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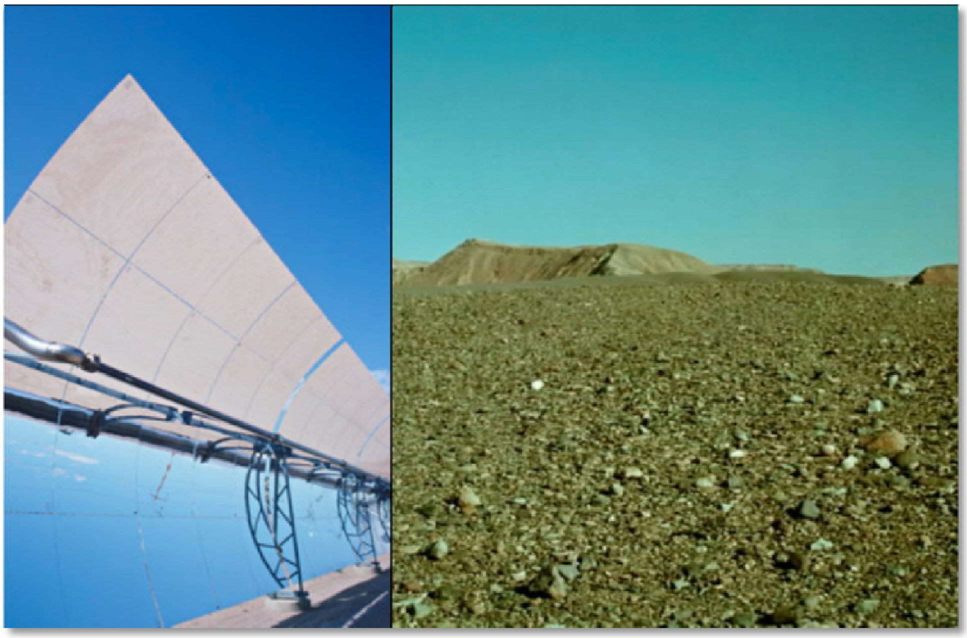

The Atacama Solar Platform:

Opportunities and Strategic Dilemmas for Building a "World-Class" Solar Cluster in Chile

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Cover:
The image on the cover shows a (left) parabolic trough of a concentrated solar power plant and an image of (right) the Atacama Desert.

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EXECUTIVE SUMMARY

The disastrous effects of climate change have progressively gained interest since the 1992 Earth Summit and the 1997 Kyoto Protocol. Since emissions from fossil fuel based power plants are a major contributor to anthropogenic green house gas emissions, an important means of mitigation is by replacing traditional power generation with new renewable alternatives. In fact, there are claims that there is a need to completely de-carbonize all global electricity generation by 2050 to prevent increased global temperatures that would have disastrous effects. This will demand a transformation on a scale that has no precedents, and will require the participation of all nations.

Solar energy has potential to be a very versatile source of energy as solar technologies present many exciting opportunities. Due to past energy crises and protests against nuclear, as well as the more recent pressures of climate change, national energy security and scarcities, solar energy technologies have emerged and gained social legitimacy. Despite their high comparative costs and current low contribution to the worlds electricity generation (< 0.1%), trends show substantial growth, and corresponding projections suggest that solar energy could provide as much as 25% of the global electricity production by 2050. Cost reductions will undoubtedly be critical for this diffusion.

Fundación Chile, a non-profit organization that fosters the creation of businesses and national economic growth in Chile by introducing innovations and developing human capital in key sectors, has recognized that the cost of solar energy technologies will soon become competitive and opportunities will emerge. As a result they, in partnership with other actors, have created the Atacama Solar Platform initiative, which aims to create a world-class solar cluster in the Atacama Desert. However, as Chile is a small emerging country and has a resource-based economy, this will be an enormous challenge.

Given this challenge, there is a need to communicate an appropriate direction for the materialization of a world-class cluster. But having simply a direction would be insufficient, therefore challenges that could emerge need to be identified such that

appropriate strategies could be developed. This has led to the following research questions:

- What could be a vision for building a “world-class” solar cluster in Chile?
- What are the main challenges of the materialization of this vision?
- What are the key elements of strategy for the materialization of the vision?

A vision for a world-class solar cluster in Chile was developed by considering what a world-class solar cluster implies for Chile, and both internal and external opportunities through trend analysis. Subsequently, three fundamental elements, which have been referred to as foundations, have been identified to build such a vision. They are as follows:

- Taking advantage of remarkable opportunities for countries like Chile in the context of an imminent process of global energy transformation;
- Using internal needs and challenges as drivers for building a sustainable energy system in Chile and developing knowledge and capabilities needed for a technological cluster;
- Building industries based on technology and knowledge production and exportation.

By reflecting on these foundations, a vision was created.

The corporate and institutional strategies of stakeholders within Chile are, however, not well aligned with these foundations. Although Chile has introduced a new energy policy that favors renewable energy, it is a policy that aims only to stimulate a market for renewables but takes a neutral position on specific technologies. As a result, only the most cost effective technologies are being diffused, and there is little incentive for entrepreneurs to explore more immature technologies, such as solar. To add to this, there is also a low awareness of the global trends regarding the imminent global energy transformation. Drivers are, rather, based on internal trends and to increase the competitiveness of the main Chilean industries.

Currently, Chile’s economy is highly dependent on the exportation of natural resources. The success of these industries has been highly influenced by the government’s neutral approach to public policy. This has arguably led Chile’s industries to focus primarily on cost reduction and increasing efficiency through technology adaptation, and neglect technology development. Despite signals that suggest an increasing awareness of technological innovation, Chile still has a considerably undeveloped innovation system.

Consequently, for Chile to pursue such a vision there is a need for considerable change in policy, business strategy and level of legitimacy of solar, all of which will present significant obstacles. The most important obstacles are related to: adopting strong innovation policy and moving away from the paradigm of neutrality in industrial policy, increasing Chile's confidence on industrialization goals, improving Chile's innovation infrastructure, reducing the risk averseness within the entrepreneurial sector, increasing the specialized human resources, overcoming core rigidities in key stakeholders, and articulating the opportunities of solar to increase its legitimacy. As a result, strategic dilemmas for the materialization of such a vision have been identified. Specifically, they relate to Chile's current neutral policies, stakeholders strategies based on catching up, mining companies' propensity to use coal and Fundación Chile's current business model.

Accordingly, elements of strategy have been proposed to address these obstacles and support policy-making and system building. The proposed elements of strategy focus on the need to reinforce a national innovation system in Chile and the general diffusion of innovation management, the need for the development of active learning systems, the need to measure the potential expansion of thermal applications in Chile, the need for increased legitimation of the solar industry and the corresponding coordination among actors. Finally, although Fundación Chile is a very successful organization, it will need to be conscious of core rigidities as they may inhibit their awareness of future opportunities related to solar.

As a final remark, for "next step" strategies for system building, there is a need for actor's in Chile to master current solar thermal technologies, accelerate the legitimacy process, and develop strategies for capturing external sources of funding for mitigation of climate change.

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1 CHAPTER 1: INTRODUCTION

1.1 BACKGROUND

The increasing concentration of carbon dioxide (CO_2) in the atmosphere, primarily due to of the consumption of fossil fuels, has been linked to an increase in the earth's average temperature. The increasing temperature has lead to global climate change and, consequently, increasing natural disasters and is threatening to cause unacceptable damage to humans and global ecosystems. In response to this threat, the United Nations (UN) agreed to the Kyoto Protocol in 1997, which sets targets for greenhouse gas (GHG) emissions reductions in industrialized nations. Since the Kyoto Protocol, the International Panel for Climate Change (IPCC) has presented evidence that suggests that there is a need to reduce 50 % of global GHG emissions by 2050, implying a reduction of 80 – 95% in Europe (IPCC, 2007).

Reducing emissions and satisfying the increasing global demand of energy requires a global participation in changing the way energy is supplied. As there is no single energy source or technology that will replace the current energy sources and meet the growing global energy demand several non-conventional renewable energy (NCRE) technologies need to be developed to industrial scales in a relatively short time. A change of this magnitude would disrupt the global economy and, therefore, represents an enormous challenge for technical change and industrial transformation.

In the case of Chile, a country with clear current and growing dependency on imported fossil fuels, the development of renewable energy seems to be an urgent matter. Given the high irradiation levels in the north of the country, to exploit solar energy appears to be an excellent opportunity. Fundación Chile, a reputable organization dedicated to value creation for the Chilean economy through technology transfer and innovation, recognizes this opportunity and has recently initiated the Atacama Solar Platform Initiative. This initiative has the intention to create a world-class solar cluster in the Atacama Desert.

Successful experiences of clustering in emerging economies exist and are well documented; however, there are only a few cases of such clusters that have achieved "world-class" status. An example in which Fundación Chile is very familiar is the salmon farming cluster in Chile. Similar to other cases, the formation of Chile's salmon farming cluster is based primarily on adaptation of mature technologies and using low cost as a competitive advantage. Adaptation and cost competitiveness are two main foundations of what is called the "catching up" strategy.

Chile's economy is primarily based on resource exports with minimal added value, where industries focus on marginal cost-reductions as a means of acquiring competitive advantage in global markets. Although Chile has been successful with the salmon cluster the creation of a world-class solar cluster represents a challenge that may be beyond the reach of simply using catching up strategies. Furthermore, solar technologies are very expensive in comparison with other technologies and are not yet mature. Their development seems to be a task that demands large resource deployment and high sophistication, something that represents a huge challenge even for stronger economies like Spain, Germany or US.

Therefore, to build such a cluster in Chile is an ambitious goal that seems to challenge the logic of past common experiences of industrialization in developing countries. As this objective has no precedents, Fundación Chile will need to determine an appropriate approach and corresponding strategies for its materialization.

1.2 PROBLEM IDENTIFICATION

For the materialization of a world-class cluster, and in order to determine a direction for policies and strategies for industrial change, there is a need for a vision. This requires a clear comprehension of a diverse scope of knowledge areas (especially technical change and industrial transformation) and adequate use of analytical frameworks, considering the analysis of similar past experiences, in order to achieve a good understanding of the actions that may be required. There is, therefore, a need for communicating through the vision an appropriate direction for the materialization of a world-class cluster.

Materializing a vision of a world-class solar cluster represents particular national challenges. Some industrialized countries like Germany, USA, or Spain are leading the development of solar technologies; however a vision of a solar cluster in Chile cannot be based entirely on experiences developed in those countries. There is a need to be aware that dynamics of industrialization in Chile may differ from other countries and this suggests unique challenges will appear.

At the same time, such a vision would need to be shared by many actors that will influence, or be influenced, by the vision. These actors would have different capabilities and different expectations of the future and, therefore, their contribution to the materialization is central. These challenges suggest the need of not only the development of an appropriate vision, but also the identification of main challenges for its materialization and, correspondingly, the development of appropriate elements of strategy.

1.3 PURPOSE AND RESEARCH QUESTIONS

Accordingly, the purpose of this thesis is to answer three specific questions:

- What could be a vision for building a "world-class" solar cluster in Chile?
- What are the main challenges of the materialization of this vision?
- What are the key elements of strategy for the materialization of the vision?

1.4 DISCLAIMER

In the present master thesis a "world-class" cluster is interpreted as a technological innovation system that embodies global leaders in the respective technology, and, as a result, the development of a capital goods industry. The vision presented in this document is the result of a creative process of the authors based on academic frameworks related to technical change and industrial transformation. It does not necessarily represent Fundación Chile's beliefs, but is delivered with the intention of being considered as a reference and support. Furthermore, the analysis during the whole document is based more on fundamentals, or foundations, rather than the details of the presented vision.

1.5 STRUCTURE

The structure of this document is as follows. In the next section (Chapter 2) we outline the analytical framework and methodology used to address the three research questions. Chapter 3 will provide a brief introduction of clustering and innovation in catching up countries, including evidence from Chile. Chapter 4 will present an overview of the solar industry. Chapter 5 will introduce the authors' proposed vision for Atacama (vision 2040), and the process in which it was developed. The vision has been based on three "foundations". Chapter 6 will identify the challenges of materializing this vision by analyzing the stakeholders' capacity of materialization and the perceived obstacles for conducting necessary changes in their strategies. Chapter 7 will present recommended elements of strategy to enable the materialization of a "world-class" solar cluster in Atacama. Finally, Chapter 8 contains the conclusions.

2 CHAPTER 2: ANALYTICAL FRAMEWORK AND METHODOLOGY

As it is shown in the introduction, the present master thesis has as a purpose the elaboration of a vision for an industrial cluster and the identification of challenges and elements of strategy to address these challenges. Given these goals, the technological innovation system (TIS) framework has been identified as the most appropriate analytical tool, as it provides flexibility for a rigorous assessment of industrial evolution and technological change (Carlsson, 2006). In this section, we outline this framework with special emphasis on its application on a formative phase of a developing system. This section also gives an overview of how the research questions were resolved and a description of the methods used.

2.1 TECHNOLOGICAL INNOVATION SYSTEM FRAMEWORK AND THE FORMATIVE PHASE

The technological innovation system (TIS) is a socio-technical system focused on the development, diffusion and use of a particular technology. The technology may be defined in terms of knowledge, products or both (Bergek et al, 2008a). A TIS is composed of structural components which are: *actors* like firms, universities, professional groups, and other organizations of interest; *networks*, that can be learning networks (users – suppliers, related firms, universities – industries) or those that seek to influence the political agenda (coalitions); and third, *institutions*, legal and regulatory aspects, norms and culture (Jacobsson and Bergek, 2006).[1]

There have been many approaches for measuring the "performance" of a TIS in order to design policies and strategies for improving it.[2] The functional approach presented by Bergek et al (2008a) is a synthesis of previous approaches and has been used as an effective tool to analyze the performance and dynamics of the system. In this

[1] Technology, in the form of artifacts or knowledge, can be considered as a fourth component (Bergek et al, 2008).
[2] This analytical framework has gained importance for innovation policy development in many countries, and will be used as a central framework for this master thesis.

approach the identification of structural components and key processes, or functions,[3] is central. These functions, which are critical to the development of a TIS, can be hindered by blocking mechanisms, affecting the development, diffusion and use of new technologies.

At the same time, Bergek et al (2008a) suggest that an effective analysis of a TIS must distinguish the development phase of the system (formative, growth or mature). Despite the increasing literature related to the study of TIS, it is recognized that the formative phase is not yet well understood (Bergek et al, 2008b) and the respective analysis of the system represents particular challenges due to high uncertainty in terms of technology and markets (legitimacy). Jacobsson and Bergek (2006) suggest that the formation of a new TIS involves the structural processes of the entry of actors, the formation of networks and institutional alignment (market formation and legitimacy). Key issues for these processes are the formation of "prime movers", and the alignment of actors' expectations through networks (entrepreneurial experimentation). Additionally, Carlsson et al (2002), claim that in this phase it is important to keep particular focus on knowledge formation, and the use and diffusion of that knowledge. From these arguments, it is possible to say that, in the case of the study of the early phase of a TIS, key functions or processes are related to legitimacy, market formation, entrepreneurial experimentation and knowledge formation.

One of the recent contributions in the study of formative phase is the construction of a typology of forms of cumulative causation, between the functions of a system, which aim to explain the dynamics of formation of TIS (Suurs, 2009). Suurs calls these forms "motors of sustainable innovation".[4] One of them is of interest for this document: the "system builder" motor. In this dynamic of formation, entrepreneurs organize themselves in networks and draw in new actors, including local government, intermediaries, and interest groups. From this basis, they lobby the government for

[3] These functions are: Knowledge development, influence on direction of search, entrepreneurial experimentation, market formation, legitimation, resource mobilization, development of positive externalities.

[4] Suurs (2009) based on for case studies on the formation of renewable energy innovation systems, detect four motors of sustainable innovation: the science and technology push motor, the entrepreneurial motor, the system building motor and the market motor. They may be linked sequentially in a process of achieving sustainable innovation.

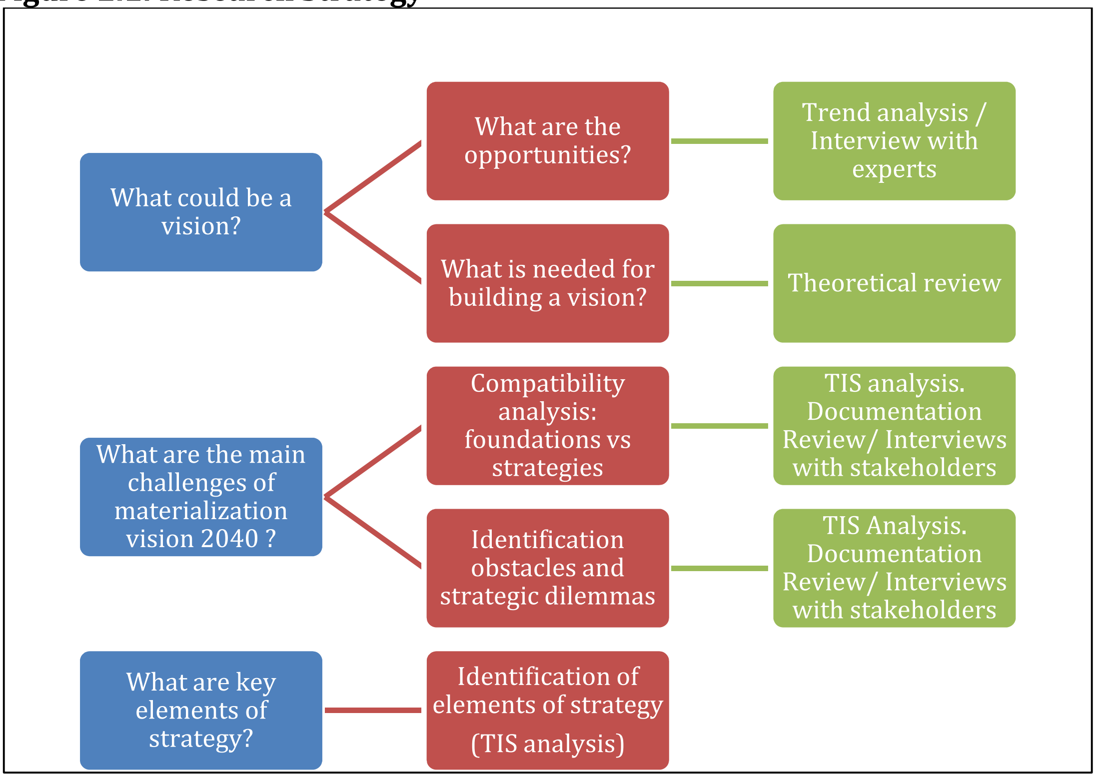
policies to mobilize resources, develop regulations and create mass markets. This motor may be stimulated by coordination and advocacy (Suurs, 2009).

In concordance with this, Bergek et al (2008b) suggest that legitimation is a key process in this phase. Legitimacy is a prerequisite for the formation of new industries and new TIS. In the earliest stage, legitimation involves getting the technology accepted as a desirable and realistic alternative to incumbent substitutes, becoming the "politics of shaping expectations". This can be done initially through technology assessments and rational arguments[5].

2.2 RESEARCH STRATEGY AND RESEARCH DESIGN

As it is presented in Figure 2.1 the research strategy aims to answer in a structured way the research questions of this study. For each question, the different research methods and analytical tools employed are described and discussed in this section.

Figure 2.1: Research Strategy



[5] Such assessments and arguments may also increase uncertainty, since actors (in coalitions) can use them to legitimize or delegitimize a technology in order to serve their own "political" goals.

2.2.1 WHAT COULD BE A VISION FOR BUILDING A "WORLD-CLASS" SOLAR CLUSTER IN CHILE?

In order to answer this question, two sub-questions were considered: (1) What are the opportunities for developing a "world-class" solar cluster in Chile? (2) What does it mean to be a "world-class" solar cluster? In the case of sub-question (1) opportunities for the materialization of a world-class cluster have been identified based on a trend analysis of the global and internal context. Sub-question (2) was answered by doing a reflection based on literature of technical change and industrial transformation.

