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# The Impact of Renewable Energy Megaprojects on Global Geopolitics: The Australia-Asia PowerLink Case

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## ABSTRACT

This work aims to analyze the impact of renewable energy megaprojects on global geopolitics, with a specific focus on the Australia-Asia PowerLink case. The goal is to explore how these large-scale energy projects influence international relations, assessing both their potential environmental benefits and negative consequences. By examining the Australia-Asia PowerLink project, the study seeks to understand how large-scale electricity grid interconnections can alter international alliances, redefine the influence of countries on the global stage, and contribute to a reconfiguration of strategic interests in the context of the transition to sustainable energy sources. Additionally, it will investigate the feasibility of applying this model to other territories

## KEY WORDS:

Energy, Geopolitics, Australia-Asia Power Link, Megaprojects, Sustainability.

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## *INTRODUCTION*

Renewable energy megaprojects have become one of the most ambitious initiatives to address global energy challenges, such as reducing carbon emissions, transitioning towards sustainable energy sources, and ensuring energy security. Simultaneously, these large-scale projects, which are international in nature and have significant geopolitical impact, raise a series of questions about how they reshape global alliances, challenge existing power structures, and redefine interactions between countries. This work focuses on the case of the Australia-Asia PowerLink, aiming to analyze how a project of this magnitude goes beyond technical and environmental objectives and affects the global landscape of international relations. Additionally, it is compared with two other renewable energy projects that will be explained later: the MENA Desertec and the Gansu Wind Farm.

The research is based on the premise that energy, a traditionally contentious issue in geopolitics, is undergoing a profound transformation with the global shift towards renewable energy sources. This process has been analyzed by various studies, which highlight how the energy transition is redefining power dynamics at the international level, shifting the prominence from fossil fuel producers to new technological and renewable resource powers (Goldthau & Westphal, 2019; Scholten & Bosman, 2016). While much academic attention has focused on renewable technologies or the local impacts of projects, less attention has been paid to the geopolitical effects of renewable energy megaprojects. Studies such as those by Scholten and Bosman (2016) and Overland (2019) emphasize that most analyses have focused on technological efficiency and environmental benefits, leaving the impact of these projects on global power relations and energy security in the background. This study seeks to contribute to this topic by framing renewable energy megaprojects as tools not only for environmental and economic transformation but also for geopolitical reconfiguration.

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## State of the question

The study of renewable energy has grown exponentially in recent years, establishing itself as a key research field within sustainability and energy geopolitics. According to Scholten and Bosman (2016), the transition towards clean energy is redefining global power dynamics, shifting the prominence from fossil fuels towards new forms of energy cooperation and competition. In this context, renewable energy megaprojects have emerged as transformation tools that not only seek to mitigate climate change but also reconfigure international relations through energy interdependence.

### 1. Main Research Lines on Renewable Energy and Geopolitics

Academic literature in this field can be grouped into three major approaches:

#### Energy Transition and Geopolitics:

Research such as that by Overland (2019) and Hafner et al. (2018) analyzes how the decarbonization of the global energy system impacts the balance of power between energy-producing and consuming countries.
It is argued that dependence on key resources such as lithium and cobalt may generate new geopolitical tensions, shifting dependence from oil and gas towards strategic minerals for renewable energy (GEOPOLITICS OF CRITICAL MINERALS IN RENEWABLE ENERGY SUPPLY CHAINS).

#### Impact of Renewable Energy Megaprojects:

Some studies have evaluated the impact of megaprojects such as Desertec, a solar interconnection plan in North Africa, highlighting how geopolitical factors and economic asymmetries led to its failure (Patt et al., 2013).
Other works have studied projects such as the Gansu Wind Farm in China, pointing out the

technological and political challenges facing large-scale renewable energy expansion (Youwei, 2015).

Electrical Interconnectors and Energy Security:

The literature also examines how electrical interconnection projects, such as the Australia-Asia PowerLink, can strengthen energy security in regions dependent on fossil fuels, like Southeast Asia. However, authors such as Goldthau and Westphal (2019) warn about the risks of new energy dependencies between interconnected countries.

## 2. Gaps in Literature and Study Relevance

While there is a growing body of research on the geopolitics of energy transition, there are fewer studies that comparatively analyze the impact of renewable energy megaprojects in different regions of the world. Additionally:
Most studies on renewable energy have focused on technological efficiency and environmental impact, leaving the geopolitical effects of these projects in the background (Scholten & Bosman, 2016).
There is a deficit of studies on large-scale electrical interconnectors, such as the Australia-Asia PowerLink, and their impact on the energy sovereignty of involved countries.
Few works have approached energy megaprojects from a comparative perspective, analyzing how political, economic, and environmental factors have determined the success or failure of these projects in different geographical contexts.

## 3. Research Contribution

This study contributes to academic literature by addressing three key dimensions of renewable energy megaprojects:
Geopolitics: It will explore how these projects are redefining international alliances and modifying power relations.
Economics: It will evaluate the benefits and risks of energy interdependence through these

megaprojects.
Sustainability: It will analyze their alignment with Sustainable Development Goals and the environmental challenges they face.

By focusing on the comparison of three emblematic cases—Desertec, Gansu Wind Farm, and Australia-Asia PowerLink—this research will fill a gap in the literature by providing a global and multidimensional analysis of these projects.

## Research question and objectives

Derived from the above, the central research question guiding this work is: **How do renewable energy megaprojects impact global geopolitics and what are their environmental implications?** And around this revolves the secondary question: What are the key factors that determine the success or failure of a megaproject?

The first question allows us to explore the transformation of international power dynamics through energy infrastructure, while the second helps us identify the critical elements that condition these projects' viability. Both questions are fundamental to understanding how renewable energy megaprojects are configured not only as technical solutions but as instruments of international cooperation and geopolitical change.

Thus, we will present the different objectives of this research work.

### General Objective:

To analyze the impact of renewable energy megaprojects on global geopolitics and the environment.

### Specific Objectives:

To evaluate the geopolitical effects of renewable energy megaprojects, especially in redefining regional and global alliances.

To examine the potential of these projects to promote long-term economic cooperation between countries.

To analyze the alignment of these megaprojects with the Sustainable Development Goals, evaluating their contribution to the transition towards cleaner energy and their impact on inequalities.

This research hypothesizes that renewable energy megaprojects, particularly solar ones, offer a viable solution for energy security. However, their large-scale implementation may generate new geopolitical challenges, redefining power dynamics at a global level. Projects such as the Australia-Asia PowerLink, which we will define later, are proposed as initiatives that have the potential to foster new international alliances and improve energy security, but they can also generate new dependencies and alter power dynamics, especially in regions where national interests are conflicting, such as Australia, Singapore, and Indonesia (Reuters, 2024). Although these projects could contribute to meeting international climate objectives, they could also exacerbate regional inequalities if relationships between involved countries are not adequately managed.

## Methodological Generalities: Time & Geographical Framework

The temporal framework primarily covers the development of these projects over the last two decades (2000-2025), with particular emphasis on the 2020-2030 period. This focus responds to the growing relevance of the global energy transition at present and the need to analyze not only current progress but also the future projections of these projects. Methodologically, the analysis centers on evaluating the recent past and present, incorporating a prospective dimension to explore possible developments and challenges that might emerge towards 2030.

**Methodology and Comparative Framework**

The research adopts a case study methodology and a comparative design to explore common patterns and differences in the geopolitical, environmental, economic, and social impacts of the megaprojects reviewed for this research.

The research is based on a theoretical approach that uses liberalism perspectives within International Relations. From this viewpoint, renewable energy megaprojects, such as the Australia-Asia PowerLink, represent opportunities to strengthen international cooperation and promote energy interdependence between countries. Liberalism allows for analysis of how these projects not only seek to mitigate climate change but also promote long-term strategic alliances through the creation of common regulatory frameworks, technology transfer, and development of shared infrastructure. Additionally, a comparative analysis will be incorporated between the Australia-Asia Power Link, Gansu Wind Farm, and Desertec project megaprojects, as well as a scenario methodology to explore possible project developments under optimistic, neutral, and pessimistic conditions.

## Description of the structure

This final degree project is divided into three main chapters, each focusing on a different key aspect of the study.

The first chapter focuses on the **Theoretical and Conceptual Framework**, that provides the foundation and background of the research. It defines issues such as what megaprojects are and examines how different theories of International Relations—such as realism, constructivism, liberalism, and structuralism—can be applied to understand them. Additionally, it identifies the main approaches and methodologies used in the literature to study renewable energy megaprojects, ending with a preliminary assessment of their potential environmental and geopolitical impacts.

The second chapter, **Context and Case Presentation**, introduces the case studies that will be compared and anlized in the following chapter: the Gansu Wind Farm in China, the Desertec Project in the MENA region, and the Australia-Asia PowerLink. This chapter provides detailed descriptions of the technical, economic, and geopolitical aspects of each project, while also analyzing their sustainability and the challenges they face. The aim is to give a clear picture of how these megaprojects operate and their relevance to global energy transitions around our two key variables of study, geopolitics and,,,,(either security or environment, choose one).

Finally, the third chapter, based on the **Comparative Analysis and case study methodologies**, compares the three cases by focusing on key dimensions like geopolitical influence, economic benefits, and sustainability. To close the analysis some feasible scenarios will be provided (optimistic, neutral, and pessimistic),in order to identify the possible effects of this proyect in the region and for the country members. This chapter identifies similarities and differences between the projects and evaluates their broader implications for global geopolitics and the shift toward renewable energy.

The project concludes by summarizing the main findings and reflecting on what can be learned from these projects to guide the development of future renewable energy initiatives.

## *CHAPTER 1: CONCEPTUAL THEORETICAL FRAMEWORK*

Este capítulo establece el fundamento teórico de la investigación, desglosado en varias secciones principales. Comenzaremos con las **Definiciones** clave relacionadas con los megaproyectos, proporcionando un contexto histórico y conceptual. A continuación, exploraremos las **Teorías de las Relaciones Internacionales**, enfocándonos en cómo el realismo, el liberalismo y el constructivismo interpretan y explican la implementación y el impacto de estos megaproyectos. Finalmente, analizaremos las **Implicaciones Geopolíticas y Económicas**, evaluando cómo estos proyectos afectan las dinámicas de poder y las economías regionales y globales. Este enfoque estructurado nos permitirá comprender en profundidad el papel y la relevancia de los megaproyectos en el escenario internacional contemporáneo.

## 1.1 Definitions

Throughout history, the expansion of world trade and globalization have driven the creation of infrastructure megaprojects aimed at facilitating commercial exchange and strengthening connections between regions. Emblematic examples of these projects include the Suez Canal, inaugurated in 1869 under Ferdinand de Lesseps' direction, connecting the Mediterranean Sea with the Red Sea, and the Panama Canal, completed in 1914 by the United States, joining the Atlantic Ocean with the Pacific. These canals have been fundamental for international trade, significantly reducing maritime routes and exemplifying the influence of geopolitical and strategic interests in their construction (Spring, 2024).

Currently, the trend has expanded towards renewable energy megaprojects, aligned with constructivism and liberalism theories in International Relations. These projects seek to promote sustainable development and international cooperation to address global challenges such as climate change. The transition towards clean energy sources is seen as a strategy to improve international security and prevent regional conflicts related to competition for fossil energy resources (El País, 2024).

In this context, it is essential to define what is meant by "megaprojects." Generally, it refers to large-scale, high-investment initiatives that have a significant impact on the economy, society, and environment of the regions involved. These projects typically involve complex interactions between multiple actors, including governments, multinational companies, and local communities, and require meticulous planning and management to achieve their objectives and mitigate potential risks.

By analyzing these megaprojects from different theoretical perspectives, we can better understand the motivations, challenges, and consequences they entail, as well as their role in shaping the contemporary international order.

Taking into consideration the type and nature of projects that will be analyzed in this work, First of all, it is defined what megaprojects are. According to Eitan (2023), energy megaprojects are large-scale, complex ventures that require significant investments and have a profound impact on society, economies, and geopolitics. These projects are often defined by their high cost, typically exceeding one billion dollars, their long duration, and their involvement of multiple stakeholders across different sectors and regions (Greiman; Flyvbjerg, 2014). A key characteristic of megaprojects is their ability to drive globalization, particularly through the integration of markets, technologies, and nation-states (Friedman, 2000). As described by Greiman (2023), megaprojects not only contribute to economic growth but also serve as instruments for major socio-economic transformations.

Megaprojects are large-scale, highly complex initiatives that demand significant financial resources and have a substantial impact on society, the economy, and the environment. These projects include infrastructures such as airports, hydroelectric dams, highways, and more recently, large-scale renewable energy facilities. In this context, renewable energy megaprojects emerge as a response to global energy challenges, promoting interconnections between countries and regions. Notable examples include infrastructures such as the Australia-Asia PowerLink, with its high-capacity solar plant and the world's longest submarine cable; the Gansu Wind Farm in China, which seeks to harness wind energy in one of the regions with the strongest winds; and the Desertec project, a global initiative focused on exploiting solar and wind energy from deserts. These initiatives not only address energy needs but also pose significant economic, social, and geopolitical implications.

Energy megaprojects, according to Greiman (2023), are part of a broader trend where globalization facilitates large-scale investments, often through public-private partnerships, enabling the construction of infrastructure that spans across borders and regions. The expansion of such megaprojects is closely tied to technological advancements that make it possible to manage complex, large-scale constructions, such as those in the renewable energy sector (Kardes et al., 2013).

