomical areas, biodiversity protection areas, and species breeding grounds where artificial light is identified as a threat, and delimited in a Species Recovery, Conservation, and Management Plan (MMA, 2023, p. 6). These areas are incorporated into broader special protection zones, where stricter lighting standards apply in order to safeguard both astronomical research and environmental integrity.

The Chilean Ministry of the Environment defines light pollution as the alteration of nighttime darkness by unnecessary artificial light. This phenomenon affects human health by disrupting sleep cycles and harms biodiversity by disorienting nocturnal species. Furthermore, it reduces the quality of the skies for astronomical observation, a crucial activity for the Antofagasta, Atacama, and Coquimbo regions, which host approximately 70% of the world's astronomical capacity (Vivanco, 2025).

Moreover, according to NOIRLab (2023), the *Norma Lumínica* is a highly comprehensive regulatory tool, as it extends controls on light-emitting sources across the entire country. It not only safeguards dark skies for astronomical observation, but also incorporates the protection of biodiversity and human health as key environmental objectives. The regulation sets limits on the brightness of industrial lighting by establishing maximum average emission levels, and applies comparable restrictions to vehicular, pedestrian, and sports lighting. In addition, it encourages a shift toward warmer lighting technologies by imposing stricter limits on blue light emissions, such as those produced by Light Emitting Diode systems.

Chapter 3

Methodology

3.1 Research Design

To answer the main question and sub-questions, this research employs a qualitative document review and analysis of Chilean environmental governance and climate regulations. This normative approach consists of descriptive research of relevant documentation and secondary sources, focusing on the environmental governance and relevant regulations of the case study of the INNA green hydrogen project.

The methodology contextualizes relevant institutions, mechanisms and provisions of the environmental governance and regulatory framework. Based on the operationalization of the model presented by Bennett and Satterfield, this research evaluates governance performance, considering the different elements introduced in the conceptual framework of this research, according to elemental objectives and attributes, and aims at understanding the interplay between institutional structures, decision-making processes, and outcomes. It emphasizes that governance must be evaluated not just by effectiveness but by how decisions are made and experienced.

This framework contributes detecting objectives and attributes of the environmental governance of the INNA project by describing diverse relevant aspects and examining the decision-making process. The document review is coded based on the conceptual framework of structures, institutions and processes, whose articulation identifies important actors, environmental regulations, laws, strategies, provisions, and key milestones of the project and its environmental impact assessment. This methodological procedure allows for the interpretation of facts and abstractions through a documented conceptual analysis supported by evidence-based arguments.

Additionally, the review of both the institutional and operational layers of the INNA project provides a broad landscape of Chile's national environmental governance, which is considered multilevel governance because decision-making is distributed across different scales and actors, transcending borders and incorporating international interests and involvement.

3.2 Data

Data analysis considered the examination of several sources, including official documentation of the main actors and institutions regarding the INNA project. For this purpose, AES Andes was assessed as the project's proponent, Chile's Executive and Legislative branches, the Scientific and Astronomical community, and Civil Society. It was also observed the relevant regulatory framework, specifically Chile's Framework Law on Climate Change (Law 21.455); the Green Hydrogen Action Plan in Chile 2023-2030; the National Green Hydrogen Strategy; the technical guidelines of the Environmental

Impact Assessment System (SEIA) under the Chile's Environmental Framework Law (Law 19.300); specifically, the "Criteria for determining the susceptibility of affecting astronomical areas", and the Light Pollution Regulations (Supreme Decree Nº 1/2022). Furthermore, the research incorporated statements from AES Andes, and other relevant public documentation regarding the INNA project, as well as academic papers, policy documents and various communications concerning the environmental externalities of the project and the protection of the astronomic ecosystem.

Table 1: Key elements identified and assessed in the governance system of the INNA process:

INSTITUTIONS	STRUCTURES	PROCESSES
REGULATORY FRAMEWORK - Environmental Framework Law (Law 19.300) - Environmental Impact Assessment System - Environmental Impact Assessments - Framework Law on Climate Change (Law 21.455) - Sectoral Regulations (energy and light pollution) - Supreme Decree No. 1/2022 (Light Pollution) - National Green Hydrogen Strategy - Green Hydrogen Action Plan 2023-2030	ACTORS AND NETWORKS - Private Sector: AES Andes - Government: Presidential Office - Ministry of Environment - Environmental Impact Service - Sectoral Ministries (MFA, MoE) - Political/Legislative representatives - Scientific/Astronomic Community: - Chilean Astronomical Society - European Southern Observatory - Max Planck Society - International and national NGOs: - DarkSky - Fundación Cielos de Chile - Local Communities: PAC	ENVIRONMENTAL IMPACT ASSESSMENT - Public Participation (PAC) - ICSARA (Information Requests) - Inter-agency Technical Review - Scientific Inputs - Evidence Integration

Source: Own elaboration based on the Environmental Evaluation Framework of Bennett and Satterfield (2018).

3.3 Data Analysis Technique: Governance Evaluation Framework

To process the data into the governance evaluation matrix, each of the elements of governance – structural, institutional and procedural– was gauged in relation to the four objectives, according to their respective attributes (qualities or capacities). The assessment was undertaken using the model of Bennett and Satterfield, which was built upon a "comprehensive list of considerations (alternately termed principles, attributes, or indicators of governance by different authors) associated with the capacity, functioning, and performance of governance" (2018, p. 2, Appendix 2). Specific matrices were developed to evaluate each of the objectives, combining multiple dimensions to enable a comprehensive assessment of a governance system.