The trend analysis is an important step of the "scenario analysis" method, which is a tool used for the development of business strategies (Magnusson, 2010) (See Box 2.1 for an overview of the method, and Appendix 3 for a detailed description of its use in this document). The trend analysis has been based on reports, government databases, official websites, web-based news articles, and academic articles. This information has been triangulated with semi-structured interviews with experts in specific knowledge areas (See Appendix 1).

Box 2.1: Scenario Analysis Method

Among other purposes, this method aims to put central strategic questions and uncertainties in perspective and generate creative pictures of the future that challenge existing perceived future models. It is used according the following steps:

Step 1: Identify the focus of the analysis, which needs to be relevant, challenging and suitable in time horizon.

Step 2: Identify historical events (globally and internally), which have important impact on the focal issue and identify the surrounding factors (current and future changes and events) that are important to the focal issue.

Step 3: Rate each factor according to the level of importance to the focal issue and its degree of uncertainty.

Step 4: Identify critical trends (factors of high importance and low uncertainty) and identify critical uncertainties (factors of high importance and high uncertainty)

Step 5: Identify opportunities from critical trends through the development of "trees" of consequences.

Step 6: Create scenarios based on critical uncertainties (Out of scope of this document)

Step 7: Develop strategies based on opportunities and scenarios. (Out of scope of this document)

The answer to the first research question is addressed in the form of *three main foundations* (see Section 2.2.2), in that a vision should be based on them. At the end of this section, a vision called "vision 2040" is described. This vision has been developed through a creative exercise based on the previous analysis.

2.2.2 WHAT ARE THE CHALLENGES OF MATERIALIZING THE VISION 2040?

This question has been answered in two stages: (1) an analysis of the stakeholders' capacity for materializing such a vision, (2) and the identification of strategic dilemmas and obstacles that prevent changes that aim to increase stakeholders' materialization capacity.

In order to develop stage (1), we evaluated the "compatibility" between corporate (or institutional[6]) strategies of stakeholders and the foundations of the vision 2040. As is shown in Section 5.3, the vision 2040 has been elaborated based on the following foundations:

- **Taking advantage of remarkable opportunities for countries like Chile in the context of an imminent process of global energy transformation;**
- **Using internal needs and challenges as drivers for building a sustainable energy system in Chile and developing knowledge and capabilities needed for a technological cluster;**
- **Building industries based on technology and knowledge production and exportation.**

This "compatibility" analysis is basically a comparison of these foundations with corporate (or institutional) strategies of stakeholders. These strategies were explored regarding three main "compatibility criteria":

a) Importance of non-conventional renewable energy (NCRE) in corporate strategies: aim to identify the compatibility with the first foundation.
b) Importance of global and internal trends of interest: aim to identify compatibility with the first and second foundations.
c) Importance of technological innovation in corporate (institutional) strategies: aim to identify the compatibility with the third foundation.

The more important these criteria are in corporate (or institutional) strategies of stakeholders, the more "compatible" are their strategies with the foundations of a vision, such as the vision 2040, and therefore, the greater their "capacity of

[6] In this report, institutional strategies are those that are developed in public institutions related mainly to regulatory framework and education.

materialization". [7] Each compatibility criterion considers key indicators presented in Appendix 2.

Regarding stage (2), main strategic dilemmas and obstacles that would prevent stakeholders from implementing changes that aim to increase their capacity of materialization, were identified. This was possible through the "compatibility" analysis previously described, and by considering the analytical framework of Technological Innovation Systems.

Both stages were accomplished by gathering information from reports, government databases, official websites, web-based news articles, and academic articles. This information has been triangulated with semi-structured interviews with representatives of main stakeholders.

2.2.3 WHAT ARE KEY ELEMENTS OF STRATEGY FOR CHILE, MAIN STAKEHOLDERS AND FUNDACION CHILE?

This question has been answered by considering the results of previous questions related to the capacity of stakeholders for materializing the suggested vision. In this way, proposed elements of strategy would aim to overcome obstacles that would eventually prevent stakeholders from increasing their capacity for materializing the vision, or, in other words, the capacity of the TIS to be formed. Elements of strategy have been elaborated using the approach of Technological Innovation System Analysis as an analytical framework; such that the mentioned capacity for materializing the vision is associated to the strength of the functions that are analyzed by the TIS analytical framework. Overcoming obstacles would mean strengthening the functions in order to generate better conditions for the materialization of the cluster. In other words, increasing the capacity of materialization.

2.3 VALIDITY AND RELIABILITY

This study aims to generate specific solutions to a singular problem by having a deep understanding of the factors of influence. Therefore, a sense of reproducibility

[7] On the contrary, low compatibility means a low capacity, which can be translated as a negative environment for the materialization of the vision 2040.

(associated to external and environmental validity) in other contexts or countries is not a final goal. Rather, constructive and internal validity become sensitive elements due to the need for analyzing complex information obtained from different perspectives and sources in an uncertain environment.

For RQ1: What could be a vision for building a “world-class” solar cluster in Chile? Possible risks of low constructive validity can be associated with the criteria that the authors have used for the identification of opportunities based on trend analysis. In this way, constructive validity has been reinforced by triangulation between the written sources of information and semi structured interviews held with some experts.

For RQ2: What are the main challenges of materializing the vision 2040? Risks of low validity can be associated to the use of “compatibility criteria” in the analysis of capacity of materialization of the vision 2040, especially when the importance of innovation was explored in corporate strategies. In order to reinforce internal validity, main indicators of innovation capacity used in previous studies are considered (Yam et al, 2004 or Wang et al, 2008). In the case of exploration of NCRE and global trends in corporate strategies, adequate indicators were designed. All these indicators are presented in Appendix 2. Additionally, constructive validity has been reinforced by triangulation between information obtained in official documents and interviews held with selected persons.

Constructive validity has depended also from a correct identification of the stakeholders of the future solar cluster as representatives of different sectors: government, industry, academia and social. As it is shown in Appendix 1, a comprehensive list of relevant stakeholders has been developed based on the experience of representatives at Fundación Chile. From this list, nineteen representatives of main stakeholders were selected (by importance and availability) for being interviewed. The selection criteria considered two main requirements: persons who are decision makers in their organizations, and who have accomplished these functions for a certain time. (This aimed to avoid interviews with people that are new in their positions). It is important to mention that the arrangement of these interviews would have not been possible without the coordination of Fundación Chile.

As presented in Appendix 1, those that were interviewed included representatives from the two largest mining companies, the largest electricity generation company in Chile and an important desalination engineering company; representatives from three industrial associations (mining, solar, fruit); four representatives of Chile's government ministries: Ministry of Energy, Ministry of Science & Technology and the Region of Atacama. Two academic experts, from the University of Chile specializing in economics and innovation in Latin America, were interviewed, as well as researchers exploring materials for PV technology at the University of Atacama. For these interviews, reliability was ensured with a correct treatment of the information obtained. All the interviews were transcribed and analyzed carefully.

3 CHAPTER 3: CLUSTERING AND INNOVATION IN CATCHING UP COUNTRIES

The traditional view in which economic growth was explained changed with the contribution of Schumpeter's work during the fifties. These contributions along with posterior empirical studies concluded that "technological advance was the key driving force behind economic growth" and "innovative performance at the organization and industry level" are central elements (Nelson and Winter, 2002). The way this growth is created depends on a micro phenomena produced by "industrial dynamics" or the interaction of a variety of new ideas, actors – who create / use technologies – and demanding customers; these systems are able to generate positive externalities

The idea of interaction among actors in the process of industrial dynamics and the need of a vigorous competition for fostering growth are compatible with the cluster phenomena described by Porter (1998). According to Porter, clusters are geographic concentrations (critical masses) of interconnected companies and institutions in a particular field. These conglomerates, compared to markets with dispersed buyers and sellers, are able to foster competitive advantages through intense competition *and* coordination.

Porter (1998) adds that the formation of a cluster involves brand-name, technology development and export, knowledge development, specialization, human capital formation, complete value chains, and the development of supporting institutions. The formation of these elements can be based on historical circumstances (like clusters in Massachusetts initiated because of MIT and Harvard research), unusual and stringent local demand (like the irrigational cluster in Israel) or the interaction of related industries. Once a cluster is formed, it is expected to experience a self-reinforcing cycle that promotes growth. This development is often particularly vibrant at the intersection of clusters, where insights, skills and technologies from various fields merge, sparking innovation and new businesses.

3.1 INNOVATION DYNAMICS IN CATCHING UP COUNTRIES

The term catching up, related to the economic term convergence, stresses the potential of developing countries to grow faster than developed countries due to some rationalities, where technology adaptation has been essential.[8] In this way, the ability of appropriating what others had innovated became the essence of the "latecomer´s advantage" (Chandra, 2006). However, it has been recognized that this ability depends strongly on the organizations' absorptive capacity or "the ability to recognize the value of new, external information, assimilate it and apply it to commercial ends" (UNIDO, 2005, p. 10). This ability does not emerge spontaneously but rather as a complex process of capabilities building.

Accordingly, scholars argue that the concept of innovation needs to be interpreted differently in countries that are in a process of industrialization or catching up. It is suggested that in these countries, the dynamics of technical change is driven more by learning and incremental innovation rather than by pure technological innovation as is the case of more industrialized economies. Countries like Taiwan or Korea have been able to develop active learning systems that had led these countries to move ahead in the path of innovation[9] (Viotti, 2001; Mathews, 2006). This learning process, according to Chandra (2006), takes place through several mechanisms like foreign direct investment (FDI), licensing, contracting, and purchases of technology or know-how.

Active learning and successful industrialization in catching up countries depend strongly on governmental action, implemented in different ways. Chandra (2006) presents a study of 10 successful cases of industrialization in latecomer countries, stressing the role of the government to encourage specific non-traditional export industries to adapt new technologies using a blend of general and industry-specific policies. This should incorporate not only traditional industrial policy but a range of activities including science and technology policy, tax policies standardization

[8] In fact Chandra (2006) claims that latecomers that matured into industrialized developing countries mastered, in a period of one or two decades, innovations that had evolved for more than a century in the west and that required sizeable costs in human and financial resources.

[9] In the discussion presented in following chapters, the formation of active learning systems will be understood as processes of "mastering catching-up"

measures, market formation, procurement policies and so on. The TIS analysis, previously mentioned, is a strong tool for policy making, and has been used for analysis of catching up countries (Jacobsson and Bergek, 2006).

3.2 CLUSTERING AND INNOVATION IN CATCHING UP COUNTRIES – EVIDENCE FROM CHILE

Unfortunately, most of the evidence on the economic impact of agglomeration or clustering has been drawn from advanced industrialized countries. This means that there is a reasonably clear view of the impact of industrial clustering on manufacturing performance in more advanced economies. However, it is possible to identify relevant cases of clustering in developing countries (Chandra, 2006; UNIDO, 2009, p. 29).

One of the most documented cases of successful clustering in catching up countries is the cluster of salmon farming in Chile. This process was initiated over 30 years ago, and according to Katz (2006) its evolution corresponds to three important phases. The first remarks several governmental interventions that pursued the development of a new industry. These interventions were diverse, such as opportunity exploration projects, introduction of first farms and collaboration with Japanese companies (Perez-Aleman, 2005). This allowed the entrance of many local and foreign firms.

In a second stage of development, the industry rapidly increased in size and complexity. The role of the state changed from being a dynamic agent inducing the inception of a new activity, to concentrating on developing a regulatory framework. In a final stage, this development experienced a major transformation in industrial structure, which came about through mergers and acquisitions, foreign direct investment (FDI) and a rapid process of industrialization. This led the industry to acquire a world-class status as one of the world's three main salmon farming countries, together with Norway and Scotland.

In this story of success, the key contribution of Fundación Chile has been acknowledged. During the 1980's, Fundación Chile invested capital to create a firm that could transfer foreign technology and develop local know-how. At the same time, Fundación Chile adapted and disseminated best practices in fishing culture and processing contributing to the quick development of the industry (UNIDO, 2009, p. 33) and allowing the entrance of new local and foreign companies, with the respective development of institutions and skills (Katz, 2006). This has not been the only case in which Fundación Chile has had the role of protagonist in industrial development in Chile. In this way, it is of interest of this study to identify some key facts of this organization.

3.3 ABOUT FUNDACION CHILE

Fundación Chile is a privately owned non-profit organization established in 1976 with the intention of fostering the creation of businesses and economic growth in Chile by introducing innovations and developing human capital in key sectors like agro industry, marine resources, forestry, environment, energy and chemical metrology. In order to transfer technologies, Fundación Chile applies traditional methods, like diffusion, training, technical consulting and its own business model innovation: the creation of demonstration companies (Cordua, 1994). Since its inception, Fundación Chile has created 76 companies that have contributed more than US$ 2 billion in turnover to Chile's economy since its creation (Fundación Chile, 2010).

Fundación Chile´s business model consist of three main phases. The first identifies an opportunity to add value through innovation. The process begins with an exploration and evaluation of market needs of innovation that could involve changes in the products, services, productive processes and modifications in the business models. The second phase involves obtaining the technologies. Fundación Chile uses three procedures for this stage: transfer and adapt a technology furnished by an outside supplier; develop it using a Fundación R&D process; or generate it through the work of a network of key R&D organizations. The third phase is the scale-up of the technology and its dissemination. Dissemination occurs through: sale and licensing of technologies, supply of technological services, certification and implementation of standards, training, seminars, publications, and especially through creation of innovative companies, always with strategic partners.

According to this model, provision of seed/risk capital as public subsidy is important especially in the initial phase of innovative projects. This is because investments that involve some degree of innovation can rarely count on financing sources due to the high risk and evaluation difficulties. In order to fund innovative ideas, Fundación Chile works in collaboration with private and public sources of funding.

4 CHAPTER 4: OVERVIEW OF SOLAR INDUSTRY

Solar energy is the renewable energy par excellence. The earth receives more energy from the sun in just one hour than the world uses in a whole year. Its simplest form is the use of solar heat from collectors, mostly for water heating, but there is strong interest for electricity production. Efficiency and costs are key factors in its development, which are highly dependent on the solar radiation indexes. In Germany this index is 1000 – 1500 kWh/m^2, Spain 1300 – 2000 kWh/m^2, USA 1300 – 2500 kWh/m^2 (NREL, 2010) and 1800 – 2500 kWh/m^2 in the Atacama Desert (CNE et al., 2008).

For this study, it is interesting to consider only direct and indirect electricity generation and heating applications. The most immediate and technologically attractive electricity generation is certainly photovoltaic (PV) conversion. For this technology, various materials are used to act as the solar photovoltaic cell (silicon based cells or a thin layer of photovoltaic material sprayed on a substrate) to convert sunlight directly to electricity. As PV technologies convert sunlight directly to electricity, generation is limited to daylight periods. Furthermore, since the electricity generation is dependent on the intensity of the sunlight, PV can present problems to grids where the peak sunlight does not match the peak electricity demand periods.

Solar thermal technologies generally use a collector to heat a working fluid. They can be divided into two main groups: low-temperature and high-temperature technologies. Low-temperature solar thermal technologies are commonly used for commercial and residential water and space heating. They can further be categorized by being active or passive systems. The most common collector technologies are based on flat plate technologies or evacuated tube technologies. Each of these system combinations has their benefits and drawbacks.

High-temperature working fluids can be achieved by concentrating solar energy with mirrors or lenses. Applications include industrial process steam, steam for a steam cycle power plant, auxiliary steam for an integrated solar combined cycle system (natural gas hybrid), water desalination, and for driving heat engines. Concentrated Solar Thermal or Power (CST or CSP) technologies use reflectors to focus sunlight onto receivers that collect sun's radiation.[10] In contrast to PV, solar thermal power generation is more efficient and cost effective. Furthermore, CSP plants can use thermal storage to extend the daily dispatch period and moderate the hourly generation. The development of the technology is, however less mature (Kohl, 2008). Furthermore, this technology is efficient only in locations with direct and high continuous radiation, and extremely flat terrain, which limits its practical use to a few global regions (Price, 2010). Although CSP plants can use dry cooling for the steam cycle, it is much less efficient and more costly than water-cooled systems.

Although solar technologies present many benefits and have minimal environmental impact, they are currently much more expensive than other renewables, with PV having the highest investment costs for renewable electricity (as compared to small hydro, wind, biomass) (IEA, 2008). This is mainly due to the dispersion of solar energy, which, consequently, makes collection very land and material demanding. Furthermore, many of the solar technologies are still experimental or immature and need further research and development in order to become commercially viable solutions (Floyd Associates, 2010). Consequently, solar currently accounts for less than 0.1% of the world electricity generation (MAC Solar Energy Index, 2010).

Recently, the unprecedented increase for the need of CO_2 neutral energy, which allows for the reduction of emissions and the promotion of energy security, is a primary driver for the diffusion of solar technologies (MAC Solar Energy Index, 2010). Federal policies and incentives play an important role in the commercialization and adoption of solar technologies. They have enabled rapid expansion of solar markets in countries such as Germany, Spain, and Japan. Spain has been pursuing solar development aggressively but the industry has stagnated economically the last years. Legislation enacted in the United States in 2008 and early 2009, however, provides unprecedented levels of federal support for U.S. renewable energy projects, including solar energy projects (Price, 2010).

In 2008, global private-sector investment in solar energy technology topped at $16 billion, including almost $4 billion invested in the United States. From 2004 to 2008,

[10] The most developed systems are: Dish/Engine Systems, Linear Concentrator Systems (parabolic trough collectors and linear Fresnel reflectors) and Power Tower Systems.

global private sector investment increased more than 25-fold (Price, 2010). As of 2008, technologies were mainly being developed in strong technology development countries with large internal markets, like China, Japan, Germany, USA, Spain and Taiwan (REN21, 2009).

PV has expanded from niche applications for aerospace in the early 60´s and an expansion after the 1973 oil crisis. It has been growing with increased environmental awareness since the 70´s to a more recent large development pushed by Japan and Germany in the 90´s (Jacobsson et al, 2004). In 2008, the grid–connected PV market grew by 70%, reaching 13 GW of capacity (REN21, 2009). The PV market shares for the top regions/countries were 31% for Europe, 22% for Japan, 19% for China, 11% for Taiwan[11], 7% for the United States, and 9% for the rest of the world.

The use of low-temperature solar thermal technology saw initial growth in Israel in 1950's because of a national water heating policy (Bacher, 2000). Since then, several countries have adopted policies supporting solar water heating systems, which has enabled wide diffusion (REN21, 2009).[12] The world increased its solar heating by 19 GWh in 2008, reaching 145 GWh, with China accounting for over 66%.

The emergence of large scale CSP was initiated in the USA by the 1973 oil crisis (Mills, 2004). Despite the subsequent drop in oil prices, CSP development continued, primarily due to the Chernobyl incident. More recently, the market has seen an exceptional expansion because of growing legitimacy of renewable energy and government initiatives (REN21, 2009).

Despite the global expansion of solar energy, solar is comparatively small to other renewables, like wind and small hydro (REN21, 2009).[13] However, large developments of solar technologies are expected in the future. Global trends of solar electricity capacity and cost reduction will be presented in Section 5.1.1.

[11] It is interesting to note that China and Taiwan present a recent exceptional development. This is basically because of their capabilities in the semiconductor industry.
[12] In 2008, the world increased its solar heating by 19 GWh reaching 145 GWh (REN21, 2009).
[13] As of 2008, the global capacities of wind and small hydro were 121 GW and 85 GW, respectively.