Furthermore, the influence of megaprojects extends beyond just technical and financial considerations; they are embedded in complex socio-political environments and often face uncertainties related to governance, stakeholder involvement, and sustainability (Greiman, 2023; Lehtonen, 2019). These projects are not only about the infrastructure they build but also about the geopolitical shifts they provoke, making them significant players in global politics and economics. Thus, understanding what constitutes a megaproject is essential for analyzing how renewable energy initiatives, such as the Australia-Asia PowerLink, can reshape international relations and contribute to sustainable global energy systems.

For analyzing megaprojects, this study will employ qualitative analysis to offer a deep and contextual vision of renewable energy megaprojects. This approach will allow us to explore aspects such as local communities' perceptions and experiences regarding these projects, as well as the social and environmental challenges they face. In terms of sustainability, we will focus on how these communities value environmental benefits, social implications, and strategies adopted to address environmental problems. This qualitative analysis is ideal for understanding the social and human impacts of megaprojects, thus ensuring a comprehensive evaluation of their effects.

Using these approaches, we can better understand megaprojects and evaluate both their achievements and their social, environmental, and geopolitical impacts. This becomes fundamental when discussing initiatives that not only seek to respond to global energy challenges but also contribute to a more sustainable future.

## 1.2 Main theories in International Relations

In this section, are covered the four main theories in International Relations that will provide the two main theoretical approaches that are relevant for the current analysis, departing from: Liberalism, Structuralism, Realism, and Constructivism. These theories provide distinct frameworks for analyzing the dynamics of international relations and are instrumental in understanding the implications of renewable energy megaprojects on the global stage. By exploring each theory, we aim to uncover the varied perspectives they offer on the interplay between environmental sustainability, economic interests, and geopolitical considerations.

### 1.2.1 Liberalism in megaprojects

**Liberalism** in international relations theory, as defined by Moravcsik (1992), emphasizes the importance of domestic factors and societal interests in shaping the behavior of states in the international system. Unlike realism, which focuses on power and security, liberalism asserts that states are not merely driven by survival instincts in an anarchical world but by the preferences and values that emerge from their internal structures, such as political institutions, interest groups, and societal needs. Moravcsik explains that state preferences, which stem from these domestic actors, significantly influence state behavior, making cooperation and conflict a result of the alignment or divergence of these preferences across states.

Liberal theory stresses that interdependence—economic, political, and social—among states leads to cooperation rather than constant conflict. Regarding Moravcsik (2003), the theory also holds that the international system is not inherently anarchic in the way realism suggests. Instead, international cooperation is possible when states recognize shared interests, particularly in areas such as trade, human rights, and environmental concerns. This framework sees institutions and international law as mechanisms to manage these preferences and interdependencies, reducing the likelihood of conflict and fostering collaboration

Liberalism in international relations places a strong emphasis on cooperation between states and the role of international institutions in addressing common problems. According to this perspective, renewable energy megaprojects are a manifestation of economic interdependence and the pursuit of collective solutions to global challenges such as climate change. Projects like Desertec, which seeks to generate solar energy in the Sahara Desert to supply Europe, highlight how transnational collaboration can foster shared objectives, such as sustainable economic growth and energy transition.

Keohane & Nye (2012) argue that complex interdependence between states reduces the possibilities of conflict, incentivizing the development of shared infrastructures regulated by international agreements. Similarly, Moravcsik (1997) points out that cooperation is based on national preferences that reflect internal economic and social interests, promoting multilateral solutions. In this sense, megaprojects are not only technological tools but also platforms for building trust between nations.

### 1.2.2 Realism in megaprojects

In his book ***Realism** and International Relations* (2000), Jack Donnelly offers a critical yet respectful survey of political realism in the context of international relations theory. He provides a foundational overview of realism, focusing on key figures such as Thucydides, Hobbes, Machiavelli, and Morgenthau, among others. For Donnelly (2000), realism is anchored in the idea that international relations are governed by the structure of anarchy, where no central authority exists above sovereign states. This results in a world where power struggles, national interests, and security concerns dominate the behavior of states.

From the perspective of realism, megaprojects of renewable energy can be interpreted as strategic tools that states use to consolidate their geopolitical power and ensure their energy security. For instance, projects like the Australia-Asia PowerLink illustrate how nations employ large-scale infrastructure to project influence, secure critical resources, and reduce dependency on external energy sources. As Mearsheimer (2001) argues, such initiatives align with the realist emphasis on the pursuit of relative gains, where states strive to maximize their power advantage in an anarchic international system. Similarly, Waltz (1979) highlights the role of sovereignty and control over vital resources in strengthening a state's position in global politics, which is evident in how megaprojects are implemented to serve strategic interests.

One of the core tenets of realism, as emphasized by Donnelly, is the notion of human nature, which realists argue is inherently selfish and conflict-prone. This selfishness translates into the motivations of states, which are primarily concerned with securing their own survival and maintaining power. According to realists, universal moral principles cannot be applied to state actions in the international arena, as the pursuit of power often overrides ethical considerations.

Donnelly also critiques common realist claims, asserting that while the theory is widely influential, many of its core assumptions about human nature and international behavior do not stand up to rigorous scrutiny. Nevertheless, he acknowledges that realism remains central to the study and practice of international relations, especially in understanding the dynamics of power, anarchy, and state interactions.

Realism, one of the most traditional theories in international relations, maintains that states act primarily to maximize their power in an anarchic international system. In the context of renewable energy megaprojects, this theory suggests that states develop them not only for environmental reasons but as strategies to secure their energy security and increase their geopolitical influence.

The Australia-Asia PowerLink project, for example, can be understood as Australia's effort to consolidate its strategic position in the Asia-Pacific by ensuring stable energy supplies to Singapore. Mearsheimer (2001) asserts that states seek to increase their relative power, and energy, as a strategic resource, plays a key role in this dynamic. Furthermore, Waltz (1979) emphasizes that energy sovereignty is an essential component of national power, and megaprojects represent an effective way to project this capacity at regional and international levels.

### 1.2.3 Structuralism in megaprojects

Structuralism, according to Sturrock (2008), is a school of thought that maintains that cultural and social phenomena cannot be fully understood if examined in isolation. Rather than analyzing individual elements, structuralism focuses on identifying the underlying structures that organize these phenomena. These structures are seen as responsible for giving meaning to the relationships between elements within a system, whether linguistic, social, or cultural. Sturrock explains that, in the context of linguistics, for example, the meaning of words does not depend on their individual definitions but on how they relate to each other within a larger linguistic system.

In the field of international relations, structuralism suggests that actors, such as states, are influenced by global structures of power and economy that define their relationships.

"Structuralism focuses on the power and dependency relationships that emerge from the global economic system. From this perspective, megaprojects can be interpreted as tools that reinforce the economic subordination of developing countries to advanced economies. For example, the Panama Canal and the Suez Canal, although fundamental to global trade, have been criticized for consolidating relationships of economic and geopolitical dependence between peripheral regions and global power centers (Greiman, 2023). Similarly, China's Three Gorges Dam, the world's largest hydroelectric project, has generated debates about social and environmental impacts on local communities while reinforcing China's position as a leader in global infrastructure (Flyvbjerg, 2014). These examples illustrate how megaprojects, although presented as development solutions, can perpetuate structural inequalities and relationships of economic dependence (Harvey, 2005).

Escobar (1995) argues that the concept of "development" is intrinsically linked to hegemonic discourses that marginalize local voices and prioritize the interests of global elites. Similarly, Harvey (2005) argues that large-scale infrastructure investments, although presented as beneficial, frequently consolidate structural inequalities by diverting economic benefits to foreign investors. Within this framework, megaprojects can be criticized for deepening dependency dynamics rather than promoting genuinely equitable development.

### 1.2.4 Constructivism in megaprojects

In the framework of international relations, constructivism focuses on how global actors (such as states, international organizations, and other non-state actors) develop their identities and behaviors through their interactions and shared social norms. According to Alexander Wendt (1999), international actors do not operate solely based on material interests; rather, their actions are deeply influenced by shared norms, social values, and collective identities that emerge from global interaction. This perspective is especially useful for analyzing how discourses such as sustainability or energy transition influence the construction and implementation of megaprojects, transforming them into tools that not only pursue technical objectives but also reflect global values and narratives.

Constructivism offers a distinct perspective by focusing on how ideas, norms, and identities influence international relations. From this viewpoint, renewable energy megaprojects are not just physical infrastructures but also social constructions that reflect emerging values and global discourses. For example, the promotion of projects such as the Gansu Wind Farm in China represents a commitment to international sustainability norms and leadership in clean energy.

Wendt (1999) points out that international structures are shaped by shared ideas, not simply by material factors. Similarly, Finnemore & Sikkink (1998) argue that international norms can evolve rapidly through processes of socialization and emulation, which explains how megaprojects are integrated into broader narratives about progress and global cooperation. These projects, therefore, are both statements of political intention and tools of economic transformation.

### 1.2.5 Reflection on Theories and Megaprojects

Megaprojects, as large infrastructure enterprises, have multifaceted implications in the field of International Relations, especially when analyzed through the main theories of this discipline. The following table offers a comparative analysis that relates key theoretical approaches—realism, liberalism, structuralism, and constructivism—with the perspectives, methodologies, and analyses applied to renewable energy megaprojects. This exercise seeks to establish how each theory provides unique tools for understanding the geopolitical, economic, and sustainable implications of these projects, thus facilitating a deeper reflection on their global and regional impact.

Table 1: Megaprojects in International Relations

| Theoretical Approach | Perspective Analysis | Methodology |
| --- | --- | --- |
| Realism - Geopolitical Focus | Renewable energy megaprojects are strategic tools that can redefine global geopolitics. The realist approach examines how energy security and disputes between countries affect the implementation of these projects, leading to new dependencies and alterations in global power. | Studies of Desertec (MENA), Gansu Wind Farm (China), and Australia-Asia PowerLink (Asia-Pacific) projects, with emphasis on power relations between involved countries (Buzan, 1991). |
| Constructivism - Normative Perspective | Megaprojects can be vehicles for international cooperation around climate change, but their implementation must be managed to avoid perpetuating inequalities. Constructivism helps understand how shared ideas and norms alter power dynamics and promote collaboration. | Comparative analysis of relationships and values between international actors involved in large-scale projects. Key regions: MENA, Asia-Pacific, and China. (Ruggie, 1998); (Keohane & Nye, 2012) |
| Liberalism - Economic Cooperation | Megaprojects offer an opportunity for economic integration between countries, promoting sustainable development and long-term economic cooperation. Projects can help mitigate global economic inequalities through technology transfer and market access. | Evaluation of economic integration of projects such as Desertec and Australia-Asia PowerLink. Focus on economic benefits and cooperation through technological innovation. (Keohane, 2005); (Ostrom, 1990). |
| Structuralism - Dependency Analysis | Structuralist analysis underscores how megaprojects can perpetuate dependencies between developed and developing countries, creating relationships of economic asymmetry. This can hinder the achievement of sustainable development goals. | Assessment of project impact in peripheral regions such as MENA (Desertec) and resource dependencies in developed countries. (Wallerstein, 2004; Arrighi, 2007). |
| Quantitative Approach - Environmental Impact and Emissions | Renewable energy megaprojects have the potential to reduce greenhouse gas emissions and improve energy efficiency on a large scale. This approach uses quantitative models to evaluate climate change effects and project viability. | Quantitative analysis of carbon footprints of Gansu Wind Farm and Australia-Asia PowerLink projects, with simulation models for emissions reduction. (Eitan et al., 2023); (Rabaia et al., 2021) |

Source: Own elaboration, based on referenced sources.

The presented table demonstrates that megaprojects are not just technical initiatives but also manifestations of complex dynamics of power, cooperation, and dependency in the international system. By applying different theoretical approaches, we can identify the various dimensions in which these projects transform relationships between states and non-state actors, from the reconfiguration of geopolitical alliances to the consolidation of normative narratives such as sustainability. Ultimately, this reflection allows for the integration of multiple perspectives for a holistic understanding of megaprojects within the framework of International Relations.

## 1.3 Megaprojects in the literature: approaches and methodologies

The analysis of megaprojects in literature requires a review of theoretical and methodological approaches used in previous research, especially in the context of renewable energies. This section explores the main approaches developed to study megaprojects from an international and multidimensional perspective, with special attention to how theories and methodologies are applied to evaluate their geopolitical, economic, and environmental impact. Identifying these tools allows establishing a solid foundation for selecting the most appropriate theories and methods to address this study's objectives.

### 1.3.1 Determination of Theoretical Approaches for the Case Study

Within the framework of this work, liberalism presents itself as the most suitable theory for analyzing renewable energy megaprojects, particularly those like the Australia-Asia PowerLink. This choice is based on its emphasis on international cooperation, economic interdependence, and the crucial role of institutions in mediating common interests between States.

Liberalism, unlike approaches such as realism or structuralism, considers that States do not act solely based on power interests, but also on the possibility of achieving shared benefits through collaboration. According to Keohane & Nye (2012), complex interdependence reduces the possibilities of conflict, as States find it more advantageous to establish mutually beneficial relationships. This is especially relevant in the case of energy megaprojects, which depend on multilateral agreements and mutual trust for their execution.