The codification of reviewed qualitative data was applied to assess different attributes, such as legitimacy, accountability, coordination or participation, among others. For this purpose, ordinal scales were defined to standardize the analysis for evaluation matrices. The matrices were labeled based on the following five categories: Very High, High, Moderate, Low, and Very Low.

The application of this set of matrices facilitated the identification of findings in a systematic manner, indicating the general and specific performances of the objectives, and enabling, for example, the research to observe relationships, patterns, gaps and opportunities, or even tensions among them. Furthermore, the use of the matrices and the coding of the key elements identified enriched the data used in analysis, enhancing the understanding and acceptance of the findings.

The Effectiveness Matrix was used to assess the extent to which governance systems achieve their intended management objectives. It examined attributes such as direction, coordination, capacity, informed decision-making, accountability, and efficiency. Each of these attributes was operationalized through observable inputs, such as the presence of clearly articulated goals (direction) or adequate human and financial resources (capacity). The evaluation considered how these inputs were translated into outputs, such as the establishment of rules, decision-making processes, and management actions. Finally, the outcomes were assessed in terms of the performance of environmental governance system and regulatory provisions, thus enabling the tracing of governance weaknesses or gaps.

The Equity Matrix introduced a dimension focused on fairness, justice, and inclusion. Its analytical application involved assessing whether governance processes and outcomes were socially legitimate and justly distributed, considering attributes such as recognition, participation, fairness, and justice, by examining inputs, such as institutional provisions for stakeholder engagement, legal protections for marginalized groups, and mechanisms for equitable distribution of costs and benefits. The main outputs included the quality of deliberative processes, representativeness in decision-making, and the existence of fair allocation mechanisms. While the outcomes were assessed in terms of inclusivity, well-being, and access to justice, with the aim of revealing distributional and procedural inequalities identified in the governance system of the studied process.

The Responsiveness Matrix was used to analyze the capacity of governance systems to adapt to change, uncertainty, and complexity, identifying if it is static and rigid, or dynamic and adaptive. The application of this matrix considered the assessments of attributes such as learning, anticipatory capacity, adaptability, innovation, and flexibility. The inputs included monitoring systems, knowledge-sharing platforms, and institutionalized processes for reflection and revision. Outputs included the generation and integration of new knowledge into decision-making, the adjustment of policies, and the experimentation with new approaches. The outcomes were evaluated in terms of resilience, adaptability, and the capacity for coping with shocks and disturbances.

The Robustness Matrix focused on the stability and persistence of governance systems over time, it was useful for analyzing structural resilience. It was used to examine whether institutions maintained their functions and legitimacy in the face of internal and external pressures, by evaluating attributes such as legitimacy, connectedness, nestedness, and polycentricity. The inputs included the presence of shared visions, institutional transparency, and multi-level governance structures; the outputs reflected the strength of networks, the alignment of actions across scales, and the redundancy of institutional arrangements. Outcomes were assessed in terms of institutional durability, consistency of performance, and the ability to withstand crises.

Overall, the matrices served as a diagnostic, comparative, and integrative tool for environmental governance analysis. They enabled a structured examination of how institutional capacities translated into functions and outcomes across effectiveness, equity, responsiveness, and robustness objectives. By linking normative principles with empirical indicators, considering multidimensional elements, the application of the framework enables environmental governance to be assessed comprehensively and systematically, which supports academic analysis and practical policy evaluation.

3.4 Research scope and limitations

This study adheres to ethical research standards, ensuring transparent and responsible use of data. Consistent with the current circumstances and recent development of the process of the withdrawal of the INNA project, this research is strictly limited to the analysis of relevant aspects related to the environmental governance and regulatory framework with regard to the proposed project. No other governing bodies were considered, such as the energetic regulatory framework stipulated in Law Nº 21.305, or the Law Nº 20.848 which establishes the framework for Foreign Direct Investment in Chile, or any national or international laws or norms that could be relevant to additional discussions.

Additionally, this research is subject to other limitations. For example, the analysis of a single-case study constrains the possibility of generalizing the conclusions. Although the case provides a comprehensive understanding of Chile's environmental governance dynamics, reflecting the configuration of actors, environmental concerns, and political conditions, the extent to which these findings can be extrapolated to broader governance processes remains limited.

Furthermore, this research presents reduced empirical diversity in terms of data sources and actor representation. The analysis primarily relies on regulatory documents, institutional reports, and public information available, which may not fully capture the range of perspectives involved in the governance process, for example the participation of local communities or other less institutionally visible stakeholders. This limitation discloses a bias toward an institutional perspective, as the analytical framework emphasizes formal governance structures and procedures, thus reducing informal dynamics, such as power asymmetries, political negotiation, or other socio-economic interests, crucial factors that explain the outcomes of the analysis.

Since the EIA process was underway when the INNA project withdrawing was announced, the analysis of the most relevant technical aspects related to the effect of the regulatory provisions regarding the environmental assessment is also limited, because technical elements of the environmental impact assessment were not disclosed at the time when this research was concluded.

Chapter 4

Research Findings, Analysis and Discussion

4.1 Findings and Analysis

This section examines Chile's environmental governance and regulatory framework related to the INNA green hydrogen project through the analytical lens proposed by Bennett and Satterfield (2018). As it was explained before, their framework conceptualizes environmental governance as a system that should achieve four general objectives: to be effective, to be equitable, to be responsive, and to be robust. Each of these four objectives were considered simultaneously across the institutional, structural, and procedural elements of environmental governance.