5 CHAPTER 5: WHAT COULD BE A VISION FOR BUILDING A "WORLD-CLASS" SOLAR CLUSTER?

To answer the first research question the authors perceived the need to consider two primary questions. First, what are the opportunities for developing a "world-class" cluster in Chile? Second, what is needed for building a "world-class" solar cluster? By developing answers for these questions the authors have been able to establish key foundations, or fundamental elements, upon which a vision for a world-class solar cluster can be elaborated. From these foundations the authors have created their interpretation of an appropriate vision, which is presented at the end of this chapter.

5.1 WHAT ARE THE OPPORTUNITIES FOR DEVELOPING SOLAR IN CHILE?

This section aims to identify what are the opportunities of developing solar in Chile. In order to identify them, both internal and global trends must be tracked. This has been done using trend analysis, a key step of the method of scenario analysis (see Appendix 3). In the following text, we present: first, main global trends and respective opportunities; second, main internal trends with respective opportunities; and third, a short conclusion.

5.1.1 TRENDS AND OPPORTUNITIES IN THE GLOBAL CONTEXT

As has been presented in the Section 1.1, the Atacama Initiative is heavily driven by the energy needs and challenges in Chile, and the opportunity of exploiting intense sun irradiation. The use of Fundación Chile's experience is a logical approach for the formative phase of such a cluster, where technologies and knowledge from abroad can be diffused into Chile and technological learning can take place. However, for the solar cluster to emerge to a world-class status, it is also needed to take into account trends and uncertainties in the imminent global energy matrix transformation (Stern, 2006) and the subsequent opportunities. To mitigate the effects of climate change, there is a need for an energy transformation on a scale that has no precedents, where power markets will need to transform from being dominated by fossil fuels to being dominated by renewable energy by 2050 (refer to Box 5.1).

Box 5.1: "The imminent process of global energy transformation"

What is the imminent process of global energy transformation?

The expected effects of climate change have been heavily studied, with scenarios forecasting global temperature rise greater than 2°C above pre-industrial levels if atmospheric CO2 concentrations rise above as little as 350 ppm (Solomon et al, 2007). The risk of such a rise in temperature could lead to "dangerous anthropogenic interference with the climate system" [UNFCCC, 1992]. The primary sources of anthropogenic greenhouse gas (GHG) emissions are produced by the combustion of fossil fuels for power generation, namely coal (IEA 2009), and as the demand for electricity is ever increasing, alternatives to such dirty fuels is needed. IPCC (International Panel for Climate Change) and experts (Copenhagen declaration, March 2009; Metz et al, 2007) have presented evidence that suggests that there is a need to reduce total CO_2 emissions in Europe by 80 – 95%, and 50% globally, and zero carbon emissions for electricity production.

What are our options?

Although there are several options that are being considered as alternatives to coal and fossil fuel based power generation, emphasis should be put on renewable energies. Besides the adoption of carbon capture and storage technology, which is often considered to be merely a transitional solution, or end-of-pipe, Verbruggen and Lauber (2009) suggest there are two options to address this "technological revolution": nuclear fission and renewable power. Although nuclear is carbon-free, it is widely contested whether the technology is sustainable as it presents other risks (Metz et al. 2007; Beck, 1992). Therefore, as Verbruggen and Lauber (2009, p. 5733) state, "for a safe climate and energy future the electricity efficiency and sustainable renewable electricity technological cluster is the only promising one."

Geels et al. (2008) suggest three reasons why this transformation will be "massive". First, the current global electricity generation is large, exceeding 19,700 TWh[14] (IEA, 2009), and is expected to grow to between much as 25,000–35,000 TWh by 2050 (European Commission, 2007). For renewables to cover the demands mentioned above, the necessary expansion could be as much as 13,500 TWh. Second, based on others findings, Geels et al. (2008) suggest the time scale for such a disruptive technological transformation will be multiple decades. Thirdly, the adoption of 'green' innovation faces many obstacles:

- Renewable Energy technologies are initially more expensive than the incumbent technologies and have lower performance.
- There are considerable uncertainties of future conditions, which discourage firms from investing in renewable energy technologies.
- Due to the effect of carbon lock-in, as proposed by Unruh (2002), renewable energy innovations do not compete on equal terms with current mature technologies.

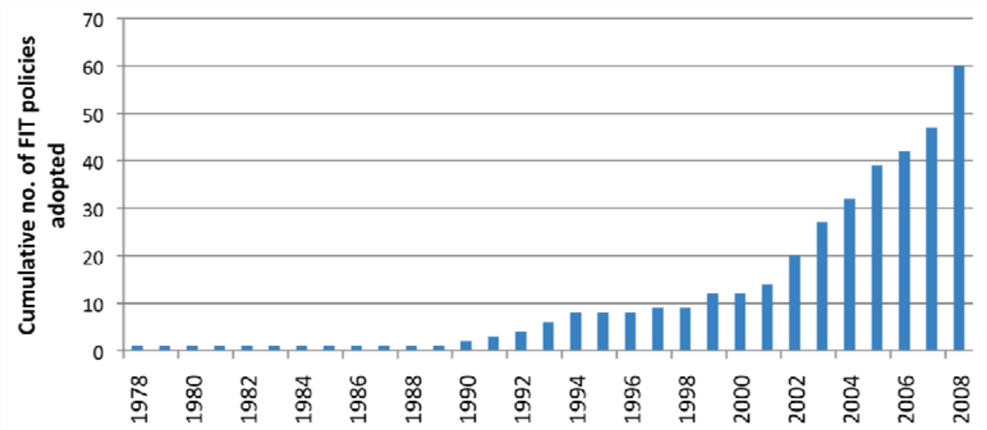
Answering the question "what are the opportunities for developing a world-class solar cluster" implies exploring the opportunities that may develop from this "imminent global energy matrix transformation." To identify the most relevant opportunities, the scenario analysis method has been applied. Accordingly two critical trends and two critical uncertainties have been selected, based on their importance relative to others. They will be presented followed by respective opportunities and possible threats.

[14] Renewables, including large hydro projects, make up less than 18.2%, or 3600 TWh in 2007 and have a capacity of 1140 GW (IEA, 2009).

5.1.1.1 Global Trend 1: Expansion of the market for renewables, including solar

According to the scenario analysis method (refer to Box 1.1), there is a strong trend towards a growth of the solar industry. This can be explained by the exponential growth of the number of countries that have adopted selective policy mechanisms, like feed in tariffs, which supports less cost-effective technologies like solar (see Figure 5.1).

Figure 5.1: Cumulative Number of Countries/States/Provinces Enacting Feed-in Tariff Policies

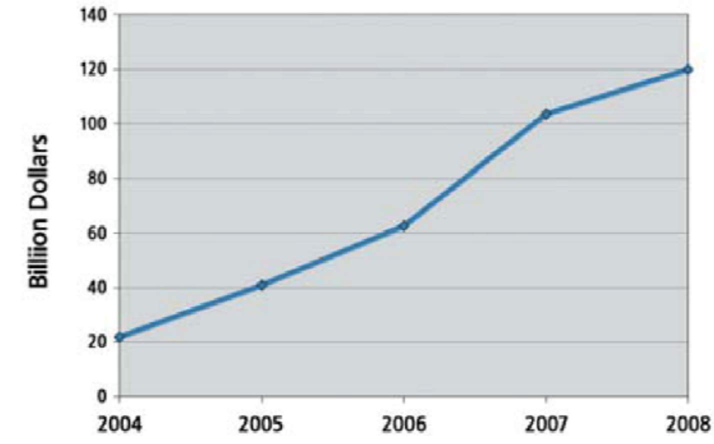


Source: REN21. 2009.[15]

There is also visible growth of the global investments in renewable energy, as shown in Figure 5.2.

[15] *Note*: Sweden is mis-represented in this table. It has a green certificate policy. Cumulative number refers to number of jurisdictions that had enacted feed-in policies as of the given year. A few feed-in policies shown have been discontinued. Many policies have been revised or reformulated in years subsequent to the initial year shown. India's national feed-in tariff from 1993 was substantially discontinued but new national feed-in tariffs were enacted in 2008. Three countries with feed-in tariffs are not shown because year of enactment is unknown: Costa Rica, Mauritius, and Pakistan.

Figure 5.2: Global Investments in renewable energy from 2004 to 2008



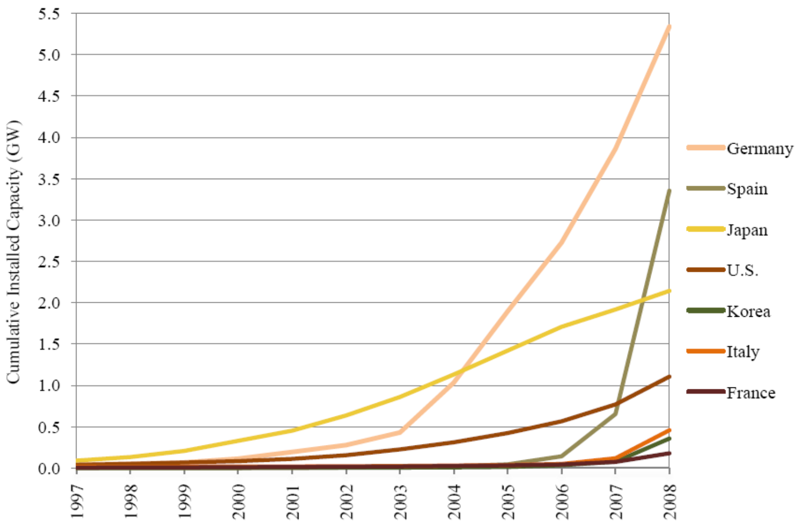
Source: REN21. 2009

Similar behavior can be noticed in regards to the global electricity capacity of PV and CSP. Global installed PV capacity increased by 6.0 GW in 2008, a 152% increase over 2.4 GW installed in 2007 (Price, 2010). The 2008 addition brought global cumulative installed PV capacity to 13.9 GW (see Figure 5.3). The cell/module production has seen impressive growth during the past decade, with a 10-year compound annual growth rate (CAGR) of 46% with main manufacturers in Europe, China and Japan (Price, 2010).

In the case of CSP, although development was stagnant since the completion of California's 364 MW SEGS (Solar Energy Generation System) in 1990, the projects under development or construction have increased dramatically since 2004 (see Table 5.1). Several new projects are under contract in United States and under development in Abu Dhabi, Algeria, Egypt, Israel, Italy, Portugal, Spain, and Morocco (REN21, 2009). Contracts for approximately 13 GW of CSP capacity have been announced or proposed through to 2015, based on forecasts made in mid-2009 (Price, 2010). Regional market shares for the 13 GW are about 51% in the United States, 33% in Spain, 8% in the Middle East and North Africa, and 8% in Australasia, Europe, and South Africa. Projects for CSP under construction, at the end of 2009, exceeded 2 GW, and California, alone, is reviewing over 4 GW of CSP proposals (The California Energy Commission, 2010).

Currently there is a process of coalition formation for the development of solar megaprojects in North Africa and the Middle East by Desertec,[16] which aims to supply 15% of the European electricity demand by 2050, primarily with solar (Desertec, 2010). As presented in Table 5.2 Greenpeace (2009) has projected the global CSP capacity to range from 18 to 1,500 GW, and supply over 7,800 TWh[17] by 2050. The International Energy Agency (IEA) recently presented a solar energy roadmap that projects that solar (PV and CSP) could provide 20% to 25% of the global electricity production, or 9,000 TWh, by 2050 (IEA, 2010).

Figure 5.3: Cumulative installed solar PV capacity in top seven countries from 1997 to 2008



Source: 2008 solar technologies market report (2010).

[16] Desertec is a concept that has been developed by the Trans Mediterranean Renewable Energy Council (TREC). The Desertec Foundation has been established, with the support of other notable actors (http://www.desertec.org/en/foundation/founders/) with the intension of building an electricity network from that stretches from North Africa to the Middle East to Germany.Wind and solar energy technologies will be used to supply power to this network.

[17] If the demand for electricity in 2050 reaches 35,000 TWh (as mentioned in Box 5.1), CSP could provide as much as 20% of the total global demand.

Table 5.1: Solar CSP built global capacity until early 2010

DATE	PLANT	COUNTRY	CAPACITY (MW)	DETAIL
1990	SEGS I - IX	USA	354	Nine plants built over 7 years
2004	Sierra SunTower	USA	1.4	Concentrated Solar Thermal
2007	Nevada solar one CSP	USA	64	2nd CSP plant built in USA
2007	Planta solar operacional	Spain	11	First commercial solar tower
2008	Andasol	Spain	58	First parabolic trough Europe
2008	Kimberlina	USA	5	Demostration plant CLFR
2009	Esolar	USA	5	First commercial solar tower
2009	Andasol I	Spain	50	Parabolic trough
2009	PS20	Spain	20	Solar power tower
2009	Puertollano	Spain	50	Parabolic trough
2009	Alvarado 1	Spain	50	Parabolic trough
2010	Extresol 1	Spain	50	Parabolic trough

Source: Historical event compilation based on articles and official reports - websites.

Table 5.2: Scenarios of Solar CSP's projected growth until 2050

	2015	*2020*	*2030*	*2050*	
Reference	4,065	7,371	12,765	18,018	MW
	11	22	40	66	TWh
Moderate	24,468	68,584	231,332	830,707	MW
	81	246	871	3,638	TWh
Advanced	29,410	84,336	342,301	1,524,172	MW
	116	355	1,499	**7,878**	TWh

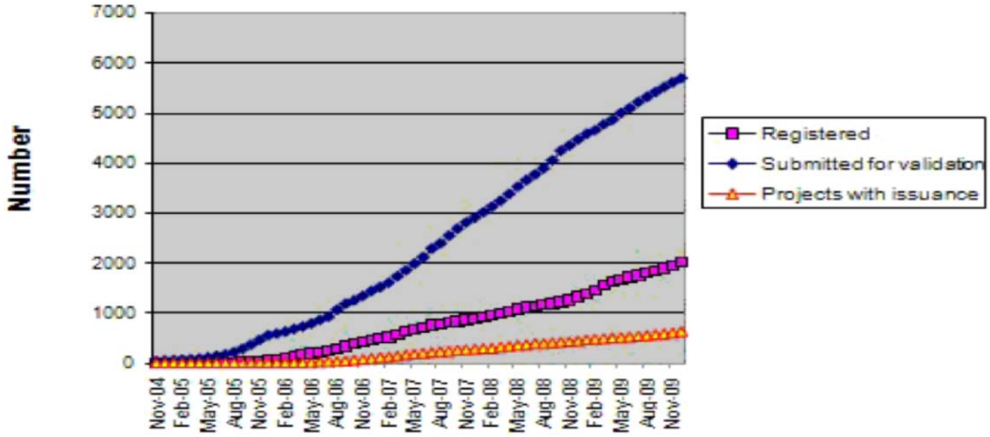
Source: Concentrated Solar Power: Global Outlook. Greenpeace, 2009.

5.1.1.2 Global Trend 2: Increasing importance of international funding for mitigation to climate change

CDM, or clean development mechanisms, established from the Kyoto protocol to encourage mitigation efforts against climate change, allow countries that are not part of Annex I[18] to trade certificates of emission reductions to industrialized countries that need to meet emission reduction targets. These mechanisms are based on an additionality criterion in which economically non-viable projects become viable as a direct result of CDM revenues. As it is shown in Figure 5.4, the implementation of these projects is continually increasing.

[18] For more detailed information refer to UNFCC (United Nations Framework for Climate Change) : http://unfccc.int/kyoto_protocol/items/2830.php

Figure 5.4: CDM projects submitted for validation, projects registered and projects issued.[19]



Source: Fennhan, J., 2009.

It is expected that these kinds of mechanisms will gain commercial importance in the future carbon market. The logic behind this is that it may be more convenient, and cheaper, to avoid new development of dirty energy sources in developing countries rather than replacing current infrastructure in the developed countries. However, some criticisms have centered on CDM´s high transaction costs (Schneider et al, 2009; Boyd et al, 2009). Until now the market dynamics remain unclear, as the CDM market is still immature. It is expected that reforms will improve the potential of these mechanisms. An alternative that has been suggested is to engage developing countries on a very large-scale program of mitigation. This would be by focusing on entire sectors, or at least large sub-sectors, in developing countries, which have a greater energy transformation potential.

At the same time, there has been an increasing social pressure for countries to adopt stricter measures against climate change. The COP 15[20] generated expectations and participation from society without precedents. Transfer of resources has been committed despite the conference's inability to achieve binding agreements of emission reduction in industrialized nations.

New, scaled up, more predictable and more accessible funding shall be provided to developing countries to enable and support enhanced action on mitigation. This will

[19] Issued CDM projects are those that have been registered and implemented, which receive Certified Emission Reductions from the CDM Executive Boards.
[20] The conference of parties is an annual convention organized by The United Nations Framework Convention on Climate Change (UNFCCC) that assesses progress in dealing with climate change.

include substantial finances for the reduction of emissions, adaptation, technology development, transfer and capacity-building for enhanced implementation of the convention (Copenhagen Accord, point 8; UNFCCC, 2010).

It is expected that drivers of these mechanisms, such as international social pressure, will continue to gain influence unless there is strong mitigation against climate change, or there is a notable reduction in the expected risks of climate change.

Critical trends are predictable and help to understand the global environment. However, they are insufficient to base the development of a world-class solar cluster. The identification of critical uncertainties may also lead to other opportunities. Furthermore, to be able develop robust strategies for the materialization of such a vision requires the identification of such critical uncertainties.

5.1.1.3 Critical uncertainty 1: Carbon lock-in in industrialized countries becomes relevant

Many scholars describe a lock-in situation of industrialized countries that have become dependent on non-sustainable energy sources due to huge sunk investments (many of them consider nuclear power as non-sustainable). These energy systems are dominated by large incumbents that influence politicians and administrations, such that “dirty” fuel technologies are maintained as the dominant designs (Unruh, 2002). Although incumbents may eventually contribute to the development of renewables, they are rarely the source of radical innovations, (Stern 2006, mentioned by Verbruggen and Lauber 2009). Furthermore, the process of technological transition is particularly difficult in OECD countries since the market for energy is stagnating and the new technologies are often substitutes, rather than complementary to existing technologies (Jacobsson and Johnson, 2000). This means the longer the process of energy transformation takes, the longer will be the dependency on traditional non-sustainable energy, and the more locked in industrialized countries will remain.

In contrast, in emerging economies the growth in energy demand is accompanied by expanding physical infrastructures and growing urbanization. This is likely to imply a greater availability of deployment sites and lower costs of deployment efforts. Importantly, this is also likely to imply lesser adverse economic impacts on incumbents and therefore less resistance to investment in "green" energy technologies.

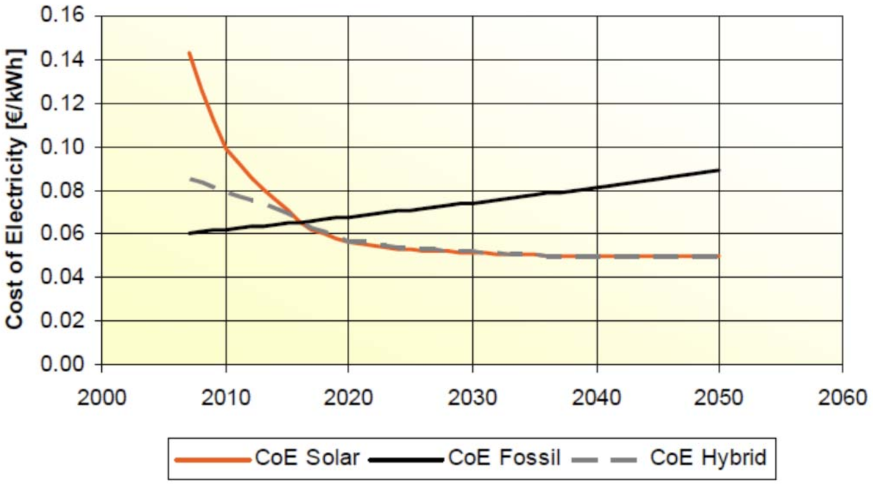
5.1.1.4 Critical uncertainty 2: CSP competes on costs with NG by 2015

Recent sources estimate that the worldwide levelized cost-of-electricity[21] (LCOE) for parabolic trough concentrated solar power (CSP) ranges between 120 – 250 USD/MWh, depending on location and not including government incentives (IEA, 2008; REN21 2008). In comparison with this, FFLA (2009) shows global average LCOE for natural gas (NG) electricity to range from 50 - 90 USD/MWh in 2007.