The Australia-Asia PowerLink, which we will analyze in depth in the next chapter, is a clear example of the need for international cooperation. This megaproject could not be realized without the support of transnational agreements between Australia, Singapore, and other Southeast Asian countries. The connection through a high-voltage direct current (HVDC) submarine cable requires not only technological integration but also a framework of shared trust and regulation that allows overcoming technical and political challenges (Sun Cable, 2023).

Liberalism also emphasizes the importance of institutions in the governance of these projects. In this case, multilateral organizations and regional trade agreements play an essential role in reducing uncertainties and creating incentives for joint investment. According to Moravcsik (1997), international cooperation is sustainable when built on common preferences and the establishment of clear rules.

The history of international relations offers numerous examples where liberalism has been key to resolving conflicts and promoting development. One of the most paradigmatic cases is the Marshall Plan, a U.S.-led initiative after World War II that not only sought to reconstruct Europe but also prevent the rise of extreme ideologies. This program promoted economic cooperation and facilitated the creation of institutions such as the Organization for European Economic Cooperation (OEEC), precursor to the OECD (Hogan, 1987).

Another notable example is the formation of the European Coal and Steel Community (ECSC) in 1951. This agreement, which united France, West Germany, Italy, Belgium, Netherlands, and Luxembourg, was designed to ensure that essential resources for war were under shared control, thus reducing tensions between countries that had been in constant conflict (Milward, 1987).

In the environmental field, the Montreal Protocol (1987) illustrates how international cooperation can address global problems. This treaty, which regulated ozone-depleting substances, was possible thanks to a multilateral effort where States recognized their interdependence in environmental protection (UNEP, 2007).

The choice of liberalism as the framework theory for this work allows highlighting the potential of renewable energy megaprojects as platforms to foster international cooperation. Initiatives like the Australia-Asia PowerLink not only address global energy challenges but also strengthen ties between States, reaffirming that the long-term solution lies in collaboration. This approach aligns with historical examples that demonstrate how interdependence and multilateral institutions can prevent conflicts and generate shared prosperity.

### 1.3.2: Megaprojects in the Current International Context

In the current international landscape, renewable energy megaprojects have acquired a central role as innovative solutions to the climate, economic, and social challenges facing the world. These initiatives, characterized by their large scale and technical complexity, seek not only to transform energy production and consumption but also to influence geopolitical dynamics and foster new forms of cooperation between nations. Thus, megaprojects position themselves as key pieces in global efforts to achieve the Sustainable Development Goals and comply with international commitments such as the Paris Agreement.

Academic literature highlights that energy megaprojects operate at an intersection of political, economic, and environmental factors, making them tools of both progress and controversy. For example, emblematic projects such as China's Three Gorges Dam not only represent significant advances in clean energy generation but also show the social and ecological challenges associated with massive infrastructure construction. Similarly, India's Bhadla Solar Park, one of the world's largest, demonstrates how these initiatives harness regional natural resources to meet global sustainability demands, although they often face criticism for their local impacts on biodiversity and communities.

From a geopolitical perspective, megaprojects like the Australia-Asia PowerLink have redefined international cooperation by connecting distant regions through interconnected energy networks. This project, which links Australia and Singapore via a high-voltage submarine cable, not only diversifies both nations' energy matrices but strengthens their strategic and economic relations. Similarly, the failed Desertec project in North Africa offers important lessons about the difficulties of implementing large international projects in regions with political instability and historical tensions, highlighting the importance of collaborative governance and community participation.

At the same time, the economic dimension of megaprojects raises important questions about their financial sustainability. The viability of these initiatives depends on considerable initial investments and effective management of associated risks, such as energy price fluctuations or changes in government policies. This highlights the need for clear regulatory frameworks and international agreements that incentivize cooperation and minimize economic inequalities between developed and developing countries.

In conclusion, renewable energy megaprojects represent a unique opportunity to transform the global energy sector and promote a transition towards cleaner and more sustainable energy sources. However, their success largely depends on how their social, ecological, and economic impacts are managed, as well as the capacity of international actors to work together under principles of justice and equity. This section seeks to lay the groundwork for detailed analysis in upcoming chapters, where specific cases of megaprojects will be examined, evaluating their potential to address global challenges of the present and future.

The following chapters will explore these tensions in detail and analyze concrete examples of operating megaprojects. Thus, it will seek to comprehensively evaluate whether they truly represent a solution to current problems or if, on the contrary, they need a profound rethinking to meet their initial objectives.

## *2. CHAPTER 2: CONTEXT - CASES PRESENTATION*

The selection of case studies in energy transition research constitutes a critical methodological process that requires rigorous analysis beyond mere geographical representativeness (Yin, 2017). In this sense, the choice of the Gansu Wind Farm (China), the Asia-Pacific Power Link (Australia), and the MENA Desertec project responds to a comparative research strategy that seeks to unravel the complexities of global energy transformation (Eisenhardt & Graebner, 2007).

The decision to select these projects arises from the need to overcome traditional analyses that tend to homogenize energy transition strategies. Each case represents a unique innovation ecosystem, facing radically different challenges: Gansu exemplifies the transformation of an emerging economy with infrastructural limitations, Australia shows the possibilities of technological innovation in a developed economy, while Desertec MENA illustrates the complex challenges of international cooperation in renewable energies (International Energy Agency [IEA], 2021).

### Selection Criteria:

1. Contextual Heterogeneity

The selected projects offer geographic, economic, and geopolitical diversity that allows for a more nuanced understanding of energy transition processes. Compared to other potential cases, these three projects present differential characteristics:

- Gansu: Represents an energy transformation model in a region with severe environmental and economic limitations.
- Asia-Pacific Power Link: Exemplifies technological cutting-edge in renewable energy implementation.
- Desertec: Offers a unique perspective on international cooperation and geopolitical challenges.

2. Methodological Innovation

Unlike studies limited to a single national or regional context, this selection allows for comparative analysis that transcends local particularities (Stake, 2005). Other projects are discarded due to their lesser capacity to generate significant methodological insights.

3. Scalability Potential

The choice is based on these projects' capacity to generate replicable models. Projects such as Noor in Morocco or Midelt Solar were discarded due to their lower potential for technological and strategic transferability (Seznec, 2018).

4. Implementation Complexity

Each case represents a unique ecosystem of challenges:

- Infrastructural limitations
- Technological barriers
- Financing challenges
- Complex geopolitical contexts

The research seeks to understand how these projects navigate the specific complexities of their contexts, overcoming traditional limitations of energy transition models (International Renewable Energy Agency [IRENA], 2021).

## 2.2 DESERTEC PROJECT IN MENA

### 2.2.1 Context

The Desertec project was an ambitious industrial initiative launched in 2009 by a consortium of German companies, whose main objective was to build concentrated solar power plants (CSP) in the desert of Africa and the Middle East to generate large-scale electricity and strategically supply not only North Africa but also Europe. [According to Hamouchene (2023), the project represented an estimated investment of approximately 400 billion euros]. According to Hamouchene (2022), Desertec presented an initial vision and committed resources, not only for North Africa but also for Europe as a response to global climate change challenges. However, despite high initial expectations and committed resources, the project not only failed in its objective of becoming a transformational energy solution [but also left important lessons about the inherent difficulties of international projects of this magnitude].

The concept behind Desertec was innovative and visionary: by leveraging the vast desert expanses of Africa and the Middle East, rich in sunlight, solar energy could be generated at competitive prices through a network of high-voltage transmission lines. [According to the International Energy Agency (IEA, 2020), the project proposed that by 2050 it could provide up to 15% of electricity consumed in Europe], managing to establish a high-voltage transmission line, which would represent a milestone in desert electrification by 2050.

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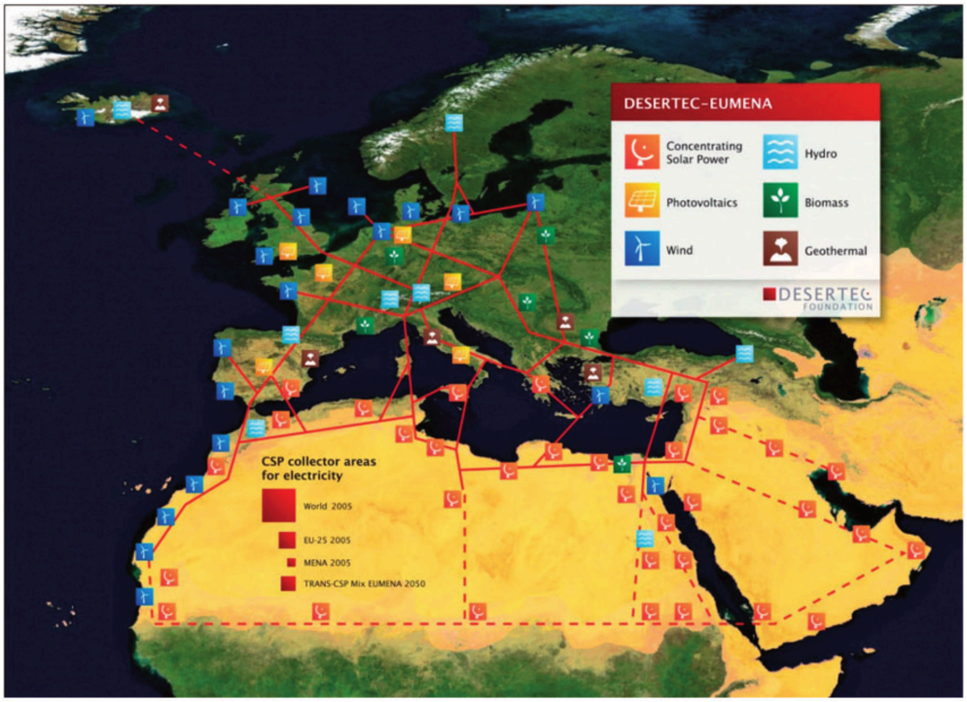
Hamouchene, H. (2022). Renewable Energy Transitions in North Africa. Journal of Sustainable Energy, 45(3), 112-130.

International Energy Agency. (2020). Renewable Energy Outlook 2020. Paris: IEA Publications.




Source: Rignall (2015)

Figure 2.2.1: Renewable Energy Resources Map of the Desertec EUMENA Project

The image displays a geographical map encompassing Europe, the Middle East, and North Africa (EUMENA region), highlighting the distribution of different types of renewable energy resources through a color-coded iconographic system.

The map employs a comprehensive energy type classification system, where red represents Concentrated Solar Power (CSP), green indicates Photovoltaic energy, blue denotes Wind Energy, and brown signifies Geothermal Energy. The visual representation reveals several notable patterns in the distribution of renewable energy resources across the region.

The most striking feature is the significant concentration of red icons, representing concentrated solar power, throughout North Africa and the Middle East. Wind energy installations, marked in blue, show a more dispersed pattern across Europe and coastal areas. Photovoltaic energy points, indicated in green, are predominantly distributed across European territories, while geothermal energy sites, marked in brown, appear in specific, isolated regions.

A particularly noteworthy element of the map is the area enclosed by red dotted lines, which indicates the zones with the highest potential for the Desertec project. This demarcation primarily encompasses North Africa and portions of the Middle East (Rignall, 2015).

The initial plan also proposed the creation of a sustainable energy infrastructure that would benefit both regions, with the potential to enhance the African economy and contribute to political stability. The project aimed not only to resolve Europe's energy crisis but also to create jobs in Africa and offer a clean alternative to fossil fuels. Indeed, Desertec was promoted as a "mutual gain" opportunity, a model where Europe would receive clean and affordable energy while Africa would benefit from investments, economic development, and greater energy autonomy.

### 2.2.2 Critics and internal controversies

Although Desertec was promoted as an innovative solution to the global energy crisis, the idea also drew criticism from various sources, including prominent voices from the ecological movement and renewable energy experts. One of the most notable critics was Hermann Scheer, known as the "solar pope" and tireless advocate for renewable energies, who was president of the NGO Eurosolar and a member of the German Parliament. Despite sharing the vision of a transition to clean energy, Scheer and others opposed Desertec due to its technocratic approach and lack of deeper sociological reflection on the project's social and economic impacts.

These criticisms were reflected in the different readings that emerged about the Desertec concept, as summarized by Schmitt (2018), in the following table:

Table 1. Different readings of the Desertec concept: an overview.

| Desertec | Internal Reading | External Critics' Readings |
|---|---|---|
| Main Character | Holistic vision (energy security, climate change, regional development) (Desertec Foundation) | Technocratic model without sociological reflexivity (Hermann Scheer, ecological movement) |
| Motivation | Ecological idealism, energy security, North-South justice (Desertec Foundation, TREC) | Ethically correct business model (DII members) |
| Energy Supply Structure | Centralized and decentralized elements (Desertec Foundation, DII) | Only decentralized elements (Hermann Scheer) |
| Technology | Only CSP (German Aerospace Center – DLR) | CSP, but also PV and wind (G. Knies, Desertec Foundation; DII) |
| Consumer Region | MENA + Europe in equal parts (Desertec Foundation, DLR; DII) | Only MENA region, export to Europe not realistic (DII 2: CEO P. van Son) |
| North-South Relations/Interregional Justice | Partnership, win-win, justice, co-development (Desertec Foundation, Club of Rome) | Neocolonialism, paternalism (external critics, publication forums) |

Source: Own elaboration, based on referenced sources.

This table offers a comparative analysis of internal and external perceptions of the Desertec project, revealing the complexity and multiplicity of interpretations about this ambitious international energy initiative.