Applying this framework to the study case enables a multidimensional evaluation of how the Chilean governance arrangements, comprising legal norms, institutions, and decision-making processes, interacted to shape the outcome of the INNA project. As indicated in the methodological design, this research adopts a normative institutional analysis, examining how governance performance is reflected not only in outcomes but also in how decisions are driven and made by stakeholders.

This subsection describes the main findings of the study case, after applying the governance evaluation framework according to the performance of the elements within the four objectives of environmental governance, presenting the following general results:

Table 2: Assessment of the environmental governance of the INNA project

Objective	Institutional	Structural	Procedural	Overall
Effectiveness	**Moderate**	**High**	**Very High**	**High**
Equitable	**Low**	**Moderate**	**High**	**Moderate**
Responsiveness	**Moderate**	**High**	**Very High**	**High**
Robustness	**Very High**	**High**	**Very High**	**Very High**

Source: Own elaboration.

4.1. 1 Effectiveness

In terms of **structural effectiveness,** as previously described, Chile's environmental governance system is characterized by a clear and functional separation of roles among key institutions. The Ministry of Environment, in charge of policy design and supervision; the Environmental Assessment Service, responsible for project evaluation; and the Superintendence of Environment, which operates through enforcement protocols, though it was not necessarily considered an active actor in this case.

From a functional perspective, the participation of different external actors providing specialized knowledge revealed that the system was open and ready to consider and evaluate additional information. However, from a capacity point of view, the documentation examined evidenced that formal State institutions were not fully aligned or coordinated. The structural configuration enabled the identification and amplification of environmental risks, contributing to the decision of withdrawing the project. Thus, considering the outcome, a high level of effectiveness was found in the performance, yet mainly due to the engagement of external actors, which meant that structural effectiveness depended on broader governance networks, beyond the formal State structure.

The **institutional** components of the revised legal framework are considered strong. Embodied in Law 19.300 and the SEIA, it evidences a highly established capacity, due to its clear mandates, procedural requirements, and regulatory authority for evaluating environmental impacts. In this case, the adoption of normative criteria was highlighted by the SEA technical guidelines, specifically by the "Evaluation criteria for determining the susceptibility of astronomical areas to impact", since the EIA of the INNA project met its main conditions. Moreover, besides the astronomical impact, the SEA applied the standard criteria of the SEIA.

However, the outcome of the case study demonstrates a moderate level in terms of performance. The institutional system contributed to the identification of environmental risks associated with the INNA project, but it was done through the mobilization of external actors, especially the scientific community. The absence of explicit regulatory thresholds for light pollution in the context of hydrogen infrastructure meant that risks were not preemptively addressed through institutional mechanisms, instead, they were articulated through procedural processes and external actor engagement.

The **procedural dimension** of effectiveness was considered very high, representing one of the strongest aspects of Chile's governance system. The procedural capacity is reflected in the design of the SEIA, which includes mechanisms for environmental assessment, public participation, and inter-agency coordination. The operative aspect was particularly strong in the INNA case. The SEIA process facilitated extensive participation, allowing hundreds of observations to be submitted and considered. It enabled the incorporation of new and relevant information into the assessment, exhibiting transparency and inclusiveness.

The process performance had a direct impact on governance outcomes. The identification of light pollution risks and their consideration in the EIA were made possible by the openness and flexibility of the assessment process. Therefore, it is highly probable that, although not directly, the performance of the process influenced the decision to withdraw the project.

4.1. 2 Equitable

The **structural dimension** of equity assessed suggests a moderate level, because, while the case demonstrates uneven power dynamics among stakeholders, the environmental governance system is open and includes diverse actors. However, their influence is asymmetrically distributed. The scientific community, for example, held significant and technically valid authority, shaping the narrative and influencing decision-making. Their expertise, credibility, and access to global networks enabled them to frame the issue of light pollution in ways that resonated with the broader public.

The mobilization of over 3,400 scientists and the advocacy from recognized academic and research institutions revealed that effectiveness was not only a product of State capacity but also of networked governance dynamics. Moreover, the public awareness of this issue due to the active engagement of political and legislative actors, reveals that equity in environmental governance cannot be reduced to participation alone; it also requires attention to who has influence.

The **institutional aspects** of equity were evaluated as low, reflecting limited capacity to address distributive justice. Chile's legal framework formally recognizes environmental rights, including the right to a pollution-free environment; it provides limited mechanisms for addressing distributional conflicts. Instead of ensuring fair outcomes and anticipating potential externalities, Chile's institutions, instead, consider diverse perspectives, focusing primarily on procedural inclusion rather than on outcome distribution. Outcomes may reflect the relative power of different actors rather than a balanced consideration of all interests or related provisions.

The **procedural elements** of equity were assessed as high, reflecting strong inclusiveness in governance processes. Although procedural inclusion does not automatically translate into equitable influence, it is emphasized that the SEIA provides formal mechanisms for public participation, ensuring that different stakeholders can submit observations and engage with the evaluation process, contributing to decision-making. In the INNA case, extensive public participation with over 4,000 observers, composed of individuals, communities, and organizations, presented more than 700 submissions, granting legitimacy to the EIA, demonstrating active engagement and high procedural fairness, and fostering expectations of equitable governance.

Nevertheless, analysis of distributive equity around the INNA project reflects the tension between global and local environmental objectives. On one hand, green hydrogen production contributes to global decarbonization efforts, generating benefits for local communities and beyond national borders. On the other hand, the environmental costs due to light pollution are localized, affecting specific ecosystems and scientific infrastructures. Given this dilemma, the absence of explicit distributive frameworks does not allow the governance system to provide clear criteria for balancing these competing interests, leaving distributive outcomes subject to the dynamics of the evaluation process.