Some diffusion projections show CSP to more than quadruple by 2015 (Pihl, 2009; Greenpeace, 2009), which will certainly enable significant cost reductions. System developers strongly believe that improvements in design will reduce this cost considerably, making it more competitive with traditional electricity sources (Price, 2010). Accordingly, projections of CSP costs have been presented by many groups, including Greenpeace, NREL (National Renewable Energy Laboratories), IEA (International Energy Agency) and DLR (German Aerospace Institute). Although Greenpeace (2009) and IEA (2008) expect the global average LCOE from CSP to exceed 100 USD/MWh in 2015, DLR (2007) projects that electricity generated from CSP could compete with NG as early as 2016 (see Figure 5.5) in regions that have high solar irradiance, like Chile, even without carbon taxes.

[21] Levelized cost of energy (LCOE) is the ratio of an electricity-generation system's amortized lifetime costs (installed cost plus lifetime O&M costs) to the system's lifetime electricity generation. The calculation of LCOE is highly sensitive to installed system cost, O&M costs, location, orientation, financing, and policy (Price, 2010).

Figure 5.5: Cost of electricity for CSP plants versus NG gas-fired combined cycle power stations.[22]



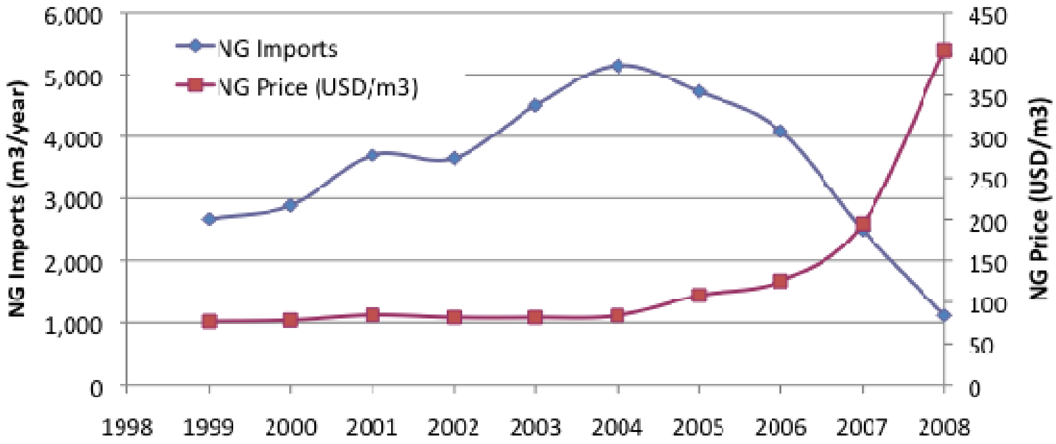
Source: Deutschen Zentrums für Luft- und Raumfahrt (*DLR*) – Germany, 2007.

The uncertainty of whether CSP will compete with NG is also influenced by Chile's recent challenges with NG and localized increase of NG prices, due to the imposed reduction of imports from Argentina the last few years (see Figure 5.6). This has forced Chile to increase the use of liquefied natural gas (LNG) to maintain operation of NG power plants (CNE, 2009). Furthermore, the World Energy Outlook 2008 comments that current global expansion of LNG re-gasification capacity could soon exceed the LNG production capacity, which would create a potential scarcity in the global LNG market (IEA, 2008).[23] Since Chile will be dependent on the LPG global market, the uncertainty of NG electricity generation is comparable to the uncertainty of future oil prices. Accordingly, it is assumed that LPG prices will continue to rise, with frequent sharp fluctuations. These conditions suggest that NG power plants will likely to be the first to be replaced by CSP.

[22] Scenario based on 5% project rate of return; 25 years life; 25 \$/MWh fuel cost with 1%/year escalation rate; and irradiance of 2400 kWh/m^2/year

[23] For natural gas to be transported to areas that do not have access to pipelines the gas needs to be liquefied such that it can be placed in transportable containers or ships. To use LNG in a NG power plant it must be first re-gasified.

Figure 5.6: Historical trend of NG imports and prices in Chile



Source: CNE (Comision Nacional de Energía) – Chile. (http://www.cne.cl)

5.1.1.5 Opportunities in the global context

In this section, we present the perceived opportunities that may emerge for developing a world-class solar cluster based on global trends. Additionally we identify some opportunities that can be generated from other identified trends of interest and from critical uncertainties.

The first trend, "Expansion of market for renewables, including solar" suggests opportunities for countries like Chile or companies that aspire to become future suppliers of mass markets of solar technology. The increased diffusion of renewables, would lead to the development of new applications and new niche markets, allowing the entrance of new Chilean actors in the market, by diversification and value chain specialization. This increasing diffusion would also reduce costs, risks and uncertainties related to adopting new technologies, increasing eventually the global demand, and favoring eventual Chilean actors that may already be in the market. Finally, the progressive maturation of the market would lead to the emergence of new dominant designs and new leaders. This would open opportunities for countries like Chile that can become host countries of these players or strategic partners.

The second trend, "increasing importance of international funding for mitigation to climate change in developing countries" suggests that countries like Chile can take advantage of these sources of funding for the development of technologies like solar. This is possible due to the criteria of "additionality", by which funding is allocated to mitigation projects that cannot be cost effective without it. This eventually would allow the implementation of demonstration projects for the formation of infant markets of solar. The early stage of these mechanisms would also suggest opportunities of entrance of new actors in the carbon certificates market, by specialization in the value chain. In the process of maturation of this market, there is no indicator of reduction of mechanisms of CDM. Rather it is expected that new, or improved mechanisms will emerge, like those suggesting strategies of mitigation at the national level. This is understood as a potential opportunity for Chile, in the case Chile decides to develop solar as a national strategy.

Additionally, other trends of interest, such as the influence of environmental issues, although not considered as critical, can be sources of relevant opportunities. This suggests that there will be more demand for green products, which will subsequently apply pressure to producers to reduce emissions in production (Stern, 2006). This can be seen as an opportunity for Chile's agricultural and mining exports for the creation of a "green" or "solar" label. Another trend of interest is the offshore phenomenon. Although not new, there is no indicator that it will reduce or will stop. It is driven mostly by the lower costs of production in emerging economies, and their increasing improvement in infrastructure. This reinforces opportunities of learning and catching up that can be used in the case of solar.

Critical uncertainties also offer possible opportunities. Because of the lock in complex discussed before, there is an increasing interest in the belief that emerging economies would have better conditions for technological innovation in the renewable energy sector, putting countries like Chile in a comparatively better situation for developing these kinds of industries. Additionally, as Chile has conditions that would allow solar to be cost effective before other countries (at least in some areas due to radiation resources and high prices of fossil fuels), there can be worthy arguments to develop an industry like solar and opportunities for the emergence of early followers. However, these drivers are uncertain and, therefore, strategies to address them must be based on scenario-analysis. Due to the scope of this thesis, they will not be presented.

Finally, the previous analysis has led also to the identification of threats of developing a world-class cluster. In general, it is possible to say that the development of a solar industry in Chile will not affect other industrial sectors. However, it has been identified a possible conflict that would emerge between the development of solar and incumbent sources of energy like coal and even the development of non-conventional renewable energies. In this sense, a main threat lies on the tensions of energy policy that tend to favor some more cost effective technologies rather than others like solar. As suggested by Dalenbäck (2010) these tensions can exist and policy makers need to be aware of that.

5.1.2 TRENDS AND OPPORTUNITIES IN THE INTERNAL CONTEXT

According to the scenario analysis method, three main internal trends have been selected among others by their relative importance. They will be presented followed by respective opportunities and threats.

5.1.2.1 Internal trend 1: Increasing Water scarcity

Despite recent declines in copper prices (Codelco, 2009) mining companies in Chile are planning major expansions for the next decade, with nineteen new mining projects and five mine expansions (Cochilco, 2010). With the expansion of the mining industry, there is an estimated increase in water consumption from 373,8 million m^3/year, in 2009, to 572,2 million m^3/year in 2017 (Cochiclo, 2009).[24] The water demand in the Atacama region alone is expected to grow by 102% from 2008 to 2020 due to the planned opening of five new mines (Global Water Intelligence, 2009). As the mining industry already exceeds its water rights in some regions, this increase in demand will need to be provided by seawater desalination. Consequently, plans are developing for the installation of 215 and 252 million m^3/year of desalinated seawater capacity by 2020, which is estimated to require over 7.5 billion USD in investments for the desalination plants alone. The Chile Copper Association's, Cochilco, most recent report on water resources highlights that water is a critical issue in the mining industry and will directly affect the economic growth of Chile.

Since mining is by far the most important industry in Chile, it is easy to overlook the needs of the agro-industry in the north. In the Atacama Region, agriculture has been allocated 85% of the natural waters, 7% to the mining industry and 8% for human consumption (Atacama GORE, 2009). This would suggest that the agro-industry

[24] The mining industry has been aware of the issue of water scarcity for some time. Since 2000 to 2006, they have been able to reduce the water consumption in the concentration (>28%) and hydrometallurgy (>50%) processes (Cochilco, 2009). Concentration: 1.1 to 0.79 m^3/ton ore. Hydrometallurgy: 0.3 to 0.13 m^3/ton ore.

would be most affected if the availability of natural waters are reduced.[25] It is expected that climate change will only exacerbate the scarcity of water (Cochilco, 2009).

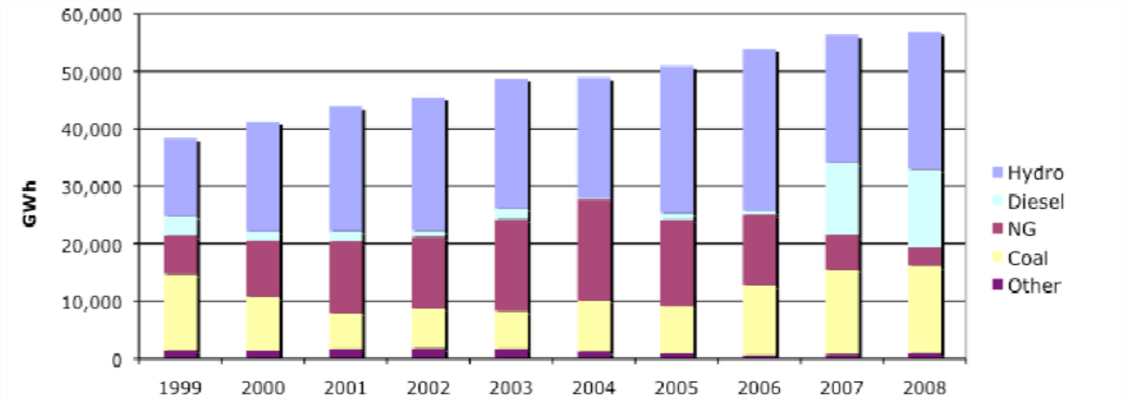
Current water purification technologies are energy intensive, and there are developments in the use of solar technologies for direct, or hybrid, water purification. Therefore, trends related to Chile's water scarcity are relevant to the development of solar in Chile.

5.1.2.2 Internal trend 2: Increasing Demand of Energy

From 1999 to 2008, Chile's electricity demand increased from 38 TWh to 56 TWh, as shown in Figure 5.7. Chile's electricity demand is expected to increase to over 90 TWh in 2020, and to over 140 TWh in 2025 (PRIEN, 2008). The Grand Northern Interconnected System (Sistema Interconectado del Norte Grande – SING), which supplies electricity to the two northern most regions of Chile, alone will grow from more than 15 TWh (CNE, 2008) in 2008 to more than 30 TWh in 2020, and 40 TWh in 2025, as in Figure 5.8 (PRIEN, 2008). Refer to Box 5.2 for a summary of Chile's electricity system. The copper industry, alone, is expected to increase its electricity consumption from 18 TWh, in 2008, to 27 TWh, by 2020, even with increases in efficiency (Cochiclo, 2010). As Chile has very little capacity for hydro expansion, particularly in the north, the increased generation will likely come from coal, unless the government intervenes and increases the support of renewables.

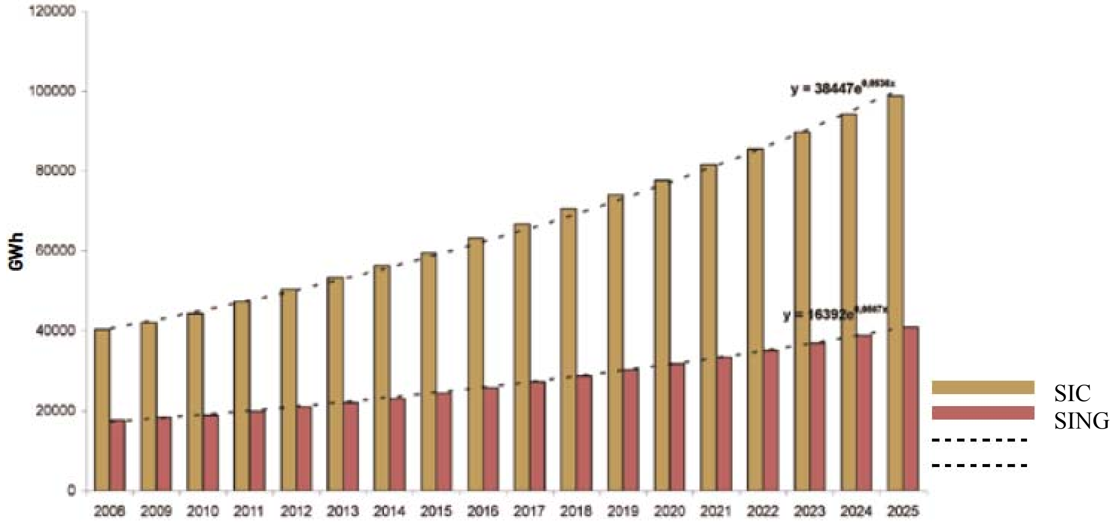
[25] Cochilco Water Report (2009) has stated the Tierra Amarilla aquifer, in the center of the Atacama Region, will be exhausted within two or three years.

Figure 5.7. Electricity Supply to Chile between 1999 and 2008



Source: CNE, 2009a.

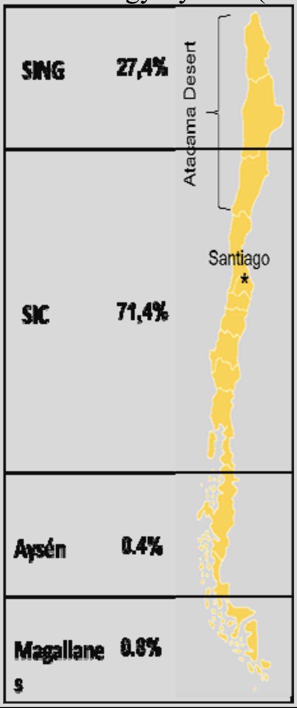
Figure 5.8: Projected electricity generation in Chile to 2025



Source: PRIEN (2008) from FFLA report “Opciones parala Matriz Enérgtica Electríca: Insumos para la Discusión”

Box 5.2. Chilean Energy System

Chile Energy System (CNE, 2009a)



The Chilean electricity system is made up four networks with two primary networks accounting for more than 98% of the electricity consumption and generation. The Central Interconnected System (Systema Intercontectado Central – SIC) is the largest of the two consuming over 71% of the national electricity generation, which supports Chile's major urban areas (CNE, 2009a). As of 2008, the majority of the electricity needs of this region are provided by large-scale hydro plants (52.3%), and only 3.3% provided by Non-Conventional Renewable Energy (NCRE). The use of electricity in the SIC is primarily for commercial and residential needs in the urban areas, and also for the support of the mining industry in the north of the network (AtacamaRegion, III).

The Grand Northern Interconnected System (Sistema Interconectado Norte Grande – SING) supports the two northern most regions and is dominated by natural gas and coal based production, with less than 1% of the electricity provided by NCRE or large hydro. Although these regions have only 10% of Chile's population, the SING network consumes over 27% of the national demand. This can be accounted for by the tremendous demands of the mining industry in the north of Chile, which consume 90% of the electricity produced in the SING network.

5.1.2.3 Internal trend 3: Increasing Energy Scarcity and Insecurity

In 2008, over 99.5% of the electricity generation capacity in the northern network (SING) and over 43% in the central network (SIC) consisted of carbon-based generation, which amounts to over 57% of Chile's total electricity generation (CNE, 2009). As 90% of Chile's fossil fuels are imported energy scarcity is certainly a concern for Chile. It is also worth noting that since Chile's primary domestic energy source is from hydroelectric plants, effects of climate change, namely droughts, could increase Chile's dependency on imported fuels.

2004 saw the initiation of a natural gas crisis in Chile (Cochilco, 2010),[26] which caused NG (natural gas) prices to increase from under 100 USD/m^3 in 2004 to over 400 USD/m^3 in 2008 (See Figure 5.6) and caused the NG imports to drop from over 5000 m^3 to nearly 1000 m^3 (CNE, 2009). Furthermore, NG went from supplying over 36% of Chile's electricity in 2004 to less than 6% in 2008. To offset this decline of NG consumption, diesel electricity generation increased by more than 600% in that

[26] Prior to 2004, Chile's primary source of NG was from Argentina, where Argentina was supplementing their exporters with imports from Bolivia. Due to the continued animosity of Bolivia towards Chile, Bolivia imposed an exportation tax on their NG and subsequently forced Argentina to transfer the added cost to Chile's imports.

period (refer to Figure 5.7). Also, imports of liquid petroleum gas increased, along with investments from electricity companies and mining companies in liquefied natural gas (LNG) processing plants, to sustain the use of some of the 4.4 GW of NG plant capacities.

With Chile's increasing electricity demand, if Chile continues to expand the use of coal or LNG it will become increasingly dependent on imported fuels, therefore compromising Chile's future energy security. Furthermore, this would not be a favorable position if global emission trading schemes develop and global pressure for emission restrictions increases.

5.1.2.4 Opportunities and threats in the internal context

The conditions that have been described above are clearly threats to Chile, both economically and socially. They have serious effects to the residential and industrial consumption of energy. In fact, these problems are drivers of initial efforts in the Atacama Solar Platform Initiative, which aims to develop "systemic solutions for solving systemic problems" (Fundación Chile, 2009; Pastene, 2010a).

In the global context of climate change, the development of renewable energy represents not only the opportunity of solving internal problems but also, of becoming aligned with trends that indicate the emergence of a global low carbon economy, as it is suggested by the urgency for emission reductions. These trends are clearly incompatible with the expansion of fossil fuel energy sources. Global influences will soon demand new low carbonized energy capacity, and countries that do it first, without having to replace large amounts of non-renewable capacity, will obtain remarkable benefits. In the case of Chile, solar represents a central option for the northern area.

At the same time, energy insecurity and energy scarcity can also lead to opportunities, on both the demand and supply sides (refer to Box 5.3), for creating knowledge and capabilities that could become sources of competitive advantage and basis of global competitive industries. As mentioned in Section 3 geographical constraints have been strong drivers for the formation of global leading industrial clusters; for example the long transportation distances, the hard climate and strict regulations forced the Swedish heavy truck industry to produce durable trucks (Nilsson and Dernroth, 1995). Similarly, the scarcity of water, and hot, arid growing conditions together with strong national desire of becoming self sufficient in food, led Israel to the emergence of advanced agricultural technologies and a world-class irrigational cluster (Porter, 1998).