Regarding the "main character," it's important to clarify that it doesn't refer to a specific individual, but rather to the entity that defines the project's interpretation. In this case, the

Desertec Foundation represents the project's comprehensive approach, which transcends mere energy generation to address global challenges such as energy security, climate change, and regional development.

The internal readings column, led by the Desertec Foundation and associated organizations, presents an optimistic and transformative perspective. From this vision, the project is configured as an innovative and comprehensive response to global energy challenges, emphasizing solutions that integrate technological development, international cooperation, and environmental sustainability.

In contrast, the external critics' readings column offers a more skeptical and analytical view. Representatives like Hermann Scheer from the ecological movement or various think tanks interpret Desertec from more complex geopolitical and socioeconomic angles. Their analyses identify potential limitations, risks of neocolonialism, and underlying power dynamics in the proposal.

The comparison elements - motivation, supply structure, technology, consumer region, and North-South relations - reveal fundamental divergences. While the internal vision advocates for a centralized model with Concentrated Solar Power (CSP) technology, critics advocate for more decentralized and local solutions. The target region also differs: the Desertec Foundation contemplates a balanced distribution between MENA and Europe, while critics point to a more extractive model focused on exporting resources from the global south.

This table thus evidences the multifaceted nature of the Desertec project, demonstrating how the same concept can be interpreted radically differently depending on the perspective of the actors involved.

These different interpretations of the Desertec project underscore the tensions between the idealistic and holistic vision of the Desertec Foundation and the more critical approaches pointed out by Hermann Scheer and other representatives of the ecological movement. While some, such as the Desertec Foundation, the Club of Rome, the North-South initiative, and others like TREC (Trans-Mediterranean Renewable Energy Cooperation) and DLI (Desertec Licensing International), saw Desertec as a form of co-development and interregional justice, others feared it could lead to a new type of neocolonialism and paternalism towards the regions of Africa and the Middle East.

Despite initial advances, the Desertec dream crumbled when the Desertec Foundation, the organization leading the consortium, decided to abandon the project in 2013. The foundation argued that the initiative had ceased to be viable due to political, economic, and social barriers, and that the costs associated with developing such complex infrastructure in an unstable region could not be justified.

The abandonment by the Desertec Foundation meant the loss of the brand and prestige it had gained in its early years. The projects that still remained standing, such as the Noor solar plant in Morocco, continued in isolation but without the support of the original consortium. Although some of these projects were successful at the local level, the concept of an interconnected transcontinental energy network between Europe, Africa, and the Middle East was forgotten.

### 2.2.3 Failure

However, like other major international projects, Desertec faced technical, political, and economic challenges far more complex than anticipated. As Schmitt (2018) explains, one of the first problems was the lack of consensus within the consortium. The companies involved had different visions about how to implement the project, which led to disagreements about the technical and financial aspects of the initiative. The lack of a clear implementation strategy and competition between consortium actors were recurring problems.

Firstly, Desertec's business model depended on large investments and cooperation agreements between Europe and African countries. However, the rapid growth of decentralized renewable energy systems, such as photovoltaic (PV) and wind energy, absorbed the financial resources and subsidies initially intended for more centralized projects like the concentrated solar power (CSP) plants proposed by Desertec (Schmitt, 2018). This shift toward more decentralized technologies diverted the political and financial support that was crucial for the project's viability.

Another key factor that contributed to Desertec's failure was political instability in the MENA region. Starting in 2011, the Arab Spring altered the geopolitical landscape in North Africa and the Middle East. The revolutions, protests, and armed conflicts that erupted in various countries in the region, including Tunisia, Egypt, Libya, and Syria, created an environment of uncertainty that discouraged foreign investment and complicated development plans. This growing political instability made infrastructure construction difficult and complicated facility security, negatively affecting the project's viability. The lack of a robust cooperation framework between Europe and regional countries made long-term agreements difficult to negotiate, especially when political tensions between actors like Israel and Arab countries complicated the participation of key companies like Siemens (Schmitt, 2018).

Moreover, the 2008 global financial crisis also played a crucial role in the project's slowdown. The global economic recession affected investments and altered Europe's energy priorities. During this period, European nations began to focus more on cost reduction and local renewable energy, such as wind power and solar photovoltaic, rather than seeking large-scale energy solutions like those proposed by Desertec. Additionally, the 2011 Fukushima nuclear disaster prompted a rethinking of energy policies in Europe, especially in Germany, which decided to accelerate the closure of its nuclear plants and focus on more local and less costly renewable energies than large-scale projects like Desertec.

Finally, the preference of countries like Morocco to develop their own large-scale solar energy projects for internal consumption, rather than focusing on electricity exports to Europe, was another determining factor in Desertec's failure. Under King Mohammed VI's direction, Morocco prioritized its energy autonomy through the development of solar facilities with a 2000 MW capacity by 2020. This approach, which culminated in the Noor I CSP plant in 2016, reflected a shift toward regional leadership rather than alignment with European interests. The award of the project to Aqwa Power, a Saudi company, showed that regional countries preferred to focus on their internal energy needs rather than follow the model proposed by Desertec (Schmitt, 2018).

### 2.2.4 Conclusions: Desertec as "Technology without Sociology" or a Long-term Option

Hermann Scheer described the Desertec concept as "technology without sociology" and considered it an expression of "new gigantomania." He emphasized that while the project's technical viability was evident, its social viability was not guaranteed. He argued that the project's realization was practically unfeasible due to political, economic, and sociological reasons, as it would involve collaboration between more than forty governments and coordination of multiple regional networks.

Scheer's opinion had a significant influence on the project's perception within his party and among other social actors, highlighting the difficulties in meeting expectations for electricity exports to Europe. For his part, Paul van Son, CEO of DII, acknowledged that while the initial mission of making renewable energies competitive in the MENA region had been accomplished, the idea of exporting electricity to Europe in the short term was unrealistic. From his perspective, connecting markets and building transcontinental electrical networks required strong political commitment and international cooperation that had not yet materialized.

The analysis of the Desertec project reveals both inherent and contingent problems that complicated its execution. Furthermore, it demonstrates that lack of political will and governance difficulties were crucial factors in its failure. Although the vision of a large-scale renewable energy system remains globally relevant, the study of Desertec highlights the importance of economic and social factors in defining innovation paths. It's possible that electricity production in North Africa may become profitable in the future, but only if the necessary networks can be built. The final reflection on the relationship between social justice and the transition to a global renewable energy system illustrates how ethical and commercial motivations can intertwine in energy project development, as demonstrated by Morocco's initiatives (Schmitt, 2018).

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Although Desertec failed as a transcontinental project, the concept of renewable energies as a solution to climate change remains relevant. The advancement of solar technology, particularly solar photovoltaic and wind energy, has considerably reduced clean energy production costs, making projects like Desertec more economically viable.

Lessons learned from the Desertec project:

1. Strategic flexibility importance: Energy megaprojects require adaptability to geopolitical and technological changes.
2. Need for decentralized approaches: Cross-border initiatives must consider local realities and not impose single models.
3. Value of regional cooperation: Successful energy transition depends on building consensus and shared objectives.
4. Relevance of technological innovation: Cost reduction in renewable energies can transform the viability of seemingly unfeasible projects.
5. Understanding power dynamics: It's fundamental to analyze North-South relations beyond the technical dimension, considering geopolitical and socioeconomic aspects.

These lessons are not only applicable to the Desertec case but can serve as an analytical framework for future international energy cooperation projects.

Today, the future of transcontinental energy projects might adopt a different approach. Instead of relying on a centralized, large-scale model, the focus could be on decentralized energy solutions that are more flexible and adapted to local political and economic realities. Initiatives such as connecting energy networks between southern European regions and North Africa, using solar and wind energy, could offer a more sustainable path for international energy cooperation.

## 2.1 GANSU WIND FARM PROJECT

### 2.1.1 Context

The global energy transition represents one of the greatest geopolitical and environmental challenges of the 21st century, with China positioning itself as a fundamental actor in this complex transformation (International Energy Agency [IEA], 2021; World Bank, 2022). According to the most recent reports, China stands as the largest greenhouse gas emitter, responsible for approximately 30% of global carbon dioxide emissions, with an energy model historically dependent on fossil fuels (IEA, 2021; Zhang et al., 2006).

This energy reality is sustained in a context of rapid industrialization and accelerated economic growth, where energy demand has historically been satisfied through a predominantly coal-based matrix. In 2020, coal still constituted about 57% of Chinese energy production, demonstrating the complexity of the decarbonization process (IEA, 2021; Liu, 2010).

The turning point in China's energy strategy can be situated at the 2009 Copenhagen Climate Conference, when the government made an unprecedented commitment: to reduce CO2 emissions per unit of Gross Domestic Product (GDP) by 40% to 45% by 2020, taking 2005 levels as a reference (United Nations Framework Convention on Climate Change [UNFCCC], 2018). This objective transcended mere diplomatic declaration, representing a comprehensive strategy for economic and energy transformation (World Bank, 2022).

In this context, the Gansu region emerges as a paradigmatic territory of China's energy transition. Located in the northwest of the country, this province of 454,000 km² and approximately 26 million inhabitants presents itself as an innovation laboratory for national sustainability strategies (Zhang et al., 2006). Its geographical configuration, characterized by desert and semi-arid zones, offers extraordinary conditions for the development of renewable energies, especially solar and wind (Liu, 2010).

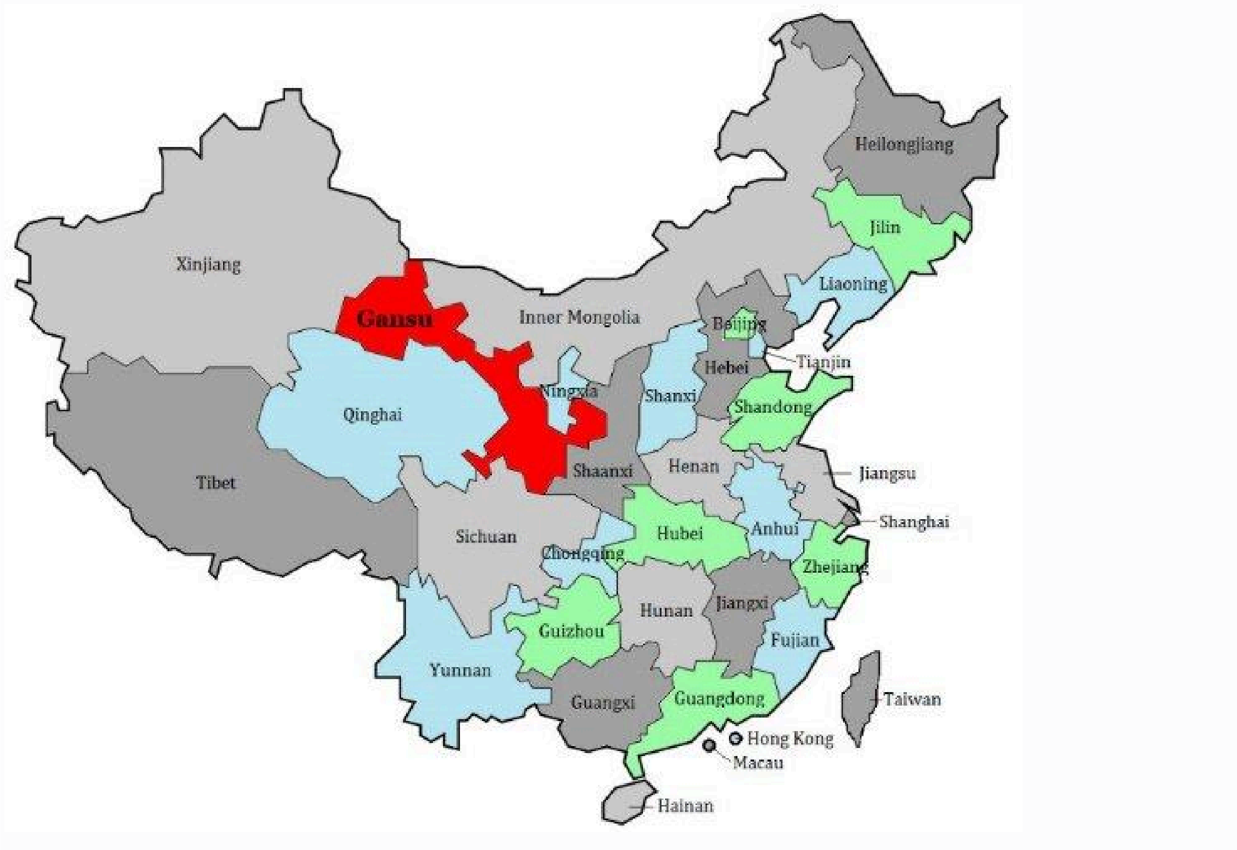



Figure 2.4: Location of Gansu Province in China's Geographic Context

The map shows China's administrative division, with Gansu province highlighted in red, located in the country's northwestern region. Situated in a strategic zone, Gansu borders provinces such as Xinjiang, Qinghai, and Sichuan, and represents a key territory for renewable energy development due to its unique geographical characteristics. The region is characterized by extensive desert and semi-arid zones, ideal conditions for developing wind and solar parks. Its geographical situation makes it a crucial point for China's energy transition strategy towards renewable sources.

The surrounding provinces appear in different shades of gray and green, providing a broader geographical context that allows understanding Gansu's specific location on China's map. Source: Ma (2023).