4.1. 3 Responsiveness:

Structurally, responsiveness is considered high, amplified by the presence of active and engaged stakeholder networks. The involvement of institutions such as the Ministry of Science, international organizations, and representatives of Civil Society, indicates that the governance system was capable of integrating expert knowledge across multiple scales. Also, the rapid mobilization of the scientific community and public actors played a crucial role in bringing attention to the issue of light pollution. These actors not only provided technical expertise but also facilitated the dissemination of information across various scales, reaching local communities, international audiences, and legislative hearings.

The openness of participation mechanisms facilitated the possibility to incorporate the new information and evidence that was presented, enabling diverse actors to contribute knowledge and perspectives. This multi-level engagement enabled the governance system to respond to emerging concerns that might otherwise have remained localized or overlooked.

However, institutional responsiveness is considered more limited because it demonstrates a reactive adaptation. While Chile has introduced regulatory measures addressing light pollution, these developments occurred in response to growing awareness of the issue rather than as part of a proactive governance strategy. The regulatory framework did not anticipate the specific challenges posed by large-scale renewable hydrogen projects, nor did it provide clear guidance for managing their environmental impacts. Despite the existence of a general regulatory framework on this matter, there is no evidence that required provisions to prevent emerging environmental impacts were fully operationalized at the time of the INNA assessment, thus revealing a limited institutional capacity for foresight. The INNA case demonstrates that Chile's governance system is highly effective in reactive but not anticipatory responsiveness.

At the procedural level, responsiveness is particularly strong. In terms of capacity, the EIA process is inherently iterative, allowing for the continuous incorporation of new information and stakeholder input. In the INNA case, concerns regarding light pollution were not fully articulated at the beginning but emerged and evolved throughout the evaluation process. The system's ability to accommodate these concerns by incorporating new elements during the EIA process, reflects a high degree of procedural flexibility.

Moreover, the performance is considered very high, as the company ultimately changed its position. While AES Andes initially expressed interest in assessing the feedback from the EIA's participatory consultation process and insisted on the project's continuity, the concerns raised significantly reduced its future feasibility. Thus, the withdrawal of the project can be interpreted as a responsive outcome, reflecting how the process adjusted in light of an emerging risk.

Despite the fact that the proposed project was aligned with Chile's green hydrogen strategy and energy transition, from a governance perspective, it is considered that the responsiveness of the Chilean system might have contributed to the withdrawal of the INNA project, and AES Andes' decision reflected strategic adaptation to an unfavorable regulatory and social environment, rather than a purely technical determination.

4.1. 4 Robustness:

The robustness of Chile's environmental governance system reflects a defining characteristic of the INNA case, yet its strength lies not merely in institutional durability, but in its capacity to absorb, structure, and legitimize the conflict without collapsing into political arbitrariness.

In terms of the ability of governance systems to maintain functionality and ensure procedural legitimacy, the evidence suggests that the governance structure was able to accommodate diverse actors and concerns, remaining stable despite significant pressure, which represents strong structural resilience. The involvement of scientific communities, civil society organizations, and international stakeholders effectively addressed the tension and diffused their interests across the governance system. The outcome shows that rather than destabilizing governance, external pressure on conflicting interests at multiple governance levels was absorbed and rearticulated through formal channels, particularly the SEIA process.

At the institutional level, robustness is reflected in the legal authority of Chile's environmental framework, particularly Law 19.300 and the SEIA. The INNA case demonstrates that these institutions provide a stable and legitimate architecture resistant to political intervention. Despite intense public scrutiny and political pressure, the Executive Branch did not interfere in the formal evaluation process, allowing the SEA to operate independently. This non-interventionist stance reflects a deeply embedded norm within Chilean environmental governance that legitimacy derives from adherence to established procedures rather than discretionary authority.

Additionally, the transparency of procedures, the availability of participation mechanisms, and the iterative nature of the evaluation process all contributed to validating the system. Even as opposition to the INNA project intensified, stakeholders continued to engage through formal channels rather than resorting to extra-institutional conflict. The SEIA provided a stable framework for decision-making, maintaining trust and reflecting consistency and predictability even under contentious conditions. This indicates a high degree of procedural legitimacy, a core component of robust governance.

However, institutional robustness also has limitations. The reliance on procedural legitimacy can affect processes, particularly in relation to emerging environmental risks. The SEIA's ability to maintain stability may come at the cost of delayed regulatory innovation or even regulatory gaps. For example, the INNA case reveals that there were no conditions granted for the development of the project under the regulatory framework, which, if applied, could have preemptively avoided undesirable outcomes for the proponent company.

4.2 Discussion:

The analysis of Chile's environmental governance dynamics regarding the evaluation process of the INNA project illustrates how development outcomes are shaped not only by economic or technological factors but also by a complex interaction between formal institutional arrangements, stakeholder interactions, and evolving regulatory provisions.

The application of Bennett and Satterfield's governance framework enabled the research to highlight that development is not a linear process, but rather a multidimensional one, involving numerous actors operating across different scales. Therefore, the study validated Saito-Jensen´s view that decision-making is distributed across different scales and actors, as well as Pattberg and Widerberg´s understanding of the interaction of governance levels among a wide range of state and non-state actors, who exercise authority and influence across borders.

Particularly, the examination through the analytical lens of Bennett and Satterfield´s framework, disaggregated across institutional, structural, and procedural elements, discloses that Chile's environmental governance system is institutionally robust and procedurally effective, but challenged by emerging environmental complexities.