Finally, as it is shown in the internal trend 1, the mining expansion projects in northern Chile will demand large investments for water desalination and energy supply. Those investments are associated not only to technology transfer processes but to the mobilization of human capital and knowledge. This would become an opportunity for leveraging the development of solutions, again on both the supply and demand side (refer to Box 5.3), based on renewable technology like solar and for strengthening the learning processes needed.

Box 5.3. Opportunity for knowledge creation in Chile

Supply Side	• Develop NCRE technologies for energy intensive mining processes (heat and electricity) • Develop efficient water purification technologies • Use NCRE and cogeneration for desalination energy supply
Demand Side	• Increase energy efficiency in industrial processes • Reduce consumption of water in industrial processes

5.1.3 CONCLUSIONS

From the previous analysis and discussion, it can be concluded that global trends related to the imminent global energy transformation such as the global expansion of solar market, or the international funding for climate change mitigation suggest opportunities for a country like Chile for developing solar technology. It is therefore perceived that a fundamental element for building a vision for a world-class solar cluster in Chile is to take advantage of the opportunities that could emerge from these trends.

Secondly, the development of renewable energy sources like solar, aligns with the emergence of a low carbonized economy and the corresponding energy system transformation required. Developing renewables means to escape from being locked in to fossil fuel technologies and become aligned with current global trends. At the same time, internal needs and challenges will be the key for the development of knowledge and capabilities that could be leveraged by resource mobilization needed for the mining expansion projects in northern Chile. Therefore, it is perceived that another fundamental element for building a vision for a world-class solar cluster in Chile is to address internal needs and challenges as drivers of the development of a new industrial sector.

5.2 WHAT IS NEEDED FOR BUILDING A "WORLD-CLASS" SOLAR CLUSTER?

The authors perceive that a "world-class" solar cluster would be, as Porter (1998) describes, a large geographical collection of complementary industries, firms and institutions, which promotes competition and cooperation. Establishing a status of "word-class" would also suggest the cluster includes actors that adopt and use solar technologies, as well as actors that are global leaders in certain technologies related to solar. Solar technological development would enable the cluster to sustain competitiveness in global markets.

UNIDO (2009, p. 48) has shown that technological learning spurs productivity growth and increases in real wages. This in turn causes firms to exit low technology, labor-intensive activities and to enter more capital-intensive, technologically sophisticated sectors. UNIDO also shows that diversity and sophistication are closely linked to "faster" economic growth in both low- and middle- income countries. Companies that produce high tech products, heavy in knowhow and light on resources are not only able to be more profitable but are also able to generate compatible networks of users and mechanisms for capturing future markets (Arthur, 1996). These companies will avoid the threats of diminishing returns, associated with commodities that face extreme competition and are heavily dependent on international prices and natural resources. Therefore, basing a cluster on technological products and increasing returns would enable sustained competitiveness in global markets.

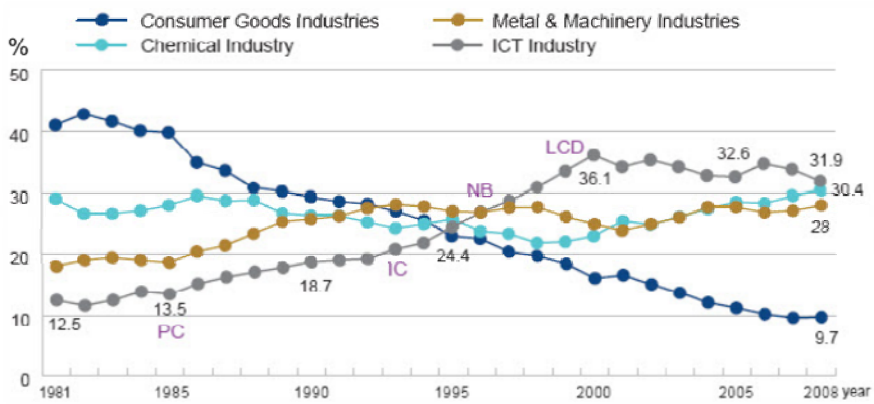
5.2.1 ARE THERE PREVIOUS CASES THAT SUGGEST SUCH AN OBJECTIVE IS POSSIBLE?

Although there are significant benefits to building a world-class cluster, it is certainly an ambitious endeavor for Chile, and for even developed countries. Chile, still an emerging country, has built a strong economy primarily on resource-based industries, including a world-class cluster in the aquaculture sector. However, pursuing industrial activities in more technologically intensive sectors, like solar, will meet other challenges or obstacles. This led the authors to the question: are there previous cases that suggest such an objective is possible?

There are examples of developing countries that have been able to emerge to develop "world-class" technological clusters. The most notable are the IT, automobile and heavy machinery industries in Korea, or semiconductor and multimedia industries in Taiwan. Part of this success is strongly linked with their respective national industrialization strategies committed to induce a transition from the exportation of light industry products to more technological products[27] in strategic sectors. In this way, governments of Korea and Taiwan sought to develop new players or to induce existing firms to invest in the new strategic sectors (Jacobsson and Alam, 1994; Mathews, 2006), establishing targets and applying different support mechanisms. The result is an evident change of the national industrial production matrix, such as the case of Taiwan. Figure 5.9 shows the transition of Taiwan's industrial development, moving away from consumer good industries, towards more technologically intensive and profitable industries, in a range of 20 years.

[27] According to UNIDO (2005, p. 144), both countries held the 4th and 5th place in a world rank of industrial technological advance by 2002.

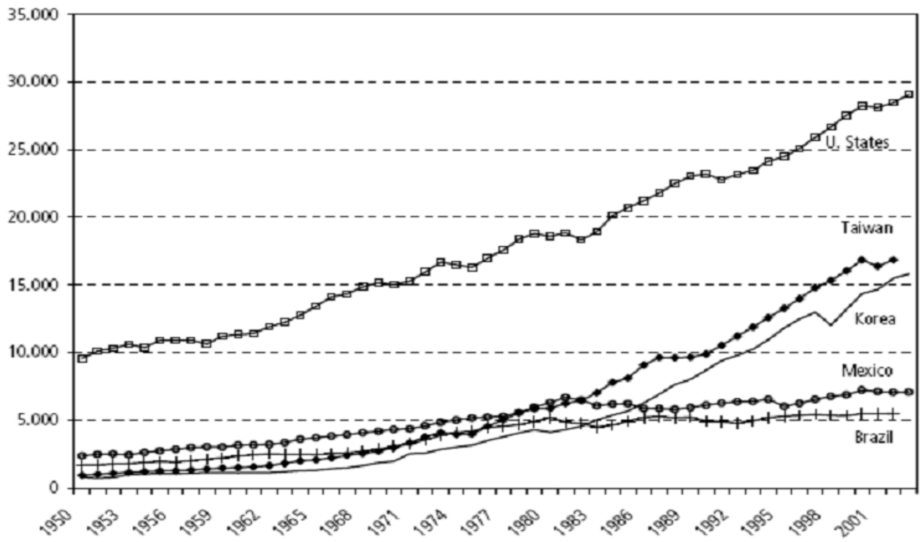
Figure 5.9: Taiwan's Historical GDP composition by sector



Source: Monthly report of the manufacturing industry, IDB / MOEA. Extracted from: Industrial development in Taiwan R.O.C. Industrial development bureau - Taiwan (2009).

Finally, it is important to mention that these industrialization processes have led these countries to experience economic growth without precedents in the last three decades. Figure 5.10 clearly shows the significant increase in GDP per capita of Taiwan and Korea, as compared to other emerging economies.

Figure 5.10: Real income per capita (1990 US dollars – PPP) 1950 -2003



Source: Groningen growth and development centre and the conference board, total economy database, 2004. Extracted from Viotti (2001)

5.2.2 WHAT IS A REASONABLE TIMESCALE?

The targeted year of materialization of an industrial cluster is critical for the development and implementation of appropriate strategies. Furthermore, a reasonable time scale is necessary for such a cluster to become legitimated and for relevant actors to become aligned. As described in Section 3, cluster formation involves the formation of several elements, and this is a process that will likely take multiple decades (Porter, 1998). Furthermore, there is a need, in the context of solar, to allow for necessary institutional changes and increased pressure from the forecasted global energy matrix transformation (refer to Box 5.1). This is particularly applicable for the case of solar technologies as they are immature, not cost competitive, almost non-existent in Chile and not well legitimated. Considering the emergence of past clusters and innovation systems (Jacobsson, 1993; Bell, 2006; Porter 1998), it is reasonable to expect a world-class cluster, based on solar technology, will take two or three decades.

5.2.3 CONCLUSIONS

Based on the previous discussion, the authors perceive that for this cluster to reach "world-class" status, and sustain competitiveness in global markets, it would need to include actors that are global leaders in the development and production of solar technologies, or complementary technologies and capital goods for the solar industries. As it is expected that building industries based on the development and production of technologies with higher sophistication would take more than two decades, appropriate strategies need to be developed with this in mind. Since the identified global opportunities of solar are based on the development of solar technologies, this would imply that a fundamental element of such a cluster is to build new industries based on knowledge and technology development and exportation.

5.3 DEFINING FOUNDATIONS TO THE VISION

Until now, two main questions have been addressed: (1) what are the opportunities to develop a "world-class" cluster in Chile?; (2) what is needed for building a world-class solar cluster? The development of answers to these questions has led the authors to consider three fundamental elements necessary to build a vision for a world-class solar cluster in Chile. From here, these fundamental elements will be referred to as "foundations" and can be summarized as follows:

- **Taking advantage of remarkable opportunities for countries like Chile in the context of an imminent process of global energy transformation;**
- **Using internal needs and challenges as drivers for building a sustainable**

energy system in Chile and developing knowledge and capabilities needed for a technological cluster;

- **Building industries based on technology and knowledge production and exportation.**

5.4 THE CREATION OF VISION 2040

The authors developed a vision that is based on the foundations presented and the identified internal drivers and external opportunities and threats (refer to Box 5.4). As the realization of such a cluster is complex, 2040 was chosen as a target date for the full development of a world-class multi technology cluster. The vision describes a cluster that will materialize within three phases of development, with the emergence of five key components.

Box 5.4: "Vision 2040: The emergence of a solar multi tech cluster in Chile"

VISION

In 2040, the cluster of Atacama is a multi technological center[28], host of (one of) the largest "green" industrial parks in the world, and world-class suppliers of technologies, particularly solar-based, and "green" energy. This contributes to the transformation of Chile, and potentially the continental region, into sustainable societies: economically, socially and environmentally.

This vision is based on three main foundations:

- Taking advantage of remarkable opportunities for countries like Chile in the context of an imminent process of global energy transformation;
- Using internal needs and challenges as drivers for building a sustainable energy system in Chile and developing knowledge and capabilities needed for a technological cluster;
- Building industries based on technology and knowledge production and exportation.

Initial phase: "supporting strong clusters and exploration of solar applications"

Component 1: Emergence of a market for solar technology adapted and improved with incremental innovations that supports and leverages strong clusters of medium sophistication: mining and agriculture.

This component is focused on current strong clusters: mining and agriculture. It is driven primarily by internal influences.

Solar technology is adapted from external suppliers according to the conditions of an infant market for solar applications. The expansion of this market is influenced by innovations that allow the introduction of solar applications in order to improve current industrial processes or technologies. At this level, these applications are more related to heat. To support this expansion

[28] In this document, a multi technological cluster is referred as a center where actors related to solar and other technologies, at different levels of sophistication, interact on processes of production, consumption and innovation.

a development of knowledge formation and specialization in solar technology installations, operations and maintenance is required. Strong knowledge networks may be created with national and international actors in order to lead the processes of adaptation and improvement of these technologies.

Intermediate phase: "Transition towards technological innovation in solar and related technologies"

Component 2: Emergence of a multi technological cluster of medium-high sophistication, from the technological interaction of solar technologies and other technologies

This component is focused on technological interactions and opportunities of niche markets; it is driven primarily by the second foundation.

The mentioned technological interactions are the result of combinations between solar technologies that have been adapted and improved and non-solar technologies explored and used in the initial phase[29]. These interactions will be sources of specialization and opportunities for creation of niche markets. These niche markets, such as solar water desalination, or solar heat for industrial applications, would be related to the production of specialized components and/or the production of technologies for customized applications.

These initial niche markets will be able to evolve through diversification into the development of technologies not necessarily solar focused such as agro industry and biotechnology based on semi-desalinated water, fluid technologies (pumping, desalination), and non-conventional industrial concepts. Both kinds of technological development, solar and non-solar driven, may demand the generation of innovations of medium or high level of sophistication.

Component 3: Emergence of a "world-class" cluster that produces and exports "green" electricity and related technologies of medium-high sophistication. This cluster is led by players who are "early movers" in the global arena.

This component is focused on the creation of a technological system of "green" electricity, and is driven by the first and second foundations.

Technological systems of electricity production are fostered in Chile with the participation of relevant global players that pursue the challenges of energy cost reduction and innovation in a "green" energy market (internal or external). On the expansion on this market, the focus is also on the development of domestic firms, sustaining a process of expansion of their activities from being simply installers and supporters to also innovators that supply technological components and knowledge.[30]

The expansion of "green" energy will provide sustainable and secure energy provision for social and industrial sectors. It will also enable companies to gain a global competitive advantage by becoming ¨early movers¨ in the appropriation of "green" energy in their business models. This competitive advantage is also in part because the energy instability of competitors who produce in non-"green" nations and regions (referring to the global challenge of the energy revolution and the potential lock in complex in industrialized countries). Consequently, Chile will eventually become an international supplier of products whose processes are highly energy intensive.

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[29] There would be further development of solar technologies that enable increases in efficiency of energy intensive industrial processes. Such processes will be both solar supported (hybrid) and solar driven (eg. desalination, steam generation, heating processes, solar chemical, hydrogen generation, etc.).

[30] In regards to this process, South Asian countries contribute with many lessons of industrialization in high tech sectors. This has occurred by fostering the strength of internal markets with local supply, as in the South Korean case, or by adopting processes of systematic learning and collaboration with Multinational Companies and promoting clustering through networks of specialized suppliers that eventually became innovators, as in the Taiwanese case.

Component 4: Emergence of highly specialized "knowledge producers" led by world-class organizations. They provide necessary human capital and support technological development in strategic sectors.

This component is focused on the process of knowledge formation as a key function of a technological innovation system. The main driver lays on the necessity of supporting every component of the vision with the adequate provision of knowledge. There is not a successful example of industrialization in higher levels of sophistication without the intervention of knowledge producers.

Therefore, there will be an emergence of highly specialized knowledge centers that can leverage the formation and growth of technological systems (solar and other technologies), which is a result of the process of clustering, as suggested in this vision (Jacobsson and Johnson, 2000; Sandén and Azar, 2005).

As the case of ITRI in Taiwan, these highly specialized organizations not only contribute with knowledge formation, related to people and knowledge, but also affect technological innovation systems by being incubators of new businesses promoting diversification and further clustering. At the same time, the role of national universities, institutes and international collaborations become relevant as contributors of knowledge formation of the system. The interaction of these actors with others in a system allows the formation of technological innovation systems[31].

Maturation phase: "Global technological leadership"

Component 5: Emergence of a "green" industrial park powered by "green" energy that hosts world-class suppliers of highly sophisticated technologies of strategic interest to Chile.

In connection with the third component, this fifth component is focused on enabling a process for the relocation of companies who carry global importance and are seeking to take advantage of operating within one of the largest "green" clusters in the world (these companies could be players in industrial sectors not necessarily related to solar technologies). This component is driven by the first and third foundation.

As mentioned above, external influences, like the immaturity of solar technology and the potential lock in complex in industrialized countries, can reduce the competitive advantage of global industrial energy consumers during the global energy transformation process. These organizations could reduce the impact of this threat by relocating operations to emerging economies such us Chile, that offer a reduction of operational costs (mainly labor) as a way of compensating the short term higher costs of consumption of "green" electricity. These organizations may achieve sustainable competitiveness in a more efficient way.

The facilitation of this relocation process is strategically pursued in order to increase the market of "green" electricity in Chile. This will promote positive feedback of supply and demand, held by an increasing number of suppliers (producers of solar electricity) and consumers (industrial energy consumers) that interact synergistically in the system. It is on this positive feedback, and its interaction with local players (generating opportunities for domestic companies for further clustering by diversification and collaboration[4)], where there is expected to be large generation of externalities. These strong consumers of "green" electricity present in the industrial park, generally devoted to the production and export of technology, may belong to industrial sectors strategically pursued by Chile.

As in the case of Component 4, the emergence of the "green" industrial park needs to be supported by the emergence of highly specialized "knowledge producers" led by world-class organizations that provide necessary human capital and support technological development in

[31] Socio-technical systems focused on the development, diffusion and use of a particular technology, in terms of knowledge, product or both. It is formed by structural components such as actors, networks, and institutions (Bergek et al., 2008a).

strategic sectors.

6 CHAPTER 6: CHALLENGES FOR PURSUING THE VISION 2040[32]

The previous section specified three foundations upon which a vision of a world-class solar cluster could be developed. Following a creative exercise, the vision 2040 was elaborated based on those foundations. This section has as a main purpose to identify the challenges, perceived as obstacles, which may hinder the stakeholders to build or strengthen the capacity of materializing the vision 2040. As the vision 2040 has been a creative elaboration of substantiated foundations the following analysis will focus on the previously mentioned foundations of the vision rather than on the specific details within the vision 2040.

Within this section, challenges are identified in two phases. In the first phase, the capacity of stakeholders for the materialization of the vision is explored by analyzing the compatibility between the foundations of the vision and corporate (or institutional) strategies of stakeholders. In this way, it is perceived that the more compatible their strategies are with the foundations of the vision, the greater the capacity of materialization.

In the second phase, it is discussed what are the main strategic changes that stakeholders would need to implement in order to increase their capacity to materialize the vision. These changes are analyzed as "strategic dilemmas." Each strategic dilemma is associated with main obstacles that may prevent stakeholders from building or strengthening their capacity to materialize the vision.

6.1 CAPACITY OF STAKEHOLDERS TO MATERIALIZE THE VISION 2040

This section explores the capacity of materialization of the vision by analyzing the compatibility between the foundations of the vision 2040 with the corporate or institutional strategies of key stakeholders. This compatibility analysis is conducted by exploring corporate and institutional strategies through three main "compatibility

[32] Some interviews referred to in this section were conducted in Spanish and were translated by the authors of this report.

criteria": (1) importance of non-conventional renewable energy (emphasis on solar) (2) importance of global and internal trends, which were identified by the trend analysis, and (3) importance of technological innovation.

The analysis is presented by categorizing stakeholders in three groups. The first group, the regulatory framework; composed of actors in the government (see Table 6.1). The second group, the general stakeholders; composed of actors in the entrepreneurial sector, the education sector and the social sector. The third group, Fundación Chile. All these actors are presented in a comprehensive list in Appendix1. As stated in the methodology, the analysis is based on information obtained from official documents related to all of them and on interviews held with representatives of the majority of the most important actors.

Table 6.1: Acronyms and names of some government entities related to the regulatory frameworks of innovation and energy

Acronym	Name of Institution	Interviewed?
CNIC	National Commission for Innovation for Competitiveness	YES
CONICYT	National Commission for Science and Technology Investigations	NO
FONDEF	Development Fund for the Promotion of Science and Technology	YES
CORFO	Economic Development Agency of Chile	NO
CNE	National Energy Commission	YES
CRE	Center for Renewable Energy	YES
CONAMA	National Commission for the Environment	NO

6.1.1 EXPLORING IMPORTANCE OF "NCRE" IN CORPORATIVE OR INSTITUTIONAL STRATEGIES

In this section results of exploring the importance of NCRE in corporate or institutional strategies of main stakeholders associated with solar development in Chile are discussed. This exploration has been based on indicators outlined in Appendix 2 such as importance of NCRE investment, technological development in NCRE or knowledge networks associated to NCRE.