However, Gansu's reality is far from an idyllic scenario. The region faces critical environmental challenges that condition its sustainable development. Water scarcity affects practically the entire territory, with 90% of grasslands degraded and forest coverage below 15% (World Bank, 2022). The industrial model, heavily influenced by external investments, has favored carbon-intensive sectors, generating additional pressure on fragile ecosystems (IEA, 2021).

Five-year plans have been fundamental instruments in structuring regional energy development. The 11th Five-Year Plan (2006-2011) projected the construction of 19 wind farms with an installed capacity of 3.8 GW, while the 12th Five-Year Plan (2012-2017) significantly expanded the objective, aiming for 10 GW by 2015 (Zhang et al., 2006). The Jiuquan area consolidated itself as a strategic hub for these developments, concentrating investments and renewable energy infrastructure (Liu, 2010).

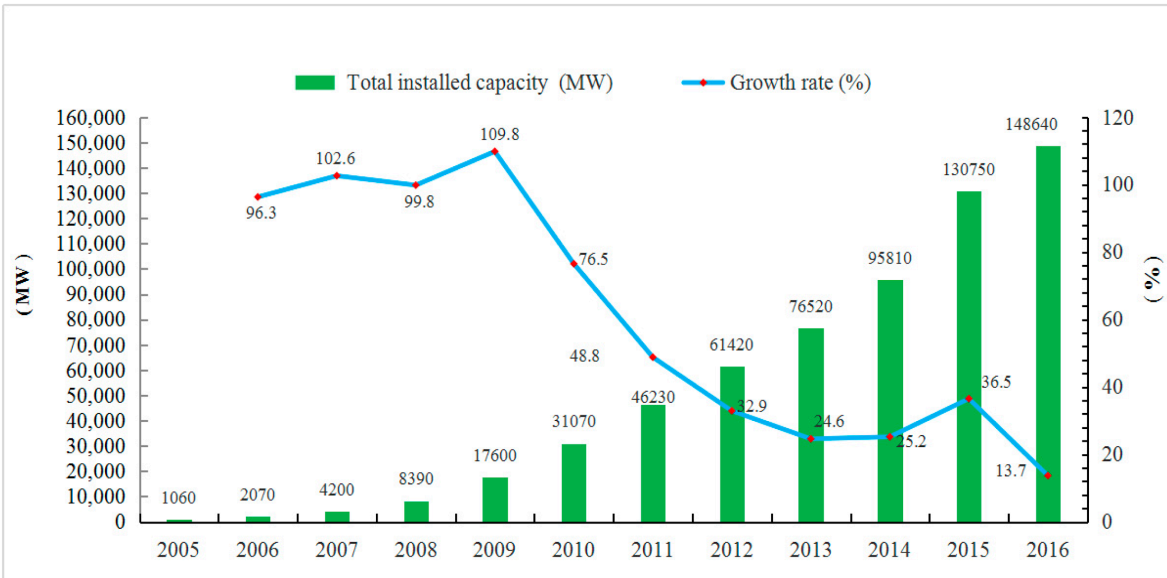
Technological evolution has been equally significant. While initially dependent on imported turbines, government support has driven domestic production, reducing costs and improving sector competitiveness (World Bank, 2022). However, technological challenges persist related to equipment efficiency and quality, as well as the economic viability of renewable energy projects (IEA, 2021).

### 2.1.2 Gansu wind farm’s outputs

The Gansu Wind Farm stands as a flagship project of China's energy transition, representing a turning point in the national decarbonization strategy. Located in a region with challenging geographical conditions, the project illustrates both the potential and limitations of large-scale renewable energy implementation.

#### Sustainable Performance

From an environmental perspective, the park has significantly contributed to reducing carbon dioxide emissions and generating clean energy instead of relying on fossil sources. According to recent data from Xinhua (2017), Gansu Wind Farm generates approximately 217 GW, and the park is on track to reach an installed capacity close to 20 GW (Liu et al., 2021). However, the phenomenon of "spillover" or energy waste goes beyond the barriers considered for full effectiveness. Problems arise when energy generation exceeds the transmission and storage capacity of the electrical grid, leading to turbine disconnection (IEA, 2016).




Source:(Luo et al., 2018)

The image shows a graph representing the evolution of total installed capacity (in MW) and growth rate (in %) of the Gansu Wind Farm between 2005 and 2016. The green line represents installed capacity, which shows significant growth from approximately 1,000 MW in 2005 to nearly 140,000 MW in 2016. The blue line indicates the growth rate, which peaked around 2006-2007 (near 100%) and subsequently showed a decreasing trend, stabilizing at approximately 17.7% in 2016. This graph clearly illustrates the project's rapid initial expansion and its subsequent maturation and stabilization.

The phenomenon of "wind curtailment" represents a critical challenge in the development of Chinese wind energy, especially in the northwest region. According to Luo et al. (2018), this term describes a complex situation where electricity generated by wind farms is not fully integrated into the power grid, forcing wind turbines to disconnect or limit production.

The causes of this phenomenon are multifactorial and reveal the structural complexities of the Chinese energy system. Grid infrastructure limitations play a fundamental role, with insufficient transmission capacity unable to absorb all generated energy. This combines with a systematic mismatch between wind generation and energy demand, where the traditional electrical system prioritizes conventional sources like coal.

Technical challenges add another layer of complexity. The inherent intermittency of wind generation clashes with the rigidity of an electrical system designed for constant energy sources. The lack of efficient storage systems aggravates the problem, creating situations where wind turbines must be disconnected despite their generation potential.

From an economic perspective, wind curtailment represents a significant loss. The costs of integrating renewable energies, combined with the lower price of wind electricity compared to other sources, create disincentives for full adoption of this technology. The graph illustrates this paradox: exponential growth in installed capacity that doesn't translate proportionally into effective integration.

The phenomenon thus emerges as a crucial obstacle in China's energy transition, revealing the tensions between the ambitious objective of renewable energy expansion and the structural limitations of the existing energy system.

The Gansu Wind Farm transcends its local dimension to become a strategic element of Chinese climate policy. It represents a turning point in the national energy transition, directly connecting China's commitments with global emission reduction objectives established in the Paris Agreement. Investment in this infrastructure not only responds to an internal development strategy but also configures as a statement of intent in the international arena of fighting climate change.

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## Environmental Impact

The environmental impact of infrastructures associated with wind farms, such as access roads and transmission lines, has also generated concern regarding their long-term sustainability. Although operating wind turbines don't emit greenhouse gases, the installation process and modifications to the natural environment can have significant repercussions. According to Ma et al. (2023), land use alteration is one of the most evident effects. The construction of roads and other necessary infrastructure for access and equipment transport modifies previously natural areas, converting them into more industrialized zones. In a place like Gansu, where the landscape is mostly rural and little altered, these changes are especially relevant, as they affect not only vegetation but also traditional land use, such as grazing and agriculture.

Furthermore, the fragmentation of natural habitats derived from the installation of these infrastructures can hinder animal species mobility. Local ecosystems are transformed, and some species may lose their migratory routes or feeding zones, which could reduce biodiversity in the region. A concerning aspect related to fauna, especially in migratory passage areas like Gansu, is the possible impact on migratory birds. Although wind turbines are designed to minimize accidents, there is always a risk of collisions, which highlights the need for additional protection and monitoring measures at these critical points.

Moreover, changes in local ecosystems, such as alterations in natural drainage or soil compaction, can also have long-term effects on vegetation and soil organisms. These secondary effects can unbalance the area's flora and fauna, generating alterations in the ecological structure that require continuous attention and control. In Gansu's semi-arid zones, as in other parts of China, these impacts can contribute to problems such as desertification, an environmental issue that is already a constant concern for the region.

Regarding the mitigation of these impacts, it is essential to carry out comprehensive and continuous environmental assessment, as indicated by studies from Ma et al. (2023). Throughout the wind farms' useful life, it is fundamental to implement practices that help minimize the ecological footprint, such as restoring affected areas, establishing wildlife corridors, and using technologies for monitoring local biodiversity. These measures are fundamental to ensure that the benefits of wind energy do not come with a significant loss of natural resources.

Despite the negative effects that infrastructures can generate, it is important to note that wind energy remains one of the cleanest energy sources available. Compared to fossil fuel-based energy sources, the environmental impacts of wind farms are considerably lower. In Gansu's case, although the impact on the natural environment is a valid concern, the long-term benefits of having renewable and emission-free energy largely outweigh the associated environmental costs, especially if effective protection and restoration measures are implemented.

### Social Impact

The park's development has had varied impacts on local communities. On one hand, it has generated employment opportunities both during the construction phase and in maintenance operations, contributing to economic development in one of China's least developed regions. However, these opportunities tend to be limited in duration and scope. Additionally, the technical training required to operate and maintain these installations has primarily benefited external workers, leaving the local population in a position of lesser benefit.

Another important social challenge has been the displacement of communities to allow for the construction of park-related infrastructure. Although these relocations are theoretically compensated, lack of transparency and insufficient payments have generated tensions with affected residents (Ma et al., 2023). Problems have also been reported regarding access to locally generated electricity, as much of the energy produced is destined for distant urban centers, leaving nearby communities with limited access.

### Geopolitical Relevance

From a geopolitical perspective, the Gansu Wind Farm represents a key piece in China's strategy to position itself as a world leader in renewable energy. This project not only reinforces the country's capacity to meet its climate objectives but also drives its competitiveness in wind technology, contributing to its global positioning in sustainable energy infrastructure.

Beyond being merely an energy infrastructure project, Gansu Wind Farm stands as a symbol of China's commitment to global energy transition. It's not just a national initiative, but a significant contribution to international efforts to mitigate climate change. The project exemplifies how emerging economies' energy strategies can become vectors of global transformation, challenging the traditional dichotomy between economic development and environmental sustainability.

Nevertheless, challenges in integrating Gansu's generated energy into the national grid have limited its geopolitical impact. The lack of efficient interconnection between renewable energy-producing provinces and major consumption centers, such as Beijing and Shanghai, highlights the structural weaknesses of China's electrical infrastructure. This problem underscores the need to invest in smart grids and energy storage to fully harness the wind farm's potential.

Table 2.1: Multidimensional Analysis of Gansu Wind Farm

| Dimensión | Aspectos Positivos | Aspectos Negativos |
| --- | --- | --- |
| Sostenibilidad | - Significant reduction of $CO_2$ emissions<br>- Generation of 217 GW of clean energy<br>- Installed capacity close to 20 GW<br>- Contribution to national climate objectives | - "Wind curtailment" phenomenon<br>- Network infrastructure limitations<br>- Frequent turbine disconnections<br>- Low effective integration of generated energy |
| Ambiental | - Renewable energy source free of emissions<br>- Alternative to fossil fuels<br>- Minimal greenhouse gas emissions during operation | - Land use alteration<br>- Fragmentation of natural habitats<br>- Potential impact on bird migratory routes<br>- Risk of contributing to desertification processes<br>- Modification of local ecosystems |
| Social | - Temporary job generation<br>- Contribution to regional economic development<br>- Boost to technical training | - Limited and short-duration jobs<br>- Preference for external workers<br>- Displacement of local communities<br>- Insufficient compensations<br>- Limited access to generated electricity |

*Source: Own elaboration based on Ma et al. (2023), Liu et al. (2021), Xinhua (2017)*

## 2.1.3 Conclusions

In general terms, the Gansu Wind Farm has symbolized the commitment to the transition towards renewable energy sources. However, its success has been limited by a series of technical, social, and economic obstacles. Although it has been fundamental in reducing greenhouse gas emissions, the problems of disconnection and energy storage reveal the complexity of the energy system transformation that requires attention at both technical and infrastructure levels.

The implementation of the Gansu Wind Farm reveals the multidimensional nature of the energy transition. Beyond quantitative achievements, the project demonstrates the need for a holistic approach that integrates technological innovation, infrastructural planning, and socioeconomic considerations for a true transformation of the energy model.

## 2.3 AUSTRALIA-ASIA POWER LINK (SUN CABLE)

### 2.3.1 Introduction

The Australia-Asia PowerLink is an ambitious megaproject designed to connect northern Australia with Singapore through a high-voltage direct current (HVDC) transmission system. This link aims to transport electricity generated from renewable sources, leveraging the exceptional conditions of Australia's Northern Territory for solar and wind generation. According to Gordonnat and Hunt (2020), this region has some of the highest insolation levels in the world, constant winds, and vast land extensions, making it an optimal environment for large-scale projects.

The project's purpose is not limited to covering Singapore's growing energy demand, but also seeks to contribute to the region's decarbonization, aligning with international climate commitments. As Halawa et al. (2021) highlight, Singapore is a nation highly dependent on natural gas for electricity generation, with 95% of its electricity coming from this fossil resource. The implementation of AAPowerLink will not only allow for diversification of its energy matrix but will also strengthen its long-term energy security.

Moreover, this connection would enable Australia to integrate into the future Asian Super Grid, a project in the feasibility phase that seeks to integrate most Asian countries into a more interconnected and sustainable energy infrastructure (Gordonnat & Hunt, 2020). Currently, electricity generation in this region primarily depends on fossil fuels, responsible for a significant portion of $CO_2$ emissions. Although Singapore, facing high energy demand, heavily relies on natural gas, the implementation of an underwater HVDC interconnector could be a viable solution to reduce emissions and improve energy security, given the country's limited renewable generation capacity. Additionally, underwater HVDC interconnectors have evolved over the past 50 years, increasing their capacity and playing a key role in energy security and renewable energy integration (Gordonnat & Hunt, 2020).