The INNA case demonstrates that the governance process of the EIA is not only determined by regulatory design but by the interaction between institutions, actors, and processes. The potential environmental externalities were effectively prevented, but through reactive action following the public pressure rather than by proactive regulation. Therefore, the project's withdrawal cannot be attributed to a single regulatory or institutional decision, but rather to the multiple effects of procedural rigor, networked governance dynamics, and emerging regulatory constraints operating across multiple dimensions of governance.

The findings indicate, in principle, that Chile's environmental governance dynamics and regulatory framework contributed to the decision regarding the withdrawal of the INNA project. The governance system functioned as an adaptive and deliberative platform in which environmental concerns, particularly light pollution undermining astronomical and scientific research, did not directly prohibit the project but enabled conditions under which it became politically, socially, and environmentally untenable.

According to the examination, institutionally, Chile's environmental governance framework provided the legal foundation for this process through Law 19.300 and its associated regulatory instruments. The SEIA, as a core institution, did not formally reject the project; instead, it provided a structured and legitimate procedural space through which concerns regarding environmental impacts could be articulated, and considered in the EIA. This sustains Jiliberto`s argument about the SEA as a process led by the sectoral decision-maker, where the environmental authority takes on an observational role.

The INNA project, given its scale and proximity to sensitive environmental and scientific areas, was subject to this evaluation process. The legal framework mandated the identification, prediction, and mitigation of environmental impacts, thereby creating the conditions under which concerns related to light pollution could be formally introduced into the assessment process.

The analysis reveals that the legal framework was comprehensive in procedural terms and exhibited limitations regarding emerging environmental externalities. The absence of specific regulatory provisions tailored to green hydrogen production meant that the evaluation of the INNA project relied on general environmental principles rather than sector-specific standards. The lack of anticipation to consider the *Norma Lumínica* evidenced a regulatory gap underscoring the challenges of governing novel industrial activities within frameworks designed for more traditional environmental impacts. This outcome supports the recommendations of Raihan and Cereceda about the need for a solid regulatory framework and regulatory policy instruments for the green hydrogen industry, to contribute to carbon emission reduction and preventing environmental degradation.

Regarding the first sub-question about the legal and environmental regulatory provisions governing the evaluation of the INNA project, it was identified that Chile's regulatory framework is characterized by a combination of general environmental legislation and sectoral fragmented regulations. The SEIA operated as the central procedural mechanism, requiring project proponents to submit detailed environmental studies assessing potential impacts across multiple domains, including considerations of air quality, biodiversity, water use, and, increasingly, light emissions. The evaluation process was supported by technical guidelines and overseen by the SEA, which articulated inputs from various public agencies.

The second sub-question, concerning the existence of provisions related to the prevention and mitigation of light pollution impacts in renewable energy projects, reveals a more complex regulatory landscape. Chile has developed specific regulations addressing light pollution, most notably through the emission standards established in Supreme Decree No. 1/2022. These regulations have been particularly significant in northern regions hosting astronomical observatories, where artificial light emissions can have profound impacts on scientific research.

Nevertheless, in the INNA case light pollution emerged as a central issue not because of explicit regulatory standards or prohibitions, but due the interaction between scientific expertise and public participation. The scientific community played a critical role in translating technical concerns about light emissions into public governance-relevant knowledge. The inclusion of light pollution within the regulatory framework could be deemed an important development in Chilean environmental governance, reflecting recognition of unconventional environmental externalities, although the application of these regulations to large-scale energy projects remains limited.

In policy terms, the analysis evidences that the current system is insufficient in addressing the full range of associated environmental impacts. Therefore, as pointed out by Skewes et. Al., regarding that energy law requires new regulatory adaptations for emerging technologies, such as renewable hydrogen, it would be relevant to explore alternatives to better articulate environmental regulatory provisions for this fast-evolving sector.

Although the SEA published in December 2025 the report "Considerations for the formulation of effective environmental measures in green hydrogen value chain projects" (SEA, 2025), it could be beneficial to build on this work to strengthen the regulatory regime, explicitly defining environmental standards, assessment criteria, and mitigation requirements for the entire hydrogen value chain, and integrating lifecycle analysis, cumulative impacts, and cross-sectoral interactions.

From a responsiveness perspective, the Chilean governance system demonstrated a high capacity to incorporate new information and adapt to emerging concerns. The SEIA process allowed for iterative engagement, enabling stakeholders to submit observations, request additional information, and challenge the adequacy of environmental assessments. This procedural flexibility facilitated the integration of scientific evidence regarding light pollution, ultimately contributing to the reassessment of the project's viability.

However, the responsiveness was largely reactive rather than anticipatory. The regulatory framework did not proactively identify light pollution as a critical issue in the context of green hydrogen development. Instead, it responded to concerns raised during the evaluation process, evidencing the limitation of a governance system that relies on adaptation rather than proactive risk assessment. The INNA case thus underscores the need for a more anticipatory approach to environmental governance, particularly in rapidly evolving sectors like the energetic.

Equity considerations regarding the governance process were characterized by an extensive and operational public participation. The scientific community, supported by international networks, and parliamentary participation, providing institutional legitimacy, had a strong influence on the outcome. However, the distribution of influence among stakeholders was uneven. Local communities, while formally included in the process, appeared to have had a less visible impact on decision-making. In terms of extensive participation, the outcome contrasts Bergamini and Pérez´view regarding a weak citizen engagement on Chile's EIA process. It reaffirms Silva´s observation about the mediated role political actors play, evidencing how senators advocating for scientific concerns enabled effective impact.