6.1.1.1 Regulatory Framework

As a non-Annex I country, Chile has no obligated targets for emission reductions. Consequently, CNE and CER do not expect emission restrictions to be imposed on fossil fuel based power generation in the near future. This will continue to favor sources of energy like coal and LNG in Chile (Interviews, 2010). Therefore, in general, there is little sense of obligation to use of NCRE by Chile.

However, in January of 2010 a new energy policy (Law 20.257) took effect, which requires electricity generation companies to provide 5% of the supplied power to come from NCRE (CNE, 2009).[33] In 2014, the policy will begin ramping up the NCRE requirements, reaching 10% by 2024. This policy complements previous policies (Law 19.940, 2004; Law 20.018, 2005), which enable small generators to participate in the electricity market by giving them the right to transfer electricity through the distribution system and providing aid to the electricity sector for renewable energy and energy efficiency.

The intention of these policies has been to stimulate the market growth of NCRE, driven by the need to ensure energy security.[34] However, these policies have been focused on supporting the most cost competitive NCRE technologies, as the commissioner is quoted to say: "for those technologies that are not yet competitive in Chile, we are creating the conditions for their development once they become competitive” (CNE and GTZ, 2009). It is clear that these policies do not favor solar.

Similarly, CNE has expressed that a Feed in Tariff (FIT) subsidy would not be relevant for the development of NCRE in Chile, given their primary goals of pursuing sustainability, reliability and energy security (Interviews, 2010). It was suggested that as Chile has an abundance of high quality sources for NCRE, NCRE would soon become competitive with traditional power generation. However other opinions in the

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[33] This policy is essentially a renewable portfolio standard, as companies can trade credits of NCRE generated electricity to fulfill their respective requirements.

[34] Prior to the recent NCRE policy, there was little investment in NCRE. After the natural gas crisis, in 2004, the government was pressured to look for more sustainable solutions. From 2005 to 2006, CORFO and CNE supported 103 research projects to study Chile’s potential for biomass, wind, micro-hydro and geothermal, with a cost of over 3.3 million USD (Informe final Estudio de Mercado, TransEnergie, 2006).

energy sector did suggest that there are signals of a new debate on NCRE mechanisms emerging in the coming years (Interviews, 2010).

FONDEF, a division of CONICYT that grants funding to high-risk collaborative technology development ventures, has no commitments to supporting the development of solar technologies in Chile (Interviews 2010). This is because solar is excluded from policies in the energy sector and, as discussed before, energy is not considered as a primary cluster in Chile, but rather a transversal (or supportive) cluster.[35] Therefore, proposals related to NCRE requesting funding compete with all other proposals from non-primary clusters. The exception is that there is collaboration between CONICYT and CORFO on a bio-fuels program.

There has been only a few government initiatives related to solar. Likely the most important policy initiative has been the governmental support for solar water heating with a law that gives a tax rebate to customers that install such systems. Also, FONDEF has awarded funding for two solar projects: the development of an irradiation model in Chile and a feasibility study of a solar chimney power plant. Finally CNE and CORFO are requesting tenders for two solar electricity plants (one 10 MW CSP plant, one 500 kW PV plant), to which they will contribute funds. However, as representatives of the energy regulatory framework reveal, the intention of these projects is not related to market formation but simply to "accelerate a process of learning the use of the technology" (Interviews, 2010).

Previous arguments may suggest that although the currently weak NCRE sector is growing the regulatory framework seems to be bias to support technologies more cost effective than solar. Furthermore, there is no indication of any coordination of the expansion a solar industry.

[35] CNIC has adopted a plan to review the primary clusters in Chile every four years, the energy sector will need to wait until, at the earliest, 2014 for this to change (there are arguments that support the idea of having renewables as main cluster).

6.1.1.2 General Stakeholders (entrepreneurial, education, social sectors)

The energy policies discussed above seem to have spurred an over-eagerness to enter the NCRE market. As of April 2010, less than four months after the inception of the NCRE policy, the installed NCRE capacity already exceeded the requirements for the 5% (interviews, 2010). The saturation of the market for NCRE has reduced the incentive to invest further in NCRE projects among energy companies like Eco Endesa,[36] and it is expected that the increase in NCRE in the energy matrix will be highly dependent on the increased national electricity demand. Furthermore, since there is still mini-hydro, biomass and wind to exploit (FFLA, 2009; UTFSM and Universidad de Chile, 2008), solar will continue to be at a disadvantage and Chile will need to wait for the cost of solar electricity generation technologies to drop before there is an expansion.

There is evidence that these policies have also induced non-generation companies to enter the NCRE market. Important representatives of the agricultural sector have claimed that some private companies in the sector have invested in micro-hydro projects (Interviews, 2010). Codelco has had a wind farm built and is collaborating in projects of renewable energy with Fundación Chile. Other non-power companies have invested in micro-hydro and wind energy as well (Interviews, 2010; CNE, 2009). ACESOL, an association composed of more than 30 small companies, is the only group of companies supporting the diffusion of solar technologies. The member companies are, however, limited to small-scale water heating system installations, and to a small extent, off-grid PV systems.

6.1.1.3 Fundación Chile

Fundación Chile has developed several initiatives in regards to renewable energy through its Energy and Environmental Division. Main projects have been related to the promotion of energy efficiency and feasibility studies for NCRE. In the case of the Atacama Initiative, it has been initiated by Fundación Chile driven more or less by

[36] Eco Endesa was the first generation company to invest in emerging NCRE technologies with the first wind farm in 2007 (18 MW, expanded to 78 MW in 2009) (CNE, 2009).

internal needs associated with energy and the comparative advantages of solar radiation.

Although there are minimal developments of solar technologies or markets within Chile Fundación Chile, through the Atacama Initiative, has been coordinating actions to induce the formation of a future solar cluster in the Atacama Desert. Fundación Chile has committed resources from Codelco and the Regional Government of Atacama (GORE) for initial exploration projects. As an example, Fundación Chile is coordinating a study of the potential applications of copper in PV thin film technology.[37] They are also coordinating the development of an off-grid solar-powered desalination plant, currently at the demonstration phase (stimulating knowledge formation and direction of search). At the same time this master thesis is part of Fundación Chile´s efforts for building a shared vision of the solar industry (influencing legitimation). Although the initiative is at a very early stage, it is worth noting that Fundación Chile is accomplishing a system building role in the development of solar energy in Chile.

6.1.2 EXPLORING IMPORTANCE OF "GLOBAL AND INTERNAL TRENDS OF INTEREST" IN CORPORATIVE AND INSTITUTIONAL STRATEGIES

In this section results of exploring the importance of "global and internal trends of interest" in corporate or institutional strategies of main stakeholders associated with solar development in Chile. This exploration has been based on global trends considered to be relevant for the development of a solar industry in Chile given the subsequent opportunities that can be derived. The trends considered are the global expansion of solar technologies and international funding for the mitigation of climate change. Critical uncertainties were also considered; they are related to the carbon lock-in complex and the near term competitiveness of CSP. Additionally, the internal trends considered are: water scarcity, energy insecurity, and increasing energy demand in Chile.

[37] This study is being developed at the University of Atacama (in collaboration with Weizmann Institute of Science - Israel).

6.1.2.1 Regulatory Framework

CER (Centro de Energía Renovables) discussed their awareness of the development of policy for NCRE in Latin America, suggesting that this could be an opportunity for Chile to act as a platform for the region (Interview, 2010). An opportunity to sell electricity to neighboring countries is, however, not part of this plan, as CNE (Comisón Nacional Energía) sees no likelihood in the short term of Chile connecting their grid to neighbouring countries (Peru and Argentina) (Interview, 2010). Furthermore, as CNE takes the position of facilitating energy security, and based on their decisions in recent NCRE energy policy, it seems that there is little influence from global trends of interest. Only the influence of internal trends is perceived as important. Accordingly, there seems to be little intention of supporting energy technology development in Chile.

However, as suggested by experts in the industrial sector, there are several arguments that support the idea that the renewable energy sector could become a primary cluster in the future. These arguments are, however, not yet well articulated or diffused (Interviews, 2010).

6.1.2.2 General Stakeholders (entrepreneurial, education, social sectors)

Trends and opportunities of the potential growing market of solar technologies seemed to present little incentive to try to take advantage of developing technologies for global markets. An exception is Aquavant, a desalination systems engineering company, which discussed the opportunities of merging renewable energy and desalination plants in northern Chile (Interview, 2010). Consequently, they have recently made agreements with foreign companies, specializing in geothermal and solar power plants, to become their Chilean representative in hopes of broadening their portfolio. Although they recognize the opportunities of learning from large multinational corporations, it is apparent that their drivers are based more on the internal provision of energy and water rather than the development of technological products.

Although the authors of this study perceive opportunities in using international funding mechanisms to develop technologies for the mitigation of climate change, these opportunities were beyond the scope of actors interviewed. CONAMA has approved fifty-one CDM projects (CONAMA, 2010), however, this proved to be of little incentive for actors to test the waters of more immature technologies, such as solar. Some representatives of Fundación Chile stated that funding from such mechanisms has been very uncertain and is only useful for the most mature NCRE technologies. Even Eco Endesa, with their wind farm qualifying as a CDM project, has seen little additionality from this mechanism (Interviews 2010).

There is, however, an awareness of the increasing global pressure for firms to reduce the carbon footprint of their products. The actual influence of this pressure seems to be low, but it is clearly being explored.

In regards to the carbon lock-in complex, there is negligible consideration of the idea that industrialized countries will face considerable challenges transforming their respective energy systems. Consequently, subsequent opportunities and Chile's comparative advantages of such a condition have not been articulated.

In regards to the expectation of CSP competing with NG in Chile by 2015, Codelco, as a part of the Atacama Initiative, is the only actor who has supported studies for solar energy with the objective to replace NG in the future. As mentioned by interviewees, Codelco would only act on these studies if they can be demonstrated as being economically feasible. This seems to confirm Codelco's position of waiting for technologies to be developed abroad to create solutions in a cost effective way for the short term.

6.1.2.3 Fundación Chile

At Fundación Chile, the incorporation of NCRE technology development in their activities is, again, rooted in improving the competitiveness of Chile's primary clusters. Specifically, they consider the use of NCRE as a means to add value to Chile's exports, as they expect an increased influence of carbon footprint on these exports in global markets. As energy and water are critical components to Chile's industry, particularly in the north, addressing these issues is also a strong driver.

The expected international market growth of solar technologies is not a direct driver of the Atacama Solar Platform, but an indirect driver, in the sense that solar technologies will soon be competitive. Therefore, it is perceived that Chile needs to be prepared to adopt such technologies. International funding mechanisms are a negligible driver for their activities.

6.1.3 EXPLORING THE IMPORTANCE OF TECHNOLOGICAL INNOVATION IN CORPORATE OR INSTITUTIONAL STRATEGIES

In this section results of exploring the importance of technological innovation in corporate or institutional strategies of main stakeholders associated with solar development in Chile are discussed. This exploration has been made based on indicators outlined in Appendix 2, such as the importance of R&D investment, technological product development or intellectual capital strategies.

6.1.3.1 Regulatory Framework

The industrial sector in Chile is based on eight main clusters: aquaculture, tourism, mining of copper, service off-shoring, processed foods, fruit, pork and poultry farming and financial services. These clusters are basically based on comparative advantages related to natural resources and labour costs. Industrial policy is mainly focused on improving competitiveness by increasing efficiency in these clusters. Therefore, technology development is not a primary focus, which means that there has not been a need for innovation policy.

Industrial policy is influenced by a paradigm of market “neutrality,” which is based on the logic that any industrial initiative must be driven by demand. As a result subsidies are generally not supported. This may be, as experts in this field understand, because some Chilean policy makers are still stuck in the mindset that neoclassical economics is the only guide for policies aiming at inducing economic growth. This paradigm assumes that the markets will self organize and there is no need for specific initiatives for industrial development, which is incompatible with innovation policy. Experts also argued that this paradigm is part of a trauma related to failures of industrial policy intervention in Latin-America during the 60's and 70's[38] (Interviews, 2010).

This is, however, beginning to change with recent initiatives, such as stronger support of university-industry collaboration, more funding available for research projects and increasing importance of risk capital funding. According to experts, this stems from an awareness of a need for more strategies that involve technology-oriented activities and the recognition of the need to address market failures at the micro level (interviews, 2010).

A major milestone has been the establishment of the National Innovation Council for Competitiveness (Consejo Nacional de Innovación para la Competitividad – CNIC) in 2005, which initiated the Innovation for Competitiveness Fund (FIC), as a public-private adviser to the president for the development of policy related to innovation and competitiveness. These organizations are trying to impact the Chilean economy by introducing strategies, and policies, that aim to strengthen competitiveness through innovation. Some of these strategies address the need to increase the importance and long-term perspective of R&D, increase stimulus of new economic sectors, or even increase directly the knowledge intensity of productive sectors (CNIC, 2009).

6.1.3.2 General Stakeholders (entrepreneurial, education, social sectors)

One important feature of Chilean business culture is that they are risk averse, much more than their neighbors (Brazil and Argentina) (Katz, 2009). Consequently, as pointed out by many of the actors, firms will generally not pursue opportunities that have long investment periods and/or high risk, particularly if opportunities are not well articulated, or there is no established internal demand. This is highlighted by CNIC as a critical issue regarding innovation in Chile, as it has been neglected by government policy (CNIC Final Report, 2006).

[38] One example has been the protection of national car industry in the 60's, which ended in disaster (Katz, 2010).

In regards to R&D in Chile, both the World Bank (2009) and CNIC (2006) indicate that the allocated expenditures to be low (below OECD average). They show that only 0.7% of the GDP is invested in R&D, and only 1/3 of this comes from the private sector (CNIC, 2006). World Bank also criticizes the efficiency of R&D resources, which was echoed by some members of Fundación Chile and some consulted experts (Interviews, 2010), suggesting that international firms are resistant to making R&D in Chile.

The low investment of R&D is consistent with actors' corporative strategies, which have been based primarily focused on cost reduction and adoption[39] of technologies. Some experts state that local actors have not been able to learn from FDI programs implemented in past decades. However, there is still need for further technology adaptation and incremental innovation in business strategies, and Chile is taking advantage of these opportunities (Interviews, 2010). A representative of the private sector supported this when he suggested that there are enough "quick wins" in the mining industry to gain advantages and R&D is not yet needed.

Since R&D is avoided, it is not surprising that Chile has been criticized to undervalue intellectual property (World Bank, 2009), which was also evident from interviews.[40] The actors interviewed showed little or no interest towards investing in patents. It was also suggested that, generally, firms in Chile avoid patenting due to a fear of revealing their competitive advantage to competitors (Interviews, 2010). Since innovation requires the interaction of actors and their ideas, this is a perceived barrier for Chilean companies, as there is a lack of trust and a tendency to keep knowledge internally (Interviews, 2010).

Due to a lack of trust between actors, knowledge networks within industries are weak. An experienced representative of the industrial sector explains that universities have not yet proved to be compatible with some needs of the mining industry, despite the

[39] Here it is important to clarify the difference between adoption and adaptation of technology. The former aims to bring to the country technologies already developed and use them as they are. The latter implied a process of innovation that aims modify or improve the technology regarding local conditions.
[40] This was highlighted by World Bank (2009) as one of the key areas of weakness of innovation in Chile, both in the private sector and in universities. Specifically, the report has the following recommendation: "Improving the institutions, regulations and practices to foster an efficient and more dynamic *IP management system."*

government incentives for university – company research collaborations. Besides not being part of the culture, it was also suggested that this may be due to the lack of incentives for universities to produce patents and collaborate with industry (Interviews, 2010; World Bank, 2009).

Furthermore, technological innovation capabilities are low. Training of engineers is primarily based on models of technology adoption (Interviews, 2010). At the same time some interviewees criticized that many of the managers have studied in the same universities and the majority of the programs have the same focus, where technology or innovation management is not incorporated. There is only one master program on innovation management launched recently by University Adolfo Ibanez. Finally, the World Bank (2009), comments that there is little attention given to fostering an entrepreneurial culture in the engineering and science departments of universities.

Despite previous statements, one important actor presented relevant importance of technological innovation in its corporative strategy. Codelco, the national mining company and the biggest copper mining company in the world, has introduced in its business model the support of new corporate ventures, or subsidiaries. These are created following mostly a model of joint venture with foreign high tech companies. Some of these new ventures have developed technological innovations unique in their applications, such as the use of bacteria for improving the lixiviation process of copper, the development of advanced robotics for mining processes or the elaboration of advanced modeling of environmental impact of extraction processes.

Additionally, BHP Billiton, which is the second most important mining company in Chile, has shown interest in learning from this model. Currently, BHP (Minera Escondida) has started programs of collaboration between industry and suppliers trying to increase capabilities of innovation locally (Interviews, 2010). This development is confirmed by interviewed experts in innovation management. They comment that only the large companies, specifically the mining companies, have clarity of technological innovation.

6.1.3.3 Fundación Chile

As described previously, Fundación Chile has made remarkable contribution to the economic growth in Chile. This has been through the application of an innovative business model, where they invest in technology-based risk ventures that the private sector will not pursue. This is by detecting business opportunities based on technology adaptation and industrial diffusion (this is discussed in Section 3.3). This model has been successful in filling technology gaps in Chile's primary clusters (Interviews 2010).

In regards to technological innovation, it is limited to incremental improvements and the use of technology rather than technology development. For example, R&D is avoided, and considered necessary only when there are not complete solutions available for the technology gaps in Chile (Interviews, 2010). As stated by some representatives, Fundación Chile has a pragmatic vision of being focused more on technology projects that, although cannot be pursued easily by private sector, involve normally low risk and have two to four years return on investment. This can be explained by one of the institutional goals that make Fundación Chile achieve "self-sustainability". This suggests indirectly that high-risk long-term projects related to immature technologies are beyond their current scope.

6.1.4 CONCLUSIONS OF "COMPATIBILITY" ANALYSIS

In this section it is presented the conclusions of the analysis of "compatibility" between the foundations of the vision and corporate or institutional strategies of stakeholders regarding three "compatibility criteria": the importance of non conventional renewable energy (emphasis on solar); the importance of global trends of interest; and the importance of technological innovation.

Considering the importance of NCRE among stakeholders: diffusion of NCRE is recent and still low, NCRE usage is driven by specific policies, and only the most cost effective technologies (such as mini hydro, biomass or wind), are used. The market is already saturated so investment of technologies like wind has stagnated. These investments are driven by energy provision instead of technology development. There are only a few activities in relation to solar. Therefore, it is concluded that the importance of NCRE is low, however, increasing through recent policies supporting the most mature NCRE.

Considering the importance of global and internal trends of interest, none of the global trends have been considered as important for developing corporate or institutional strategies. It appears, however, they have influenced some actors to consider future technology adaptation. Many of the projects related to solar have been developed based more on internal drivers like energy insecurity. Although there is an awareness of global trends among some stakeholders, there is little articulation of opportunities developing from these trends. Therefore, it is concluded that the importance of these trends is low.

Considering the importance of technological innovation among stakeholders: in general R&D is not pursued, intellectual capital is neglected, knowledge networks are weak and investments involve low risks and are mostly designed for a short term returns. For the majority of actors, innovation is related to incremental improvements and adaptation of technologies already developed externally. However, some initiatives indicate an increasing awareness of the importance of technological innovation. Therefore it is concluded that the importance of innovation (as technological innovation) is low, but clearly increasing.

From this, it can be inferred that there is low compatibility between the foundations of the vision and current corporate or institutional strategies. Some key stakeholders, however, show higher compatibility. Additionally, recent efforts in the fields of innovation and renewables suggest that this compatibility is increasing and could be accelerated with appropriate stimulus. Therefore, the results of this analysis can be summarized as a low, although increasing, capacity for stakeholders to materialize the vision 2040.