### 2.3.2 Route selection

In northern Australia, several large-scale renewable energy projects are transforming the regional energy landscape. Notably, the Sun Cable project in the Northern Territory, with a planned capacity of 10 GW, is currently in the development phase but facing significant financial challenges following its bankruptcy declaration in 2022. Complementarily, the Asian Renewable Energy Hub in Pilbara proposes 15 GW of solar and wind energy, currently undergoing environmental assessment and permit acquisition, with projected construction start around 2025 (Gordonnant & Hunt, 2020).

These developments aim to leverage favorable wind and insolation conditions to supply renewable energy both to Southeast Asia and to the local mining industry. The projects, which include photovoltaic solar and wind parks with capacities exceeding 10 GW, are strategically distributed between Pilbara and Tennant Creek. The Tennant Creek project, still in preliminary planning stages, demonstrates the potential for expansion of these initiatives, while associated energy storage systems enhance their efficiency and stability.

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Figure 2.3.2 Proposed Route for the Asia-Pacific Power Link - Energy Interconnection between Australia and Singapore

The image illustrates the proposed submarine solar energy cable project route between Australia and Singapore, designed to transport electricity generated by solar parks in Australia's Northern Territory to Singapore. The map shows the route crossing Indonesia, with strategic connection points and different stages of energy generation and transmission.

Key map elements:

- Origin Point: Darwin, Australia (solar generation zone)
- Submarine route through Indonesia
- Endpoint: Singapore
- Iconography representing different stages of generation, storage, and transmission

The marine route suggested by Xodus for the report covers a distance of 3,200 km, passing through the Timor Sea and reaching Singapore, with variations in water depths. The deepest section is located in the Timor Trench, with depths of up to 1,900 m and steep slopes.

### 2.3.3 AUSTRALIA-ASIA POWER LINK COST

The Australia-Asia Power Link, which plans to connect Australia with Singapore through an HVDC (high-voltage direct current) submarine cable, is a large-scale project with an estimated cost of around $6 billion. This budget is based on a detailed analysis covering technical cable definition, route selection, and transportation and installation strategy (Gordonnat & Hunt, 2020).

The cost breakdown shows that cable supply represents the largest portion of the budget, reaching 77% of the total, with an average cost of $720,000 per kilometer. Cable installation and transportation, although logistically complex phases, constitute a smaller proportion of the total cost, with installation at 13% and transportation at 3%. Additionally, minor expenses such as planning, project management and engineering (PM&E), and insurance are included, totaling an additional 7% (Gordonnat & Hunt, 2020).

The project's logistical challenges are significant, involving the manufacture and transportation of approximately 320,000 tons of cable from northern Europe, using a fleet of specialized vessels for transport and installation. The installation strategy is planned as a 2.5-year campaign involving two cable-laying vessels (CLVs), supported by four heavy-lift vessels (HLVs) that continuously transport cable sections (Gordonnat & Hunt, 2020).

Moreover, a phased construction approach has been chosen to minimize risks and facilitate implementation. Instead of directly laying the complete 3,200 km link from Australia to Singapore, an initial connection to Indonesia is proposed as an intermediate phase. This phase allows dividing the project into manageable segments, generating revenue before completing final phases and reducing initial capital requirements, while also leveraging HVDC technology advancements and adapting to geopolitical or regulatory changes (Gordonnat & Hunt, 2020).

This staggered approach not only distributes risk but also improves the project's cash flow, allowing revenues generated by initial phases to finance subsequent stages. Thus, the final connection to Singapore is expected to occur after the Indonesian segment is operational, facilitating the project's overall feasibility and execution (Gordonnat & Hunt, 2020).

Financing for the Australia-Asia Power Link comes primarily from Sun Cable, the project's development company. Sun Cable has attracted several high-profile private investors, including billionaires Andrew Forrest and Mike Cannon-Brookes, who have invested capital to advance the project's initial stages. These investors seek long-term return on investment through selling renewable electricity generated in Australia and exported to Singapore.

Additionally, the project could benefit from financing from public and multilateral institutions interested in promoting renewable energy projects and reducing global carbon emissions. For example, regional development banks like the Asian Development Bank (ADB) or the World Bank might offer financing or guarantees that facilitate project execution and minimize financial risks.

Ultimately, the project's cost will be recovered through long-term electricity purchase agreements (PPAs) signed with customers in Singapore and Indonesia. These agreements ensure stable revenues for Sun Cable and its investors, thus allowing investment return and long-term project sustainability.

### 2.3.4 KEY CHALLENGES

The project faces various logistical and technical challenges, starting with the complexity of HVDC cable transport and installation, which requires meticulous coordination between specialized vessels, such as cable-laying and heavy-lift ships, to ensure materials and personnel arrive on time. Additionally, the seabed in areas like the Java Sea is particularly congested, necessitating cable protection from damage caused by fishing activities and other obstacles, and burying them at an appropriate depth to avoid inconveniences.

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The Singapore Strait, a highly transited maritime passage, demands special designs to protect cables from anchor damage and other navigation hazards, while also managing the magnetic effects generated by cables that can interfere with ship compasses. Climate conditions are also a factor to consider, as they can delay cable-laying operations, so contingency margins are contemplated for both transit and installation to mitigate these effects.

Submarine cables are exposed to hazards such as fishing gear and dragged anchors, requiring protection by burial at depths between 0.6 and 1.5 meters. Moreover, in deep areas like the Timor Trench, the installation process must be handled carefully, as tension generated during cable laying can damage cable structure.

Regarding cable repair, the process is also challenging and requires careful planning to ensure repairs can be effectively made on the seafloor. Additionally, seismic activity in southern Indonesia increases the risk of seafloor movements that could damage cables, making geophysical studies crucial for selecting a safe route.

Cost management is another challenge due to the high costs associated with operating specialized vessels and equipment. Balancing project profitability while maintaining the budget is crucial. Furthermore, the project depends on highly skilled personnel for cable installation and joining, implying securing their availability and continuous training throughout the project's duration.

Equipment reliability is key, as any failure or delay in transport ships or laying equipment can postpone the project. It is also fundamental to have adequate infrastructure at both project ends to handle cables and ensure local infrastructure supports the arrival of heavy-lift vessels.

The project also faces regulatory obstacles and the need to obtain environmental and marine permits in Indonesia and Australia, which can delay implementation phases. Logistically, cable manufacturing and delivery will be managed through multiple suppliers, requiring proper planning to avoid delays.

Finally, integrating renewable energy sources from Australia to Indonesia presents technical challenges, as cable infrastructure must be capable of handling renewable energy fluctuations, requiring a robust design to ensure system efficiency and stability (Gordonnat & Hunt, 2020).

### 2.3.5 Geopolitical Impact and Energy Sovereignty

One of the most relevant aspects of this project is its impact on energy geopolitics. Singapore, heavily dependent on fossil fuels for energy generation, would greatly benefit from a clean and sustainable electricity source from Australia. This would allow Singapore to diversify its energy supply and reduce its vulnerability to natural gas price fluctuations, on which it currently bases most of its electricity generation. However, at the same time, the energy sovereignty of the involved countries, especially Australia, would be affected. Singapore's dependence on Australian renewable energy could generate political tensions over the control and management of energy infrastructure, which could have repercussions at the regional level, especially in a context where power interests and energy security play a crucial role in international relations.

### 2.3.6 Environmental Impact and Sustainability

Cross-border electrical interconnection projects, while promising, present significant environmental and social challenges. The construction of transmission lines, especially in relatively virgin border regions, carries an environmental cost (Do & Burke, 2022). Additionally, interconnection can incentivize coal use, as evidenced in the Hongsa project in Laos, with negative consequences such as water and air pollution, damage to nature and local livelihoods, and contribution to climate change (Do & Burke, 2022; McCartney & Brunner, 2020; Tran & Suhardiman, 2020). Coal-fired power plants in ASEAN are estimated to be responsible for around 20,000 additional deaths per year (Koplitz et al., 2017, cited in Do & Burke, 2022). The construction of new hydroelectric dams, such as those in the Mekong, also raises significant environmental and social risks, including biodiversity loss, ecosystem alteration, and impact on the livelihoods of millions of people (Do & Burke, 2022; Hirsch, 2020; Intralawan et al., 2018). A similar example is found in Sarawak, Malaysia, where dam development for electricity export has generated concerns about land appropriation and impact on indigenous communities (Cooke et al., 2017, cited in Do & Burke, 2022). Often, environmental impact assessments underestimate these costs by limiting themselves to areas near the dam, without considering larger-scale implications (Do & Burke, 2022; Hirsch, 2020). These cross-border impacts can hinder progress towards multilateral and unified electricity trade, generating opposition from local communities and civil society (Do & Burke, 2022; Suhardiman & Middleton, 2020; Tran & Suhardiman, 2020; Wu, 2016; Yong, 2020).

Add to bibliography: https://www.researchgate.net/publication/352821391_Australia-Asia_power_link_environmental_and_cost_assessment

### 2.3.7 Future Perspectives

The success of AAPowerLink could set a precedent for future renewable energy megaprojects in the region. According to (Halawa et al., 2018), this project will be a reference for international electrical grid integration and renewable energy export. Additionally, it will drive advances in technologies such as massive energy storage and the manufacturing of higher-capacity HVDC cables, benefiting not only Australia but also other countries committed to energy transition.

The Australia-Asia Power Link is not just an innovative technical infrastructure, but also an example of international cooperation in the fight against climate change. Despite technical, economic, and regulatory challenges, its implementation promises to transform the region's energy dynamics, strengthening energy security and accelerating the transition towards a more sustainable future.

# *3. CHAPTER 3: COMPARATIVE ANALYSIS*

Chapter 3 delves into the analysis of renewable energy megaprojects from the perspective of liberalism in International Relations. Using a comparative method, the study examines three emblematic projects with different levels of success - Gansu Wind Farm in China, Desertec in the MENA region, and Australia-Asia PowerLink - to understand how international cooperation and economic interdependence can drive global energy transition. The analysis is not limited to a static comparison but is complemented by a scenario analysis for the Australia-Asia PowerLink, considering three possible futures if it is finally implemented: an optimistic scenario of full success, a neutral scenario with partial implementation, and a pessimistic scenario. The objective is to go beyond technical aspects, exploring how these projects function as tools of political and economic integration, and what factors determine their development. Through a qualitative analysis covering geopolitical, economic, and sustainability dimensions, the chapter seeks to identify common patterns and lessons applicable to future renewable energy projects, thus contributing to understanding how states and private actors can collaborate in building a more sustainable energy future.

## 3.1 Methodological Aspects

As proposed at the beginning of this study, the work is framed within the theory of liberalism in international relations, which highlights economic interdependence and international cooperation as key elements in the governance of renewable energy megaprojects. This theory provides an ideal framework for analyzing how states and private actors collaborate in the planning and implementation of these infrastructures, considering that their viability depends not only on technical and economic criteria but also on their political and social acceptance (Keohane & Nye, 2012). In coherence with this approach, the methodology used in this work is based on two main analytical tools: comparative analysis and scenario analysis, both widely used in studies of geopolitics and sustainable energy (Flyvbjerg, 2014).

The choice of a qualitative approach responds to the nature of the object of study, as renewable energy megaprojects involve a series of political, economic, social, and environmental factors that cannot be analyzed solely through quantitative data. While numerical indicators of investment, energy generation, and costs are relevant, the geopolitical impact and sustainability of these projects largely depend on the dynamics between the actors involved, their strategic interests, and the political acceptability of the project in question (Moravcsik, 1997). Seeking to answer fundamental questions such as: How do renewable energy megaprojects impact global geopolitics? and What are the key factors that determine the success or failure of a megaproject?, this section details the two methodologies to be used: comparative analysis and scenario analysis.

The analysis will focus on unraveling how these projects:

- Reconfigure power relations between states
- Generate new forms of economic interdependence
- Establish international cooperation frameworks
- Identify structural barriers to their implementation

Through a qualitative approach combining comparative analysis and scenario projection, the research seeks to go beyond technical description, delving into the complexity of international relations and global energy transition.

The temporal framework of the analysis covers the last two decades, with a focus on projects developed between 2010 and 2030, given that this period coincides with a boom in renewable energy investments and a significant change in global policy towards decarbonization.

### 3.1.1 Comparative Analysis Methodology

Comparative analysis is a common tool in social sciences and will be essential in megaproject research, as it allows identifying success and failure patterns by studying specific cases within the same sector. A comparative case study model will be used, in which selected projects will be examined based on three key dimensions:

1. Geopolitical Dimension: Examines the impact of megaprojects on international relations, their influence on energy security, and how they modify the power balance between States.
2. Economic Dimension: Evaluates the financial viability of projects, the investment model adopted, private capital participation, and the economic benefits they generate.
3. Sustainability Dimension: Analyzes environmental impact, compatibility with Sustainable Development Goals (SDGs), and the project's social acceptance.

Each case will be analyzed using primary and secondary sources, including reports from international organizations, academic literature, and data from governmental and business sources (Greiman, 2023). The comparison will allow extracting lessons applicable to future projects, identifying determining factors in their success or failure.