Robustness is evident in the stability and legitimacy of Chile's governance system throughout the INNA process. Despite significant controversy and pressure, the system maintained its procedural integrity, with decisions being processed through established institutional channels rather than through external political intervention. The withdrawal of the project, while influenced by external pressures, occurred within the framework of the SEIA, reinforcing the legitimacy of the governance system.

Chapter 5

5. Conclusions and recommendations

In the context of energy transition, the research embraces a development perspective in which there is a fundamental challenge of reconciling economic development with environmental sustainability. Chile's ambition to become a global leader in green hydrogen production, a strategy closely linked to climate mitigation and economic modernization, interacts with localized environmental protection and governance dynamics. The study engages with the concept of environmental impact as an externality, illustrating how green hydrogen promotion, although promoted for its potential to reduce greenhouse gas emissions, a positive externality, can also generate negative local externalities, such as light pollution and environmental disruption.

Through the analysis of the findings, it is possible to affirm that Chile's environmental governance dynamics contributed to influencing the decision of cancelling the INNA project. This is explained through a combination of procedural effectiveness, structural network engagement, and adaptive responsiveness, all operating within a robust but institutionally limited regulatory framework.

It was also found that the legal regulatory provisions governing renewable hydrogen production did not provide a comprehensive or anticipatory basis for evaluation, relying instead on general environmental legislation and technical guidelines. Similarly, provisions addressing light pollution, though advanced in certain respects, were not fully integrated into the governance of this large-scale energy project, requiring their interpretation and enforcement within broader assessment processes.

Although the case study of the INNA project provided a comprehensive understanding of Chile's environmental governance dynamics, reflecting the configuration of actors, environmental concerns, and political conditions, the extent to which these findings could be extrapolated to broader governance processes is narrow. In addition, limited empirical diversity in terms of data sources and actor representation reduced the range of perspectives involved in the governance process analyzed, while upholding the institutional dimension. With this in mind, for example, further analysis, based on a comparative approach, examining different regions or types of infrastructure projects, could strengthen the academic debate.

The disaggregated governance evaluation framework provided an explanation and assessment for the INNA outcome. Institutional elements were considered moderate due to regulatory gaps; structural elements were mainly high due to the multiple actors' active engagement; and procedural elements were very high due to the effectiveness of the SEIA. Ultimately, the withdrawal of the INNA project illustrates that environmental governance in Chile operates not as a rigid system of rules but as a dynamic and adaptive process, where outcomes are shaped by the interaction of institutions, actors, and procedures. This configuration allows the system to address complex environmental challenges, even in the absence of fully developed regulatory frameworks, but it also highlights the need for more anticipatory and integrated approaches to governance in the context of the energy transition.

In light of the above, this paper suggests further academic and policy research on specific elements of environmental governance in Chile. To illustrate, it is worth navigating more on the analysis of distributive equity. The INNA project disclosed the tension between global and local environmental objectives, shown on the ambition of green hydrogen production to contribute to global decarbonization efforts, while generating environmental costs undermining specific ecosystems and scientific interests. This dilemma discloses the absence of explicit distributive frameworks and notes the importance of expanding the discussion, which can contribute to the governance system by enhancing its capacity to provide clear criteria for balancing competing interests, to ensure more predictability.

Additionally, addressing the institutional reactiveness and limited anticipatory governance capacity is valuable and explore ways to strengthen information and communication flows within institutional governance that could pave avenues to incorporate foresight mechanisms, including scenario planning, strategic environmental assessment, and early-stage risk identification processes. These tools would enable regulators to anticipate potential environmental conflicts associated with emerging technologies and would enhance regulatory clarity and reduce uncertainty for project developers.

Another recommendation is the integration of light pollution regulation into the governance of large-scale energy projects. It is crucial to leverage the current significant progress in regulating artificial light emissions, connecting these provisions to the evaluation of renewable energy infrastructure, perhaps by incorporating them into environmental impact assessment guidelines, to ensure that considerations regarding light pollution are integrated from the earliest stages of energy projects.

Appendices

APPENDIX A.

Table A.1 Effectiveness Evaluation Matrix

Objective	Capacity	Functioning	Performance	Evaluation	Justification
Institutional	Strong legal framework; limited scope for emerging issues. Law 19.300, SEIA; no hydrogen-specific regulation.	Clear procedures; but regulatory gaps. Interpretive application of general EIA rules	Identified risks; but reactively. Risks identified but not preemptively regulated.	Moderate	Although Chile possesses a robust structured legal framework under Law 19.300 and SEIA, it evidences the absence of sector-specific regulations for green hydrogen and comprehensive integration of light pollution standards. Risks such as light pollution were not anticipated institutionally but emerged during the evaluation process, which reflected that effectiveness depended on interpretive flexibility rather than clear regulatory guidance.
Structural	Diverse actor landscape; but reliance on external expertise. Diverse actors incl. scientists, NGOs.	High interaction and knowledge exchange between actors.	Outcomes shaped by networks and actors´ interactions. The risks were effectively amplified.	High	The scientific community represented by SOCHIAS, ESO, MPG and CSO such as DarkSky and Fundación Cielos de Chile translated technical concerns into governance-relevant issues, enabling the system to identify risks beyond institutional capacity. These actors and networks provided specialized expertise that translated technical concerns into policy-relevant arguments, enabling the identification of light pollution risks, which

					compensated institutional gaps.
Procedural	Well-developed participation mechanisms. Strong SEIA process and participation.	Active and inclusive. Iterative evaluation and public input	Direct strong influence on outcome (withdrawal).	Very High	The SEIA functioned as the primary driver of governance outcomes. Its iterative design and continuous submission, review, and integration of stakeholder observations, allowed environmental concerns such as light pollution to gain prominence over time. This demonstrated that procedural mechanisms not only facilitated participation but actively shaped final outcomes by structuring how evidence is assessed and legitimized.