6.2 WHAT ARE THE STRATEGIC DILEMMAS AND OBSTACLES FOR IMPLEMENTING THE VISION 2040?

The previous analysis has revealed a "low, but increasing capacity" among Chilean stakeholders for materializing the vision 2040. It is possible then to argue that they will have low capabilities, or willingness, to pursue such a vision with their current corporate or institutional strategies. With stronger legitimation of the vision 2040 the willingness to pursue such a vision may increase. This would, however, lead to a fundamental dilemma: “shall we keep our current strategies, or shall we change them in order to materialize the vision 2040?”

In this section, this dilemma will be expanded into four specific dilemmas. For each of these dilemmas the targeted actors are identified and a brief explanation of the dilemma is given. Each dilemma will then be concluded with a discussion around the question: what are the main obstacles for changing corporative or institutional strategies? This discussion is elaborated according to the TIS analytical framework and is based mainly on the arguments from the compatibility analysis.

6.2.1 DILEMMA FOR REGULATORY FRAMEWORK: APPLY TRADITIONAL NEUTRAL POLICY OR SUPPORT A SOLAR INDUSTRY?

This dilemma is associated directly to government and policy makers; however other actors that can potentially influence policy may be included.

In this dilemma, applying neutral policy refers to maintaining the traditional paradigm of policy making, which is focused on improving competitiveness by increasing the efficiency of current strong clusters. In this paradigm, technological innovation and support for industrial development of infant technological sectors would not be promoted. In contrast, supporting a solar industry means to move away from the principle of neutraliy and to apply policies of market formation[41] on specific industrial sectors that embody technologies that currently are not cost effective but are likely to be of strategic importance for Chile. As presented in Section 4, policies of market formation have been a key factor for engaging renewables in global industrial activities.[42]

[41] One of the most diffused policies in regards solar electricity has been the “feed in tariffs” scheme.
[42] Policy, not location, makes the biggest difference in the expansion of renewables”. Stated by Dörte Fouquet, executive director of EREF´s -European Renewable Energies Federation. New Energy Magazine, October 2009. For more information see the German case of solar technology development: Jacobsson and Lauber, 2006.

It is important to mention that other successful catching up countries have faced the same dilemma in the past. Jacobsson and Alam (1994, p.59) describe the Korean efforts of fostering more technological infant industries in an environment dominated by incumbents. Korea had to develop strategies that treated well established industries quite differently than the infant industries, which were the particular targets of selective intervention. The mentioned strategies aimed to exploit comparative advantages of incumbents *and* build new ones in the case of infants.

6.2.1.1 What are the main obstacles for supporting a solar industry?

One of the main obstacles for supporting a solar industry lies in the fact that Chile does not have strong innovation policy, and traditional industrial policy is designed upon the neutrality paradigm described above. Without appropriate market formation policies the development of an industry, like solar, would be narrowed to supporting niche applications of solar thermal and to activities based on installation. Electricity would be a distant reality in this scenario, at least until it is cost effective. The formation of a market of cost effective applications in solar could be possible but this is probably insufficient for the emergence of a world-class cluster. According to Bergek et al. (2008a), if a nursing market is too small, it will not sustain a sufficient number of actors to create critical mass.[43]

At the same time, there is low awareness of opportunities of developing a solar industry in Chile among the Chilean actors (See Section 6.1.4). This would mean that solar would be given lower priority than traditional industrial sectors or even other NCRE technologies. Without clarity or diffusion of these opportunities, solar industry will not likely be considered as strategic. Therefore, a solar industry will not be supported by more progressive initiatives that aim to induce the development of more sophisticated industrial sectors (refer to Section 6.1.3.1 for a discussion of the initiatives of CNIC).

The low level of coordination between energy and industrial policy would be another important obstacle in developing a solar industry. As stated in Section 6.1.1, the

[43] In the Swedish wind power case, the first demonstration program in the 1980s only allowed for 2 MW turbines to be built and the first commercial market consisted of isolated investments by farmers and economic associations. This was not enough to provide a market space to support early entrepreneurial initiatives (Bergek, Jacobsson and Sandén, 2008).

energy regulatory framework is focused on goals related to energy provision, and perceived to be achievable without using feed in tariffs. However, when the development of an industry like solar was discussed, it was understood that an initiative of this nature can harmfully intervene with the energy sector strategies (Interviews, 2010). Therefore, the industrial sector, or leaders behind the initiative, would have to look for other mechanisms for supporting such an initiative. A low level of coordination between governmental institutions of different sectors may eventually make it too difficult to articulate efforts around solar due to its own complexity and involvement in different sectors like industry and energy.

Finally, there are policy initiatives that may give the impression that NCRE development is supported in Chile, but in reality the benefits of these policies are only accessible for the currently most cost effective technologies (See Section 6.1.1). These initiatives are based on the belief that solar technology should compete with the other NCRE, and that solar will soon become cost competitive in Chile. As stated in Section 5.1.1.5 this belief has been recognized as a threat for the development of a solar industry.

6.2.2 DILEMMA FOR STAKEHOLDERS: APPLY CATCHING UP TO INCREASE EFFICIENCY OR GO BEYOND CATCHING UP?

This dilemma is relevant to all stakeholders in general (entrepreneurial, educational and social sector)

This dilemma deals with the difference between developing solar technology (see Section 4) and previous experiences of technology adaptation (catching up) in Chile. As it is stated in Section 6.1.3, previous experiences of innovation have been related to the adaptation and incremental innovation of more mature technologies. The main intention of such innovations has been to improve cost reduction and efficiency in current strong clusters. Going beyond catching up refers to adopting innovation strategies (R&D, technological product development, intellectual capital management, etc) and technology development in more sophisticated sectors.

6.2.2.1 What are the main obstacles for going beyond catching up?

One of the main obstacles for going beyond catching up is the high risk aversion of the entrepreneurial and industrial sector in Chile. This behavior causes entrepreneurs and decision makers to avoid the natural risks that technology development involves. This behavior would also propagate a dependence on "demand pull"[44] in business development preventing initiatives that would aim to achieve technological increasing returns[45] and early mover advantages.[46] Chile's risk aversion also influences policy, as shown in Section 6.1.3, which has forced Chile to have a bias towards "neutrality".

At the same time, there is a strong mindset that argues against the possibility of achieving high goals in regards to technology development and economic growth. This is mainly supported by diverse arguments held by interviewees who stressed the lack of professionals and resources devoted to R&D, as well as the low innovation capacity of Chile compared with developed nations.

It is also worth acknowledging that the lack of infrastructure for innovation in Chile is a serious obstacle. This is primarily due to the institutional weaknesses of the national innovation system. As mentioned by experts of innovation in Chile (interviews, 2010), there are low levels of incentives for innovative entrepreneurship, such as low availability of risk capital, as well as high discount rates for such funding. Low importance of R&D, product development or intellectual capital management in current strategies is additional evidence of these weaknesses.

Chile also has a low level of technological capabilities and lack of specialized human resources. This is particularly evident in knowledge development related to science and technology, and innovation management. These obstacles prevent the formation of knowledge systems even at the local level in Chile. This also prevents Chile from

[44] This refers to the condition of waiting for a market to form before entering that market. In regards to technology, this refers to waiting for the market articulating a demand for a technology before developing the technology.
[45] Bigger fraction of knowledge in production costs, network effects and mechanisms of capture of mass markets (Arthur, 1996).
[46] Create the standard and the rules, Low-cost position, create and protect intellectual property, tie up strategic resources, increase switching costs for the producer, increase switching costs for the customer. (Dorf and Byers, 2006).

having the adequate absorptive capacity (Section 3.1) to take advantage of external sources of knowledge like FDI, joint ventures, licensing, or even technology adoption.

6.2.3 DILEMMA FOR PROJECTS OF MINING EXPANSION: SOLVE PROBLEMS WITH CHEAPER ENERGY, OR PUSHING FOR SOLAR?

This dilemma is associated with actors involved in the mining expansion projects: among others, mining sector, GORE (Regional Government Atacama), central government, companies related to water technologies and Fundación Chile.

This dilemma emerges within the context of the mining expansion projects in the Atacama Desert. As it was expressed in Section 5.1.2, these megaprojects will demand the provision of nearly 250 million m^3/year of desalinated seawater by 2020. As is well known, water desalination is a highly energy intensive process. Therefore, to support these megaprojects it is expected high resource mobilization in energy and water infrastructure, which will demand the intervention of world-class external suppliers.

At the same time, this dilemma emerges in the context of the Atacama Initiative. In this initiative, Codelco, GORE and Fundación Chile have initiated exploration projects of solar applications related to industrial heating processes and solar desalination. These projects have as final goal to evaluate the feasibility of these initiatives and estimate the real costs of using solar energy in comparison with coal, the cheapest alternative. Codelco expects to have a wide use of solar, if it demonstrates to be feasible (Interviews, 2010).

Solving problems with cheaper energy implies basing decisions on a traditional mindset of cost reduction and high efficiency of current activities. These decisions would lead the mining companies to choose the cheapest energy option to support the expected mega infrastructure. In this case solar could replace coal if it demonstrates to be cheaper.[47] In contrast, pushing for solar implies basing decisions on innovation and technology development strategies. This means to take advantage of the large resource mobilization expected for these megaprojects for building nursing markets of

[47] Since it is well known that solar technologies are not cost competitive and it is uncertain of its future cost reductions, there are no clear indicators when it will compete with coal.

solar technology,[48] even in the case solar projects are not currently economically feasible. Desalination applications with solar would be of key interest.

6.2.3.1 What are the obstacles of pushing for solar?

One of the main obstacles of pushing for solar is the strong tendency of pursuing traditional strategies. As it is presented in Section 6.1.3 the general focus on short term investments, cost reductions and efficiency of main clusters (especially mining) would lead organizations to suffer from "core rigidities."[49] These "core rigidities" could deter them from pursuing other business strategies, like diversifying in other more technology driven sectors. These obstacles can be propagated by a low awareness of opportunities for the formation of a solar industry in Chile (such as those presented in Section 5.1) and by the current success of incumbent industries related to the high prices of raw materials.[50]

The low innovation infrastructure, capabilities and human capital, especially in the regions within the Atacama Desert, are critical obstacles in the push for solar. This would pressure main mining actors to mobilize resources associated to the megaprojects without engaging local suppliers or knowledge networks. This may eventually hinder the knowledge absorption from the needed technological solutions, like desalination, and hinder a possible formation of niche applications from the interaction of such solutions with solar technology. Additionally the development of NCRE, specifically solar, in Chile is still incipient and faces challenges related to: the lack of trained engineers,[51] the lack of confidence and experience with the technologies, the lack of service and capital goods companies, and the uncertainty of operation costs and power factors.

A neutral participation of the government in these megaprojects would reinforce the risk averse behavior of actors. This would lead actors to continue with strategies

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[48] It is needed to acknowledge that it wouldn't be possible to think in a total supply of solar electricity for these megaprojects.

[49] According to Leonard-Barton (1992), values, skills, managerial systems, and technical systems that served the company well in the past and may still be wholly appropriate for some projects, are experienced by others as core rigidities or inappropriate sets of knowledge. "Core capabilities are the flip side of core capabilities".

[50] In the last years, copper prices have been the highest in the last 40 years. (Codelco, Annual report 2008).

[51] Only four universities were found to exhibit even marginal activities in solar research.

based on short term investments and cost efficiency. As a result there would be an exclusive and massive use of coal for satisfying the new energy demand.

6.2.4 DILEMMA FOR FUNDACION CHILE: BUILDING A SOLAR CLUSTER BASED ON THE CURRENT BUSINESS MODEL OR GOING BEYOND?

This dilemma is associated to Fundación Chile in the specific situation of building a solar cluster in the Atacama Desert.

As discussed in Section 6.1.3, adopting solar technology is not similar to previous experiences of technology adaptation in Chile. In the opinion of experts of innovation management, solar technology can represent challenges that have not been faced before due to two conditions (Interviews, 2010): (a) Time: in current circumstances there will be an urgency to obtain results in the short term, and therefore, lead to a low acceptance for long term projects like solar (b) Funding: this kind of development (solar) would need large amounts of resources that may be beyond the scope of many organizations.

As explained in Section 6.1.1.3, Fundación Chile is acting as a system builder in the development of the solar industry in Chile. To accomplish this role with the current business model implies to implement and diffuse those applications (opportunities previously explored) that will be considered feasible in a short-medium time. Their main criterion to evaluate the feasibility of technologies is to focus on possible efficiency gains for the mining sector through energy cost reductions.

Accomplishing the role of system builder using a business model that goes beyond their current business model implies the use of the strengths of their current business model, but also filling corresponding gaps in order to face challenges (related to the time of projects and finding larger funding) from a new perspective. These gap-filling activities could allow the emergence of a technological innovation system.

6.2.4.1 What are the main obstacles for going beyond Fundación Chile's business model?

The main obstacle is related to the eventual influence of core rigidities in Fundación Chile. These core rigidities are associated to the eventual existence of inertia to change strategies that have been very successful in the past but could hinder success when it is needed to take new approaches. This is something that successful organizations have suffered in the past, especially when previous success is highly recognized. This inertia could be related also to the need of accomplishing internal goals like financial self-sustainability that could lead to Fundacion Chile to support just projects with short payback periods.

Core rigidities could pressure the management of the Atacama solar project to find solutions only in the scope of use of the current business model of Fundación Chile, associated to technology transfer of more mature technologies and focus on cost efficiency, even when other more appropriate strategies may be required. Consequently, the process of building a solar cluster could be limited to the rate of global maturation of solar technologies rather than be stimulated by proactive strategies. Furthermore, core rigidities could hinder the role of Fundación Chile as an effective system builder, or prevent Fundación Chile from detecting and, therefore, exploiting the opportunities that the development of a solar industry may have for Chile.

7 CHAPTER 7: KEY ELEMENTS OF STRATEGY

As it is mentioned earlier, the materialization of a world-class solar cluster in Chile is an enormous challenge. Given this, the resulting question is: what should be the strategies for materialization? In our perspective, strategies should aim to overcome obstacles that can prevent stakeholders from strengthening their capacity for materialization. According to our analytical framework, this capacity is related to the performance of those functions upon which the performance of a technological innovation system depends.

Before attention is given to the obstacles and the attempts of overcoming them, it is necessary to recognize the role of Fundación Chile as a system builder. The existence of a system builder with a high degree of prestige in the political arena, as is the case of Fundación Chile, becomes a powerful mechanism to accelerate and catalyse the formation of a TIS. Successful industrialization experiences, like the salmon farming, are clear local examples of this approach.

In order to identify appropriate elements of strategy it is also necessary to recognize the general issues related to the solar industry. Within previous sections of this document it has been shown that solar technologies are not yet mature, and their development is mostly pushed by the effects of the growing knowledge of climate change, as well as nations energy insecurity. The climate change phenomenon is applying pressure on countries to reconsider how energy is produced and consumed and think within in a global context. The effects of climate change will eventually open opportunities without precedents for industrial development. They will also set up new trends and standards of technological direction, upon which countries will need to choose to be aligned, or not. In parallel with the global pressures, it has been shown that Chile is experiencing internal changes, or “cracks”, related to their recent energy crisis and a rapidly increasing energy demand stimulated by the expansion of the mining industry. Additionally, these cracks could be related to the acknowledged new and increasing importance of the use of renewable energy and Technological Innovation at the national level. Both are stimulus for the implementation of non-conventional strategies of industrialization in Chile.

Taking into account all these issues, there is a need to acknowledge that the development of strategies must start by recognizing the central role of the system builder. Given the particular case of solar, the system builder must recognize the convergence of external and internal driving forces, and the subsequent opportunities, which become key criteria for the development of strategies.

However, strategies should not only depend on the pursuit of opportunities. Obstacles that could hinder the capacity of materialization of stakeholders must also be identified such that they can be overcome. In this section elements that could be used for developing strategies are given. These elements, and subsequent strategies, are intended to facilitate the overcoming of the previously identified obstacles. Additionally, this section will suggest direction for a next step of system building. To be clear, these elements of strategy are not intended to be detailed strategies, but to provide criteria useful for the generation of strategies.

7.1 GOING BEYOND CATCHING UP

To go beyond catching up, four elements of strategy are perceived. Firstly, there is a need to strengthen structural change at the institutional level in order to foster a system of innovation (building or reinforcing intellectual capital institutions, venture capitalists sector, risk capital funding, etc). This can be supported by promoting technological entrepreneurship in both universities and the private sector. This would contribute to reducing the risk averse behavior of actors in Chile. Here CNIC has a key role. Since this is a relatively young organization, its work has to be enhanced and diffused.

Secondly, there is a need to diffuse the opportunities of industrialization based on technological innovation, in general, and opportunities of building a solar industry, in particular; this may contribute to the legitimation of the foundations of the vision 2040 and eventually of the solar industry in Chile. In fact, one of the key lessons in the Taiwanese successful industrialization experience has been the diffusion of innovation management by different means (Mathews, 2006). Adequate legitimacy of solar in Chile will increase national expectations and create better conditions for the emergence of the solar industry.

Thirdly, there is a need to increase knowledge formation, technological capabilities and to master catching up on solar technologies. As mentioned in Section 3.1, successful experiences in newly industrialized countries show that "active learning" lead to success in catching up and is, at the same time, needed in order to go beyond catching up. Active learning implies learning from external sources (Foreign Direct Investment, Join Ventures, or through technology intelligence units) and stimulating the internal learning processes by institutional building. Here Taiwan offers important lessons with the creation of ITRI.[52] As it is emphasized in Section 3.1, stimulating learning processes will require the application of conservative and non-conservative policies at the regulatory framework.[53]

Finally, considering Chile's lack of similar industrial experience, due to the particular characteristics of the technology, and the uniqueness of the global context, it should be noted that solar technology development in Chile would require the application of some unprecedented strategies.

7.2 SUPPORTING A SOLAR INDUSTRY

In order to support a solar industry in Chile, three elements of strategy are perceived. Firstly, policy needs to be influenced. This can have two complementary goals: (1) to stimulate innovation and technological development as a competitive strategy for the Chilean industrial sector (fostering the national system of innovation); and (2) to promote the emergence of new industrial sectors of strategic importance. This may eventually strengthen the influence of innovation and technology development in the national strategy of industrialization. The intentions of these suggested activities is to

[52] ITRI (Industrial Technology Research Institute) is one of the foundations of the multimedia cluster in Taiwan. ITRI not only performs functions deeply related to R&D, but also activities of education and training. Additionally ITRI has developed a role of venture capitalist, founded more than 150 companies, most of them knowledge intensive. (Mathews, 2006) (*www.itri.org.tw*)

[53] According to Chandra (2006), industry-specific policies for fostering technology transfer in successful catching up countries fall into several categories like: Negotiating with MNCs (multinational corporations), spinning off domestic firms, facilitation acquisition and dissemination of technologies, promoting exports, developing industrial clusters, providing regulatory services, supporting industry organizations and coalitions, and meeting technical manpower requirements.

allow the emergence of infant industries that are focused particularly on more sophisticated sectors, as well as maintain success in strong traditional industrial sectors. This involves a progressive change in the regulatory framework, from a neutral and rigid approach to a framework that is able to promote the emergence of new industries. The achievement of these goals would generate a better climate such that solar could eventually be considered as a sector of strategic importance for Chile. Without these actions the future solar cluster would not receive the support needed to reach world-class status.