### 3.1.2. Scenario Analysis Methodology

Scenario analysis is a methodology widely used in strategic planning and energy studies, as it allows projecting different possible outcomes for a specific project based on political, economic, and technological variables (European Commission, n.d.). In this study, three scenarios will be constructed for the future of the Australia-Asia PowerLink megaproject:

1. Optimistic Scenario: The project is successfully developed, achieving an efficient transition to renewable energies and consolidating new strategic alliances between Australia and Asia-Pacific.
2. Neutral Scenario: The project faces delays and cost overruns but is partially implemented, with limited impact on regional decarbonization.
3. Pessimistic Scenario: Regulatory problems, conflicts of interest, and technological limitations prevent the project's realization, reinforcing fossil fuel dependence in the region.

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Scenario construction requires a systematic analysis of variables that can condition its development. Following the methodological framework proposed by Börjeson et al. (2006), the process involves a rigorous identification of critical factors that can influence the project's trajectory.

## Key Variable Identification

1. Technological Variables

Technological innovations constitute a fundamental element in project viability. According to Gordonnat and Hunt (2020), advances in high-voltage direct current (HVDC) transmission and energy storage can substantially modify the Australia-Asia PowerLink's prospects.

Factors to consider:

- Solar energy transmission efficiency
- Energy storage capacity
- Submarine cable innovations
- Technological resilience to extreme environmental conditions

2. Political Variables

The regional geopolitical context determines the viability of energy interconnection projects. Thompson and Martínez (2021) highlight the importance of cooperation dynamics between Australia and Singapore, as well as the role of other regional actors.

Analysis elements:

- Diplomatic relations stability
- International climate commitments
- Regional powers' influence
- Energy cooperation frameworks

3. Economic Variables

The economic dimension represents a critical factor in energy megaproject implementation. The IEA (2022) underscores the importance of innovative and sustainable financing models.

Aspects to evaluate:

- Investment model (public, private, mixed)
- Implementation costs
- Investment return
- Regional economic impact
- Regulatory Variables

The legal and regulatory framework configures a determining element in transnational project viability. ARENA (2022) highlights the complexity of regulatory frameworks in international energy infrastructures.

Analysis elements:

- Legal frameworks for energy interconnection
- Environmental regulations
- Commercial agreements
- Technology transfer regulations

Table 3: Scenario Analysis Matrix

| Variable | Optimistic Scenario | Neutral Scenario | Pessimistic Scenario |
|---|---|---|---|
| Technology | Cutting-edge HVDC technology implementation | Functional technology with limitations | Technological failure |
| Political | Smooth international cooperation | Partial cooperation | Intergovernmental conflicts |
| Economic | Complete financing | Partial financing | Lack of investment |
| Regulatory | Favorable legal framework | Complex regulations | Insurmountable regulatory barriers |

Source: Own elaboration

The methodological scenario process in this work is constructed through specialized literature collection, energy interconnectors, political risk analysis, and feasibility assessments conducted by organizations such as the International Energy Agency (IEA, 2022), as well as historical trends analysis.

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## Cross-Validation

The cross-validation in this study involves a rigorous process of contrasting and verifying collected information. This process is developed in three main dimensions: First, information contrast between different sources involves comparing data from academic publications, governmental reports, studies from international organizations, and specialized energy sources, aiming to identify coincidences and resolve potential discrepancies, ensuring information coherence and reliability. Second, the analysis of variable consistency evaluates the interrelation between variables identified in different scenarios, verifying internal logic in each scenario's projection by examining how changes in one variable might affect others, guaranteeing a realistic modeling of potential project developments. Third, scenario probability evaluation involves a probabilistic analysis of proposed scenarios, considering historical factors, current trends, and expert projections, which allows weighing the relative viability of each scenario and identifying the most probable and those with lower materialization potential.

Additionally, it is complemented by the Delphi method, which involves structured consultations with experts from various fields. This approach allows validating and contrasting information, reducing biases and improving the rigor of prospective analysis.

Bibliography:

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## Justification of the Comparative Method

The comparative method is justified by its ability to identify cross-cutting patterns in renewable energy megaproject implementation. Flyvbjerg (2014) notes that comparative analysis is essential in megaproject evaluation, as it allows distinguishing success and failure factors in different geopolitical and economic contexts.

A case-oriented comparison design is chosen, following Lijphart's (1971) approach, in which projects with similar characteristics in terms of scale and ambition are selected, but with differences in financing, regulation, and political context. Comparing these three cases will allow extracting lessons transferable to future global energy initiatives.

Moreover, liberalism provides an appropriate theoretical framework for this analysis, as it allows interpreting these projects not only as state power instruments (as realism would), but as mechanisms that foster international cooperation through economic and energy interdependence (Keohane, 2005).

## Sources and Methodological Validity

The methodological rigor of this work is sustained by source triangulation, combining academic literature with empirical data and case studies. Indexed publications in databases such as Scopus and Web of Science will be prioritized, as well as reports from relevant institutions like the World Bank, IEA, and the United Nations Environment Programme (UNEP, 2022).

The combination of comparative and scenario analysis will allow in-depth evaluation of renewable energy megaprojects' impact on global geopolitics and particularly the relevance of the main project analyzed here. Through this methodology, the aim is not only to understand the factors determining its viability but also to contribute to designing strategies for its future development in a sustainable energy transition context.

## 3.2 Comparative Analysis of Megaprojects

As mentioned precisely, this chapter is framed within Liberalism in International Relations. From this perspective, renewable energy megaprojects are not just technical infrastructures but also function as economic and political integration tools (Keohane & Nye, 2012). They are considered facilitators of interstate cooperation, reducing conflict potential by creating energy interdependencies that strengthen global stability (Moravcsik, 1997).

To evaluate these projects, a comparative method will be used, which allows analyzing similarities and differences in governance, financing, and geopolitical impacts of three key initiatives: Gansu Wind Farm (China), Desertec (MENA), and Australia-Asia PowerLink (Australia-Singapore). The comparative analysis will be structured in three dimensions: geopolitical, economic, and sustainable, as noted in the previous section.

### 3.2.1 Geopolitical Dimension

From a liberal perspective, renewable energy megaprojects can be interpreted as facilitators of international stability by promoting cross-border cooperation (Oye, 1985). States and companies participating in these projects have incentives to coordinate energy policies and create common regulatory frameworks, thus reducing conflict risks.

Gansu Wind Farm: China's Energy Leadership

China has utilized Gansu Wind Farm as an instrument of energy diplomacy, positioning itself as a key actor in renewable technology export (Gyatso et al., 2023). This project is framed within the Belt and Road Initiative (BRI) strategy, promoting economic interdependence with other Asian countries through shared energy infrastructures (Buckley & Nicholas, 2017).

Desertec: A Failed Case of International Cooperation

Desertec's failure illustrates how the lack of interstate coordination and robust institutions can hinder a megaproject's viability. Although the EU and North African countries shared the objective of promoting solar energy, the absence of binding agreements on infrastructure ownership, energy prices, and supply security weakened the project (Schmitt, 2018). This reinforces the liberal idea that multilateral institutions and agreements are fundamental to sustaining international cooperation (Keohane & Nye, 2012).

#### Australia-Asia PowerLink: Energy Integration in the Indo-Pacific

The Australia-Asia PowerLink case represents an opportunity to consolidate an integrated energy market in Southeast Asia, reinforcing Singapore's energy security through positive interdependencies with Australia (Gordonnat & Hunt, 2020). This project highlights the role of public-private partnerships in renewable energy governance, aligning with the liberal approach to transnational cooperation in strategic sectors (Moravcsik, 1997).

### 3.2.2 Economic Dimension: Megaproject Feasibility and Financing

One of the primary challenges of energy megaprojects is their high cost and the need for sustainable financing. The financing model of each case influences its success or failure.

#### Gansu Wind Farm: State Investment and Chinese Leadership

Gansu Wind Farm has been primarily financed by the Chinese state and state-owned enterprises, which has allowed maintaining the project despite issues such as energy overproduction and transmission capacity limitations (Yunna & Ruhang, 2013). This model demonstrates how states can act as strategic investors to drive key sectors, ensuring long-term stability.

#### Desertec: Lack of Consensus and Private Sector Withdrawal

Unlike Gansu, Desertec depended on European private investment, generating difficulties in securing sustained financing. The 2008 economic crisis and the lack of governmental incentives led to the withdrawal of key investors (Schmitt, 2018). This confirms the importance of state support and investment agreements in the viability of large-scale energy projects (Flyvbjerg, 2014).

#### Australia-Asia PowerLink: Hybrid Investment Model

Australia-Asia PowerLink combines private investment and governmental support, backed by Sun Cable and other strategic actors. This approach balances risks and benefits, ensuring more stable execution compared to Desertec (Gordonnat & Hunt, 2020). This case reflects the liberal vision that collaboration between the private sector and states is key to financing the global energy transition (Keohane, 2005).

### 3.2.3 Sustainability Dimension: Environmental Impact and SDG Alignment

Megaprojects must align with the Sustainable Development Goals (SDGs) to guarantee long-term viability.

- Gansu Wind Farm has reduced carbon emissions but faces energy waste problems due to lack of electrical interconnectivity (Ma et al., 2023).
- Desertec could not fulfill its sustainability objective due to transmission infrastructure limitations and socio-environmental conflicts in North Africa (Schmitt, 2018).
- Australia-Asia PowerLink promises to be a model of sustainable energy integration, with lower environmental impact and greater social benefits if it overcomes its regulatory challenges (Gordonnat & Hunt, 2020).

A comparative synthesis of the impact of three renewable energy megaprojects—Gansu Wind Farm, Desertec, and Australia-Asia PowerLink—follows, examining three key dimensions:

- Economic: Includes costs, profitability, and financial viability.
- Social: Evaluates impact on local communities and generated employment.
- Geopolitical: Examines the project's role in international cooperation and energy security.

This table summarizes previous findings and aligns with the comparison framework established on page 8 of the thesis, where the comparative structure was initially defined.

Table 3.2: Comparative Analysis of Renewable Energy Megaprojects: Economic, Social, and Geopolitical Impacts

| Dimension | Gansu Wind Farm (China) | Desertec (MENA - EU) | Australia-Asia PowerLink |
|---|---|---|---|
| Economic Impact | - Estimated investment: 17.5 billion USD (IEA, 2022)<br>- 80% financed by the Chinese state, remainder by private investors<br>- Overcapacity problems reduce investment return<br>- Could generate up to 30,000 GWh annually, sufficient to supply 3% of China's electrical consumption (Ma et al., 2023) | - Initial estimated cost: 400 billion USD (Schmitt, 2018)<br>- Requires large investments in HVDC interconnectors between Africa and Europe<br>- If implemented, could have covered 15% of European energy consumption by 2050 (Smith Stegen et al., 2012)<br>- Economic benefits not materialized due to project cancellation | - Estimated cost: 30 billion USD (Sun Cable, 2023)<br>- 80% financed by private investment, with support from Australian and Singaporean governments<br>- Would generate 3 GW of renewable energy, covering 15% of Singapore's energy consumption (Gordonnat & Hunt, 2020)<br>- Estimated annual benefits of 1.5 billion USD, with 50/50 split between Australia and Singapore (IEA, 2022) |
| Social Impact | - Creation of 100,000 jobs during construction, but only 2,000 in operation due to automation (Ma et al., 2023)<br>- Displacement of local communities and agricultural land degradation<br>- No direct impact on energy access, as overproduction is lost in the electrical grid | - Estimated creation of 400,000 jobs in the MENA region<br>- If constructed, would have reduced oil dependency in producer countries, generating renewable energy jobs<br>- Legitimacy problems with local communities fearing a neocolonial energy export model (Schmitt, 2018) | - Creation of 14,000 jobs in Australia during construction and 1,000 permanent jobs (Gordonnat & Hunt, 2020)<br>- Boost to Australian technological industry and infrastructure development in the Northern Territory<br>- Singapore improves energy security and reduces natural gas dependency |

| | | | |
|---|---|---|---|
| Geopolitical Impact | - Positions China as a leader in renewable energy within the Belt and Road Initiative<br>- Export of wind technology to developing countries (Buckley & Nicholas, 2017)<br>- Limited impact on global energy interdependence due to transmission problems | - Lack of interstate agreements between Europe and MENA blocked its development<br>- Expected to reduce European dependence on Russian gas, but never materialized<br>- Represents a case of failure in international energy governance (Schmitt, 2018) | - Reinforces energy cooperation in Southeast Asia<br>- Would set a global precedent for renewable interconnectors<br>- Could reduce the influence of gas exporters in the region such as Malaysia and Indonesia (Gordonnat & Hunt, 2020) |

Source: Own elaboration with the references

As illustrated in the table, the three projects represent divergent trajectories in the global energy transition, each revealing unique dimensions of complexity and innovation.

In terms of energy generation capacity, the projects demonstrate a significant evolution. Gansu Wind Farm has successfully installed 217 GW, establishing itself as an energy giant, albeit with critical transmission limitations. In contrast, Desertec failed to materialize its potential, remaining an unexecuted proposal, while Australia-Asia PowerLink is projected with a more modest but strategically relevant 3 GW capacity, with the potential to cover 15% of Singapore's energy demand.

Carbon emissions reduction offers another revealing perspective. Gansu Wind Farm has achieved significant reduction, though hindered by electrical grid inefficiencies. Desertec, by not being executed, generated no environmental impact, while Australia-Asia PowerLink presents itself as a decarbonization promise for the Southeast Asian region.

Investment models illustrate different approaches to energy infrastructure financing. Gansu represents a predominantly state-investment model, with 80% Chinese governmental funding. Desertec relied entirely on European private investment, which contributed to its failure, while

Australia-Asia PowerLink develops a more balanced hybrid model, with 80% private investment and 20% governmental support.