Source: Own elaboration.

Table A.2 Equitable Evaluation Matrix

Objective	Capacity	Functioning	Performance	Evaluation	Justification
Institutional	Recognition of environmental rights	Limited tools for distributive justice	Trade-offs unresolved and uneven outcomes.	Low	There were no clear criteria identified balancing global vs local impacts. The legal framework does not provide clear criteria to balance climate benefits (renewable energy or hydrogen) against localized environmental costs (light pollution), leaving trade-offs unresolved.
Structural	High participation of diverse actors	Unequal influence (scientific dominance)	Epistemic imbalance due scientific dominance.	Moderate	Although multiple actors participated, the scientific community exerted disproportionate influence due to its expertise and international legitimacy,

					reflecting epistemic inequality. Scientific actors held disproportionate authority due to epistemic legitimacy, highlighting the persistence of knowledge-based inequalities distributed within formally inclusive systems that helped to shape the outcomes.
Procedural	Strong public participation mechanisms - EIA	Broad access and engagement to process & EIA	Participation impactful but unequal influence	High	Strong engagement due to inclusive participation mechanisms, but with but uneven influence. Hundreds of observations and stakeholder inputs were incorporated, demonstrating strong procedural fairness, although influence remained uneven across actors.

Source: Own elaboration.

Table A.3 Responsiveness Evaluation Matrix

Objective	Capacity	Functioning	Performance	Evaluation	Justification
Institutional	Limited emerging regulatory updates. Existing regulations including light pollution	Reactive adaptation. Need to adapt to new issues	Limited anticipation. Reactive rather than anticipatory	Moderate	Presented a reactive adaptation because the regulation evolved after issues emerged. The system adapted to light pollution concerns only after they emerged in the INNA process, reflecting reactive rather than any anticipatory governance strategy.
Structural	Strong multi-level engagement.	Fast and effective	High adaptability of agencies	High	Rapid actor mobilization. Actors quickly raised concerns.

	Active networks	mobilization of actors			Scientific networks and NGOs rapidly mobilized, bringing attention to light pollution and influencing governance dynamics at national and international levels.
Procedural	Flexible and open assessment processes SEIA	Iterative engagement and review of process	Adaptive outcome (withdrawal decision)	Very High	The process incorporated new information effectively with iterative flexibility. The SEIA allowed reiterative reassessment of the project, integrating new evidence and concerns, ultimately shaping the outcome.

Source: Own elaboration.

Table A.4 Robustness Evaluation Matrix

Objective	Capacity	Functioning	Performance	Evaluation	Justification
Institutional	Stable legal regulatory framework	Independence of institutions	Legitimacy is acknowledged and maintained	Very High	The process was not politically overridden, showing a stable legal system. Despite political and public pressure, the government did not intervene in the evaluation process, preserving institutional integrity and legitimacy. The SEIA provided a transparent and predictable framework that absorbed pressure without any institutional breakdown.
Structural	Strong and distributed networks of actors	Effective conflict management	Systemic stability, no disruptions	High	Multiple actors absorbed pressure which reflects the conflict diffusion. The involvement of multiple actors prevented

					concentration of conflict within state institutions, enhancing system resilience.
Procedural	Consistent and transparent process	Conflict managed formally. Transparent and predictable	Trust in system; credibility	Very High	Stakeholders remained within system and continued to engage through the SEIA rather than external conflict, demonstrating procedural system stability and granting high legitimacy to the process.

Source: Own elaboration.

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APPENDIX B.

Tables of assessment criteria for the objectives are provided. Consider attributes, characteristics, outputs and outcomes of environmental governance, based on Bennett and Satterfield`s Evaluation Framework.

Table B.1. Effectiveness Data and Criteria Matrix: Supports maintenance of system integrity and functioning

Attributes (Qualities or Capacities)	**General Characteristics or Inputs (Capacity)**	**Idealized Outputs (Functioning)**	**Idealized Outcomes (Performance)**
Direction	Scope, goals and aims are comprehensive, clearly articulated and communicated to stakeholders. Clear boundaries on action and scope exist.	Defines what effective action encompasses and sets milestones for achieving success.	• Improvement in ecosystem functioning. • Greater biodiversity or species. • Increases in productivity of system or provisioning of ecosystem services. • Better environmental health.
Coordination	The roles, functions, and mandates of different governments, agencies and organizations are coordinated. A coordinating body or unit is present.	Produces system of rules for use, mechanisms for exclusion, management actions and spatial coverage that are complementary and adequate to achieve objectives. Provides a forum for discussion, debate, negotiating and resolving trade-offs.	
Capacity	Capacity, skills and resources are sufficient and are being actively developed. Capable and visionary leadership is	Enables successful decision-making and the initiation, organization, implementation and evaluation of actions.	

	present. Mechanisms are present to resolve conflicts between groups.		
Informed	Planning and management decisions and actions are informed by best available information and integration of a diversity of knowledge types and systems.	Increases the likelihood that management actions will lead to effective outcomes.	
Accountable	Procedures are present to hold governors accountable for performance of system. Mechanisms are in place to ensure that means and rationales for making decisions are transparent.	Ensures that governors act on mandated decisions and that effective actions are being taken.	
Efficient	Efficacy guides decisions regarding management actions and deployment of resources. Time requirements of actors are reasonable. Economic costs and actions taken are commensurate with productivity of system.	Maximizes the productivity of management actions while minimizing the wasteful use of available resources.	

(Bennett and Satterfield, 2018, p. 3)

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Table B.2. Equitable Data and Criteria Matrix: Employs inclusive processes and produces fair outcomes.

Attributes (Qualities or Capacities)	**General Characteristics or Inputs (Capacity)**	**Idealized Outputs (Functioning)**	**Idealized Outcomes (Performance)**
Recognition	Policies and processes ensure acknowledgement of, respect for and incorporation of diverse perspectives, values, cultures and rights. Views of marginalized and vulnerable groups are considered.	Facilitates socially acceptable governance and perceptions of legitimacy. Aids in the design of management actions that are appropriate to the social context.	• Inclusion in decision-making processes. • Improved socio-economic outcomes. • Increases in quality of life or wellbeing. • More fair distribution of wealth. • Better access to justice and protection of rights.
Participation	Spaces and processes to enable participation and collective choice are present. Structures that ensure the representation and engagement of different stakeholder groups are in place.	Contributes to just power relations and decision-making processes. Leads to plans and actions that represent the interests of different groups. Allows parties to democratically debate decisions and maintain dignity.	
Fair	Mechanisms are in place to ensure socio-economic costs and benefits are just and fairly distributed. Rights and responsibilities are shared and assigned fairly. Unequal circumstances are considered.	Ensures a fair balance of costs and benefits accrue to different groups.	

Just	Laws and policies are present to protect local rights and mechanisms ensure that groups have access to justice.	Ensures rights (e.g., title, historical tenure, access, use, management) are not undermined and that reparations or compensation are made for past damages.	

(Bennett and Satterfield, 2018, p. 4)

Table B.3. Responsiveness Data and Criteria Matrix: Enables adaptation to diverse contexts and changing conditions.

Attributes (Qualities or Capacities)	**General Characteristics or Inputs (Capacity)**	**Idealized Outputs (Functioning)**	**Idealized Outcomes (Performance)**
Learning	Monitoring, evaluation, reflections and communication of performance is institutionalized. Processes and platforms are in place to co-produce knowledge and enhance social and institutional memory.	Ensures that information is produced, documented, shared and informs decision-making.	• Enables the resilience of resource. • Enables the resilience of local communities. • More adaptable institutions to changing conditions. • More flexible institutions that can be altered to work in different contexts.
Anticipatory	Long-term planning and foresight thinking are institutionalized. Known and unknown risks and opportunities are considered, analyzed and planned for.	Produces plans and steps to prepare and prevent consequences of unexpected risks. Enhances knowledge, capacity and flexibility for disturbance.	
Adaptive	Spaces for reflection and deliberation are institutionalized. Processes exist to revisit and evolve policies,	Ensures that management plans and actions are being actively adapted to reflect changing social-	

	institutions and adapt actions.	ecological contexts and new knowledge.	
Innovative	Innovation and experimentation is encouraged and success and failures are monitored. A higher risk tolerance is embodied.	Allows change to be seen as an opportunity. Enables new and more effective ideas and actions to emerge.	
Flexible	Policies exist that recognize the need to downscale environmental management and conservation models to fit local realities. Efforts are taken to understand and document about the diverse contexts where policies are applied and to deliberate on necessary adjustments.	Enables governance systems and management models to be adjusted to better fit with local social, cultural, political, economic and environmental contexts.	

(Bennett and Satterfield, 2018, p. 4-5)

Table B.4. Robustness Data and Criteria Matrix: Ensures functioning institutions persist, maintain performance and cope with perturbations and crises.

Attributes (Qualities or Capacities)	**General Characteristics or Inputs (Capacity)**	**Idealized Outputs (Functioning)**	**Idealized Outcomes (Performance)**
Legitimate	A collective vision shapes policies and guides actions at all scales. Institutional legitimacy is conferred (e.g., in policy) and perceived (e.g., by constituents). Governors act with integrity and consistency. Institutions are transparent.	Ascertains that there is support from above and that there is a supportive constituency.	• Institutions are strengthened and well supported. • Institutional performance and functioning is more or less consistent. • Institutions persist over time.
Connected	Networks of organizations and actors are strongly linked	Helps to bridge between and across scales. Creates supportive	

	vertically and horizontally. Bridging organizations are present. Processes are in place to support network development, to develop social relations and to support mutual learning.	community, produces social capital, fosters respect and trust and builds social memory. Encourages communication, information exchange, enables diffusion of innovations, and facilitates collaboration.	
Nested	Tasks are assigned to appropriate levels. Decision-making authority and responsibility are conferred to the lowest level possible. Self-organization is encouraged and supported. Authority and responsibility is supported by adequate state or other outside support (legal recognition, political will, time commitment) and oversight.	Empowers appropriate entity to take necessary action. Allows also for shaping and adapting institutions and decision-making processes to different local sub-contexts (social circumstances, governance, ecologies) within larger system.	
Polycentric	Decision-making and action taking centers in multiple places, across jurisdictions and at multiple scales interact and cohere towards a common goal. Institutions are present that are diverse and redundant - that serve similar purposes and have overlapping jurisdictions and functions.	Helps to buffer against change in one location. Ensures that the governance system does not collapse when faced with adversity or crises.	

(Bennett and Satterfield, 2018, p. 5-6)

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