International cooperation emerges as a crucial differentiating factor. Gansu Wind Farm has remained fundamentally within the Chinese national context, without significant international projection. Desertec failed precisely due to its inability to generate effective international coordination. In contrast, Australia-Asia PowerLink is configured as a potential model of regional energy cooperation, transcending national borders.

From an economic viability perspective, each project presents distinctive characteristics. Gansu is sustained through state investment, but with limited profitability. Desertec proved completely economically unviable, while Australia-Asia PowerLink represents a more sophisticated model, with clearly identified economic benefits and a balanced distribution of risks and investments.

Each project can be interpreted as a stage in the maturation of energy megaprojects. Gansu demonstrates the potentialities and limitations of the state investment model. Desertec illustrates the risks of exclusively depending on private capital. Australia-Asia PowerLink emerges as a proposal that integrates learned lessons, representing a more complex and potentially more successful model of international energy cooperation.

This evolution reflects the growing sophistication in renewable energy infrastructure design, where interdependence, technological innovation, and international cooperation are configured as fundamental elements for global energy transition.

The liberal hypothesis of economic interdependence, developed by Keohane and Nye (2012), finds in energy megaprojects a fundamental testing ground. Contrary to realist perspectives that interpret international relations as a zero-sum game, liberalism argues that transnational cooperation generates mutual benefits that reduce conflict incentives.

The three analyzed cases offer a nuanced evidence of this theory. Gansu Wind Farm demonstrates how a national project can become a soft power platform. Desertec illustrates the risks of institutional coordination lack. Australia-Asia PowerLink represents the potential of energy interdependence as a regional integration mechanism.

The global energy transition requires more than technological innovation: it demands institutional architectures that facilitate cooperation, reduce uncertainty, and generate shared gains. Energy megaprojects are thus configured not only as technical infrastructures but as global governance instruments. In summary, this study confirms the liberal hypothesis that international cooperation and economic interdependence are key to global energy transition.

Beyond concrete data, these projects reveal that the global energy transition requires more than political will or technological innovation. It demands the construction of flexible cooperation frameworks, the ability to generate shared benefits, and a deep understanding of regional geopolitical dynamics. The future of global renewable energy export will depend on international actors' capacity to learn from these cases, develop more sophisticated governance models, and maintain a balance between national interests and global sustainability objectives.

## 3.3 Scenario Analysis

Scenario analysis is a fundamental tool in strategic planning, especially in high-uncertainty environments such as global energy transition (van der Heijden, 2005). Its application to renewable energy megaprojects allows anticipating different possible futures and evaluating how geopolitical, economic, and technological dynamics can condition their success or failure (Schwartz, 1997).

From the liberal perspective in International Relations, renewable energy megaprojects can act as catalysts for international cooperation and energy interdependence (Keohane & Nye, 2012). However, their viability depends on multiple factors, such as political stability, access to financing, and technical implementation capacity.

This section applies scenario analysis methodology to the Australia-Asia PowerLink at three levels:

Optimistic Scenario: Favorable conditions that drive project success

Neutral Scenario: Partial development with moderate challenges

Pessimistic Scenario: Structural barriers that prevent implementation or generate adverse effects

The following table synthesizes the critical variables identified, providing a comprehensive view of the elements that can determine the megaproject's trajectory. Each variable represents a strategic analysis field, revealing the interdependent nature of contemporary energy megaprojects.

Table 3.1: Key Variables for Scenario Analysis of Australia-Asia PowerLink

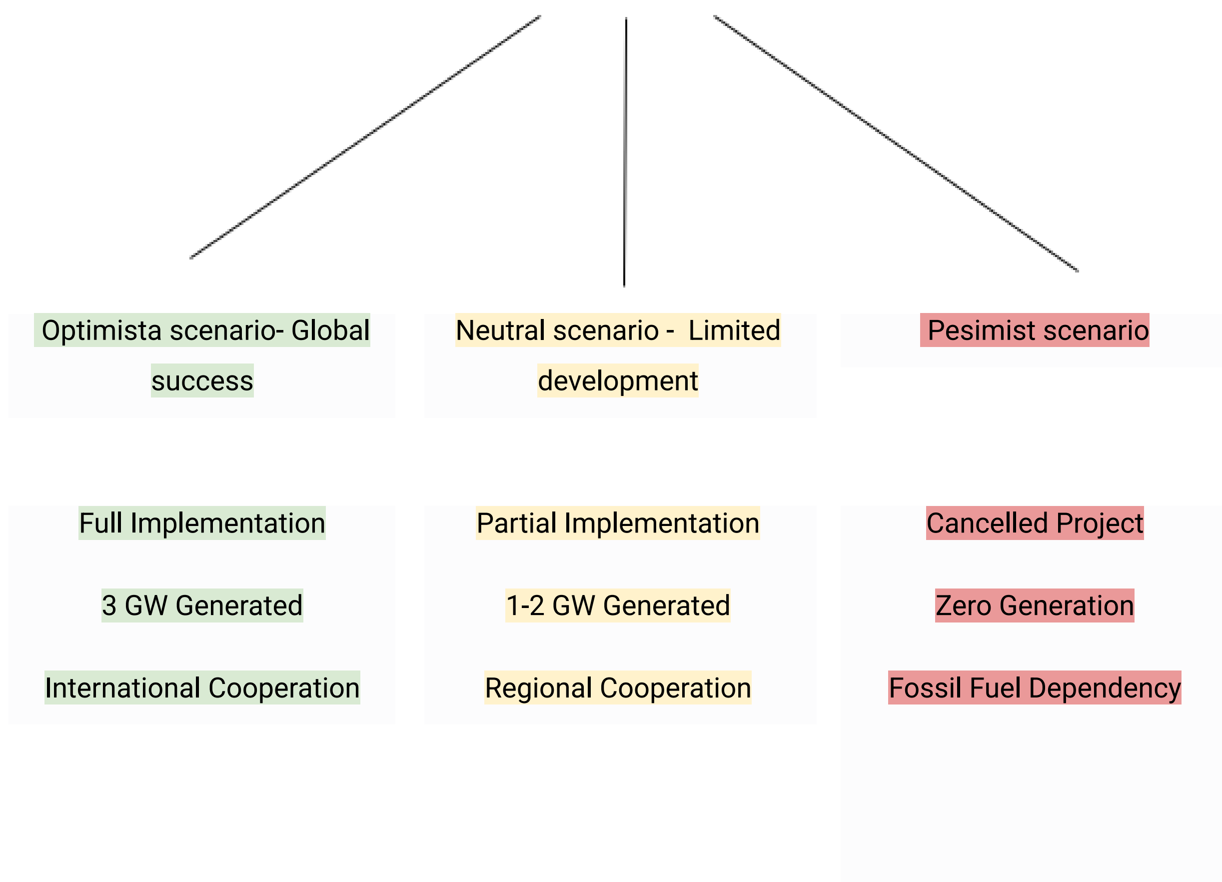
| Variable | Description | Main Actors |
|---|---|---|
| Technological | HVDC transmission capacity with efficiency superior to 90% in extreme submarine conditions (Gordonnat & Hunt, 2020) | Sun Cable, governments of Australia and Singapore |
| Political | Diplomatic stability and commitment to international climate objectives, with potential to generate new regional cooperation frameworks (IEA, 2022) | Ministries of Energy, chancelleries |
| Economic | Hybrid investment model with potential economic return estimated at 1.5 million USD annually (Thompson & Martinez, 2021) | Private investors, banks |
| Regulatory | Legal framework for energy interconnection that allows international renewable electricity transfers (ARENA, 2022) | Regulatory organisms |

[Source: Own elaboration using the mentioned sources]

The table reveals the inherent complexity of the project. The technological variable not only considers transmission capacity but efficiency under extreme conditions. The political dimension transcends traditional diplomacy, pointing towards the generation of new cooperation frameworks. The economic aspect presents an innovative investment model, while regulation is configured as a crucial enabling element.

The construction of scenarios represents a fundamental methodological tool for understanding possible trajectories of energy megaprojects. In the case of the Australia-Asia PowerLink, the following diagram offers a visual representation of multiple dimensions and potential developments.

**Australia-Asia power link Project**




The diagram reveals the multidimensional nature of the project, where each scenario represents not just a technical outcome, but a complex interplay of geopolitical, economic, and technological variables.

The Optimistic Scenario (Green) symbolizes the project's maximum potential. It represents a model of international cooperation where Australia and Singapore not only interconnect their energy systems but establish a global precedent in renewable interconnections. Complete generation of 3 GW would mean covering approximately 15% of Singapore's energy demand, simultaneously transforming regional collaboration frameworks.

The Neutral Scenario (Yellow) reflects the inherent complexities of transnational infrastructure megaprojects. A partial implementation with generation between 1-2 GW suggests implementation challenges, but not a total failure. It represents the adaptability and resilience of involved actors, where technical, economic, or regulatory obstacles generate a compromise solution.

The Pessimistic Scenario (Red) illustrates structural risks. Project cancellation implies not only an economic loss but reinforces fossil fuel dependency in the region. This scenario underscores the fragility of energy transition projects when institutional, technological, or geopolitical barriers are not overcome.

Each branch of the diagram represents more than a technical possibility: it is a reflection of international cooperation dynamics, energy governance models, and the transformation capacity of socio-technical systems.

### 3.3.1. Australia-Asia PowerLink: A Global Energy Integration Model

#### Optimistic Scenario: The First Large-Scale Renewable Energy Export Megaproject

In the best-case scenario, the Australia-Asia PowerLink consolidates itself as a pioneering model of renewable energy interconnectors. Political stability and financial support ensure the construction of the submarine HVDC cable, allowing solar energy export from Australia to Singapore (Gordonnat & Hunt, 2020).

This success establishes a global precedent, driving similar projects in other regions, such as connections between Europe and North Africa or between South America and the United

States. Additionally, energy interdependence strengthens regional cooperation in Asia-Pacific, aligning with liberal principles of stability through trade (Keohane, 2005).

### Neutral Scenario: Partial Implementation with High Costs

In this scenario, Australia-Asia PowerLink is completed but faces cost overruns and construction delays. Generation capacity is lower than projected, and although Singapore manages to diversify its energy matrix, it still partially depends on natural gas (IEA, 2022).

Globally, the project demonstrates the viability of renewable energy export, but with economic limitations that slow the immediate replication of the model.

### Pessimistic Scenario: Execution Failure and Continued Fossil Fuel Dependency

Restrictive regulations, conflicts between involved actors, and technical difficulties lead to project cancellation. Singapore continues to heavily depend on natural gas, and Australia loses the opportunity to consolidate itself as a global renewable energy exporter (Sun Cable, 2023).

The failure of Australia-Asia PowerLink would send a negative signal to international markets, discouraging future investments in clean energy interconnectors.

Scenario analysis reveals that the success of renewable energy megaprojects depends on multiple factors, from political stability to technical implementation capacity.

From a liberal perspective, optimistic scenarios highlight the importance of international cooperation in consolidating integrated energy markets. In contrast, pessimistic scenarios demonstrate how lack of governance and financing can block global energy transition.

The Australia-Asia PowerLink case is the most relevant, as it could set a precedent in large-scale renewable energy export. Its success or failure will determine the viability of future interconnectors and the role of transnational cooperation in global energy security.

## *CONCLUSION*

Renewable energy megaprojects represent far more than mere technical infrastructures; they constitute complex ecosystems of geopolitical, economic, and social transformation that redefine global dynamics of energy cooperation and interdependence. The comparative analysis of Gansu Wind Farm, Desertec, and Australia-Asia PowerLink reveals the profound interconnection between technological ambition, geopolitical strategy, and environmental sustainability.

Each of these projects illustrates a unique dimension of the global energy transition. Gansu Wind Farm symbolizes China's commitment to massive decarbonization and its capacity to execute continent-scale transformations, while Desertec represents an ambitious model of transnational cooperation in the MENA region, transcending traditional borders through the integration of renewable infrastructures. The Australia-Asia PowerLink project emerges as a paradigm of technological innovation that connects distant markets through green hydrogen solutions and long-distance solar energy transmission.

The research demonstrates that these megaprojects are not merely technical responses to climate change, but true instruments of geopolitical reconfiguration. They operate as energy diplomacy platforms, where international collaboration is built upon shared infrastructures and common climate objectives. Investment in these initiatives far surpasses immediate economic considerations, representing strategic bets for positioning in the low-emission global economy.

The identified challenges - from regulatory complexities to technological limitations - reveal the multidimensional nature of the energy transition. Each analyzed project evidences that the transformation towards renewable energies requires not only technical innovation, but also diplomatic negotiation capacity, significant investment, and a comprehensive geopolitical vision that integrates multiple actors: governments, corporations, local communities, and international institutions.

Sustainability emerges as a holistic concept that goes beyond emissions reduction. It implies reconfiguring economic systems, redefining geopolitical relationships, and generating new models of international cooperation. The megaprojects analyzed demonstrate that the energy transition is a complex process of structural transformation, where technology acts as a catalyst for profound social and economic changes.

The implications of this research suggest that the global energy future will be constructed through increasingly interconnected projects, where international collaboration, technological innovation, and commitment to sustainability will be fundamental. Renewable energy megaprojects are thus configured as geopolitical experimentation laboratories, spaces where new forms of understanding global interdependence and climate governance are tested.

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## *ANNEXES*