Secondly, there is a need to form and strengthen advocacy coalitions. Such coalitions may increase the legitimation of knowledge and technological innovation as a national competitive strategy and solar technology as a strategic sector. The formation of coalitions may also contribute to influencing policy in favor of the new industry, as it happened in the emergence of the technological innovation system of solar in Germany (Jacobsson and Lauber, 2006). In the case of solar in Chile, these coalitions can be composed of organizations with direct interests in the sector (Codelco, Regional Government of Atacama, Fundación Chile, solar entrepreneurs, etc). They could also be supported by groups interested in sustainability. It is important to remark that there is strong global social legitimacy for solar technology in comparison to other traditional and even non-traditional energy sources.

Thirdly, there is a need to promote leadership, proactive roles and coordination for innovation. As addressed by Santana (interview, 2010) leadership and proactive positions from governmental institutions play a central role for leading initiatives involving others and for identifying the appropriate support mechanisms. Improving coordination at the policy-making level would suggest the need of coordinative organizations.[54] These institutions need to have strong enough authority to legitimate initiatives and persuade other organizations accordingly.

[54] In regards to innovation initiatives, these organizations receive the name of coordinators of the national system for innovation, like the case of VINNOVA in Sweden. CNIC would have the same role in Chile; however it is also acknowledged that Fundación Chile has accomplished roles of coordination.

7.3 PUSHING FOR SOLAR IN PROJECTS OF MINING EXPANSION

To push for solar in Chile's mining expansion four elements of strategy are perceived. First there is a need to strengthen legitimation of solar at the technical level. This means to turn mining companies' view of solar technology, from a cost reduction opportunity for their current processes, into a business opportunity for diversification and sustainable competitiveness. This can be supported by a comparison of the future costs of developing a solar industry with the future costs of internalizing negative externalities of being locked in to currently cheaper sources of energy like coal.[55] This can also be supported by identifying and diffusing opportunities of building a solar industry in Chile, such as those presented in Section 5.1.

As mentioned in Section 5.1.2.1, there are expected to be significant investments in building desalination plants to meet the demands of the expanding mining industry (as much as 7.5 billion USD). If 5% of these investments were allocated for the diffusion of a concentrated solar power (CSP) plant, it would amount to 350 million USD. This is approximately the cost of the recently commissioned Andasol 1 plant in Spain (DLR, 2010), which has a capacity of 50 MW, and produces 150 GWh/yr (Flagsol GmbH, 2010). A 50 MW CSP plant in Chile could cover over 20%[56] of the annual power requirements for the expected desalinated water demand, and reduce CO_2 emissions by as much as 150000 tons/yr.[57]

Secondly, there is a need to combine synergistically the technological capabilities already developed by some key stakeholders, such as the highly specialized mining industry in Chile, and its local and international world-class suppliers. As it is presented in Section 6.1.3.2, Codelco have developed some world-class innovations using a model based on technological subsidiaries. This is likely Chile's most important source of technological entrepreneurship. Combining the established technological capabilities can be possible by strengthening alliances with the mining

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[55] Internalizing negative costs refers to the future cost of a product's, or service's, carbon footprint or the costs of future emission control/reduction in carbon-based power plants.

[56] This is assuming that such a CSP plant would produce 150 GWh/yr and each cubic meter of desalinated water requires 2.5 kWh of electricity, and the annual demand for desalinated water is 250 million m^3.

[57] This value was calculated assuming the CSP plant would be replacing a coal power plant and using an average CO_2 emissions value for coal power generation to be 2249 lbs/MWh, or 1.02 tons/MWh (US EPA, 2010).

sector by stimulating the involvement of other entrepreneurs: namely suppliers and facility installers. These entrepreneurs are called to supply services and components for applications in global markets, such as industrial heat (including concentrated solar thermal). They are also called to absorb knowledge that will come from foreign companies and after that, called to diversify in areas like new components and applications. The evolution of these entrepreneurs would be in parallel with the emergence of world-class knowledge centers in related technologies to support the entrepreneurs and reduce their perceived risks.

Consequently, there is a need to stimulate cooperative interaction between the technology-innovation driven entrepreneurial sector and the government. Although still small, this entrepreneurial sector exists already in Chile (for example Codelco's technological subsidiaries) and can be extended to the solar industry. Cooperation with the government would become crucial. Firms active in technology entrepreneurship in Chile face bigger risks (market or technical) as compared to those in countries with stronger innovation infrastructures, therefore they need the support of the government. For example, as stated before, the Korean government applied different forms of intervention to foster their more technological infant industries. These instruments were: industrial policies, trade policies and even policies that aimed to influence attitudes and perceived opportunity sets of entrepreneurial sector (Jacobsson and Alam, 1994, p.60).

Finally, it is needed to build and strengthen absorptive capacity and knowledge formation (human capital, equipment, laboratories, etc) in Atacama and other regions that will be involved with the megaprojects of mining expansion. These actions would have the intention of maximizing the transfer of knowledge from foreign investors to local suppliers, universities and other actors. This could eventually lead to the emergence of an active learning system of water desalination in the Atacama Desert.[58] As expressed before, the technological interactions between desalination and solar thermal applications may produce promising niche markets.

[58] See Section 3.1 for an explanation of active learning.

7.4 GOING BEYOND FUNDACION CHILE'S MODEL

For Fundación Chile to go beyond their current business model, they need to strengthen innovation management. This is necessary to increase their consciousness of, and capacity for overcoming, eventual core rigidities that could hinder the achievement of critical milestones for solar development or even the detection of new business opportunities. However, this does not imply not using core capabilities. As Benavente argues (interview 2010) there are values and capabilities that are inside Fundación Chile that are essential for the development of a project of such magnitude (in regards to the solar cluster). Fundación Chile needs to be recognized for their leadership, coordination, credibility, relatively long term commitments, access to funding among incumbents industries and the government, and others. Coordination efforts with key institutions could be stimulated in order to obtain complementary capabilities. It will also be important to strengthen collaboration with initiatives generated in CNIC.

7.5 NEXT STEP[59] STRATEGIES FOR SYSTEM BUILDING

To give direction for the next step in building the system,[60] a role initially pursued by Fundación Chile, three elements of strategy are perceived. Firstly, there is a need for Chile to master the catching up (active learning) of solar thermal technologies that could be compatible with solar electricity production. These technologies could reach, in the short term, technical legitimacy in Chile,[61] and achieving the formation of a market would be easier, considering current obstacles for materializing the vision 2040. In that sense, the formation of an initial internal market can be based on applications related to heat, which can be complementary to CSP (concentrated solar power) electricity generation technologies. The idea is to exploit opportunities of the global market of solar electricity by producing compatible components that could be used also for heating purposes not necessarily related to electricity generation but accessible for the formation of internal market.

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[59] These strategies are only considered as a first step, so that they do not consider elements for the consequent materialization of the vision 2040 in its total time scope.
[60] See section 2.1 for an overview of the concept of system builder.
[61] With solar legitimacy we mean cost benefit analysis considering negative externalities of use of coal and opportunity cost for moving into the solar sector.

It is, therefore, necessary to measure the potential expansion of thermal applications in Chile. This is necessary to determine which correct support mechanisms would be needed to ensure an adequate expansion of these applications that would allow them to achieve critical mass in the case that cost feasibility is insufficient to achieve this purpose. As stated before, size matters for a nursing market, and, because of the coming mining mega projects, desalination applications can become key points of interest.

Finally, it is again worth mentioning that external funding for climate change mitigation is an opportunity, which can be exploited to support goals of building niche markets of NCRE technologies. For this, it is needed to have a deep understanding of the real scale of the global energy transformation and the maturing funding mechanisms for non Annex I countries. It is therefore suggested to consider the development of a "national strategy for the development of solar technology, as a national effort for climate change mitigation" (Section 5.1.1.5) that can be proposed and negotiated within the Kyoto Protocol framework.[62]

[62] Due to the urgent need to scale up efforts of carbon mitigation in developing countries, international negotiations have identified the need to explore "nationally appropriate mitigation actions". One of three main policy scenarios is the sectoral CDM, a mechanism that aim engaging developing countries on a very large scale mitigation actions by focusing on entire sectors. (Boyd et al, 2009)

8 CHAPTER 8: FINAL CONCLUSIONS

Global action against climate change demands a strict reduction of CO2 emissions, implying a dramatic change in the way modern society produces and uses energy. This change demands the development of non conventional renewable energy technologies at industrial scale in a relatively short time. In Chile, renewables are not only a matter of global significance. As Chile faces problems of energy insecurity and a rapid increase of national demand, the option of renewables is critical for them. It is in this context that Fundación Chile, an organization that promotes industrial development in Chile, pursues the materialization of a world-class solar cluster in the Atacama Desert.

The aim of this master thesis was to answer three main questions:

- What could be a vision for building a "world-class" solar cluster in Chile?
- What are the main challenges of the materialization of this vision?
- What are the key elements of strategy for the materialization of the vision?

It was argued that a vision for building a "world-class" solar cluster should consider three main foundations upon which it can be built. These foundations are:

- **Taking advantage of remarkable opportunities for countries like Chile in the context of an imminent process of global energy transformation**. Such opportunities are related to the expected global expansion of the market of solar technologies, the increasing importance of external funding for climate change mitigation in developing countries, and eventual comparative opportunities for countries like Chile (referring to countries that have increasing energy demand and no obligations to replace dirty energy infrastructure).
- **Using internal needs and challenges as drivers for stimulating the growth of a sustainable energy system in Chile and developing knowledge and capabilities needed for a technological cluster**. These needs, such as the increasing water scarcity or the energy insecurity, can become sources of knowledge generation and capability building. They can also be convenient stimulus for aligning the country to a direction compatible with the global trends that involve transforming the energy systems towards sustainability.

- **Building industries based on technology and knowledge production and exportation.** It was shown that, for the case of solar, the development and eventual export of knowledge and technology is necessary for a cluster in Chile to achieve world-class status and sustain competitiveness in global markets. Furthermore, by reflecting on the recent industrialization of other catching up countries it was shown that this is not an impossible goal for Chile.

The vision 2040 has been developed by the authors of this document through a creative process, which was based on these foundations. With the exception of Fundación Chile, the vision 2040 was not presented to any of the stakeholders interviewed in this study. This vision describes five components that outline processes for which the cluster can build world-class leaders in the production and exportation of knowledge and technologies related to solar energy generation, as well as other means of 'green' energy generation.

Materializing a vision such as the vision 2040 represents a considerable challenge to current stakeholders, due to the low compatibility between their current corporate or institutional strategies and the foundations of the vision. To be able to increase their capacity of materializing the vision 2040 the stakeholders need to adjust their current strategies in order for them to be able to: support the industrial development of solar technology; go beyond catching up strategies; and to legitimize solar as a profitable business opportunity rather than as an energy commodity. For Fundación Chile this change implies going beyond its current business model.

The necessary change is not an obvious choice. Although the vision may be materialized with current strategies, stakeholders would face strategic dilemmas of whether to change (and bear the risks and efforts associated) or to keep current strategies. The most important obstacles that could hinder change are related to: the lack of strong innovation policy; the paradigm of neutrality in industrial policy; the low legitimacy of a solar industry in Chile; high risk aversion of entrepreneurial sector; low self confidence on industrialization goals; the low innovation infrastructure in Chile; the lack of specialized human resources; and core rigidities in key stakeholders.

In order to overcome obstacles, elements of strategy must be considered for policy making and system building. They address general, but critical issues such as legitimation of the solar industry, the coordination between actors, the development of active learning systems (like a system of desalination technologies in the Atacama Desert), the reinforcement of a national system for innovation in Chile and the general diffusion of innovation management competencies. Being conscious of future core rigidities must be considered for Fundación Chile, as an element of decision making.

It is also recognized that Fundación Chile, having a role of a system builder, becomes a powerful element that could be determinant for the formation of the solar industry in Chile. Regarding particular issues related to this industry, Fundación Chile must be able to identify and have a clear understanding of external forces and internal changes such that a cumulative combination of drivers can be used for the designs of appropriate strategies that could exploit real opportunities for Chile.

Finally, next step strategies are given as suggestions to Fundación Chile in order to reinforce its role of system builder. These strategies suggest the implementation of actions that can permit Chile to master catching up of solar thermal technologies. This development should focus on applications that could be compatible with technologies that can be used for the generation of electricity, in order to capture these markets. It should also accelerate the legitimacy of a solar industry in Chile in order to generate conditions for the emergence of an infant industry. Finally, it should enable the development of strategies for capturing external sources of funding for mitigation to climate change, as a means of leveraging efforts of market formation in early stages.

APPENDICES

APPENDIX 1: Stakeholders and Relevant Interviews[63]

Primary Stakeholders	Contact	Position	Sector	Description
Acciona Energia S.A.			Industry	Global energy company with expertise in CSP
AES Gener S.A.			Industry	Generation Company in Chile with several coal plants
Aquavant (Chilean industrial water purification company)			Industry	Desalinization and energy systems engineering
BHP Billington: Enscondida			Industry	Chile's second largest mining company
Centro National de Energia			Government	Energy policy
Centro Renovables de Energia (Renewable Energy Center)			Government	NCRE Technology Energy Policy
Chile Solar Energy Association (ACESOL).			Industry	Representative of solar water heating systems
Chile Sustentables			Social	Environmental Non-governmental organization
Codelco			Industry	Chile's largest mining company
CORFO			Government	Chile Economic Development Agency
EcoEndesa			Industry	Chile's largest power company
(Fund for the Promotion of Science and Technology Development)			Government	S&T funding and policy

[63] *Highlighted stakeholders were not interviewed*

Primary Stakeholders	Contact	Position	Sector	Description
Fundacion Chile		Director of Environment and Energy	Govern / Industry	Business development for Chile by technology transfer
Fundacion Chile		Manager of Human Capital and Information Technology	Govern / Industry	Business development for Chile by technology transfer
Fundacion Chile		Manager of Business and Corporate Strategy	Govern / Industry	Business development for Chile by technology transfer
Fundacion Chile		Director of Solar Energy Development	Govern / Industry	Business development for Chile by technology transfer
Fundacion para desarrollo fruticola		Director - gerente	Industry	Agro-industry
Gobierno de Atacama (Atacama Regional Government)		Development Manager	Government	Social and economic development
International Copper Association		Executive Director	Industry	Stimulates international demand for copper
Mining Industry Robotic Solutions (MIRS)			Industry	A high tech subsidiary of CODELCO
Universidad de Chile			Education	Solar technology
Universidad de Atacama			Education	Training
Universidad de Atacama			Education	Investigating applications of Copper in PV cells
Universidad de Chile / CNIC		Professor	Education	Economics & Innovation
Universidad de Chile		Professor	Education	Economics & Innovation

Secondary Stakeholders	Contact	Position	Sector	Description
Chamber of Commerce			Industry	Entrepreneurial sector
Comision Chilen del Cobre			Industry	Mining Sector
Comision de energia Camara Diputados			Industry	Energy Sector
Grape Growing association			Industry	Agro industry
Ingeniería y Desarrollo Tecnológico S.A.			Industry	high tech engineering company
Ministry of Industry			Government	industrial policy
Wine makers association			Industry	Agro Industry

Experts

Organization/Institute	Contact	Position	Sector	Description
Chalmers University of Technology	Sandén, Björn	Professor	Education	Technical Change and PV Industry specialist
Solar Energy Association of Sweden & Chalmers University of Technology	Dalenbäck, Jan-Olof	Vice president / Professor	Industry/ Education	Swedish Solar Water Heating
Chalmers University of Technology	Kushnir , Duncan	PhD student	Education	Nano-technology, Lithium
Chalmers University of Technology	Baumann, Henrikke	Associate Professor	Education	Industrial Symbiosis and Green Labelling

APPENDIX 2: Key indicators for exploring corporate or institutional strategies

Key indicators for exploring importance of innovation

In order to explore innovation capacity we focus on key indicators like:

- Importance of R&D investment in corporate strategy (entrepreneurial sector)
- Importance of technological product development for competitiveness (entrepreneurial sector)
- Importance of intellectual capital assets (entrepreneurial sector)
- Importance of investment in risk capital sector – degree on appearance of innovative firms (entrepreneurial sector)
- Importance and impact of knowledge networks (universities, entrepreneurial sector)
- Degree of specialization and size of human capital formation (universities)
- Degree of support for innovation policy (government)

These indicators has been extracted from the extensive literature of innovation audit and has been tested in many recent surveys such us the one presented by Yan, et all. (2004).

Key indicators for exploring importance of NCRE capacity

In order to explore focus on renewable energy we focus on key indicators like:

- Importance of NCRE investment in corporate strategy (case of entrepreneurial sector)
- Importance of technological development in NCRE (entrepreneurial)
- Importance and impact of knowledge networks (universities, entrepreneurial sector)
- Policy for NCRE (entrepreneurial sector, government)
- Degree of specialization and size of human capital formation (universities)

Criteria for exploring importance of internal and global trends

In order to explore the awareness of the main trends of impact in the international and local context, the following criteria are applied:

- Analysis of their current activities related to NCRE and identification of perceived opportunities and threats.
- In case the organization is aware of the trends and do not have related activities in NCRE, perception of threats or blocking mechanisms are identified.
- In case the organization is not aware we would present some opportunities and we would collect the perception of the stakeholders in relation to those opportunities.

APPENDIX 3: Using the method of scenario analysis for identification of opportunities for a world-class solar cluster

In this appendix, it is presented the results in each step of the scenario analysis method applied for the identification of opportunities.

Step 1: address the focus of the analysis, which has to be relevant, challenging and suitable in time horizon. In our case the focal issue is: "What are the opportunities/threats and critical uncertainties of implementing a solar technological cluster in Chile?"

Step 2: Identify historical events that have important impact on the focal issue. Accordingly, the most important events related to the solar industry (mainly in the last five years) were identified and organized in a chronological way. Important connections between them were stressed.

Step 3: Identify the surrounding factors that are important for the focal issue – now, and in the coming years. A list of 15 factors has been developed by the authors and is presented as follows:

1. Countries increasingly adopt policies for renewable.
2. Demand for desalination plants increases.
3. CSP competes on costs with NG by 2015.
4. Carbon Market increases in attractiveness and size.
5. Difference of electricity price (industrialized/developing countries) increases.
6. Carbon lock-in in industrialized countries becomes relevant.
7. Demand for electricity increases in developing countries faster than the developed world.
8. External founding is allocated in emerging economies in projects of mitigation against climate change.
9. New NCRE policy in Chile favors only the most mature renewable technologies.
10. Solar electricity capacity increases globally.
11. Fossil fuels are decreasing and demand for cars is increasing.
12. Petroleum prices go up.
13. International electricity generation is becoming more decentralized.

14. Asia go ahead with PV industry (more Asian countries start develop solar technologies: China, Taiwan, Japan, Korea, India).
15. Industrial policy in Chile is bias to support traditional industrial sectors rather than high tech sectors.

Step 4: Based on the factors identified, trends and critical uncertainties can be developed by placing the factors in a diagram according to their level of importance and degree of uncertainty. (See Figure A.0.1)

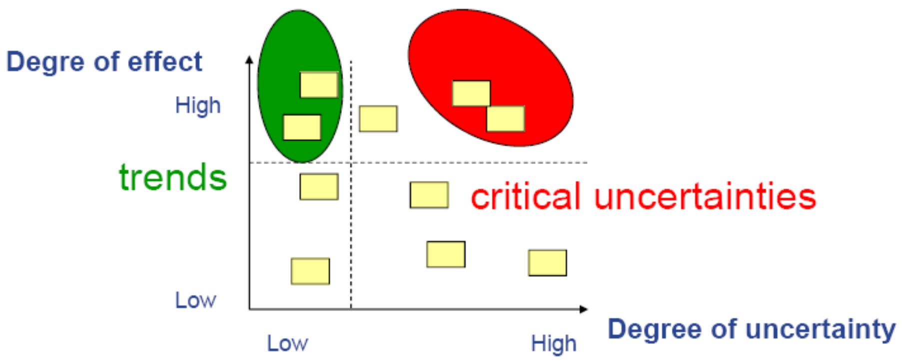


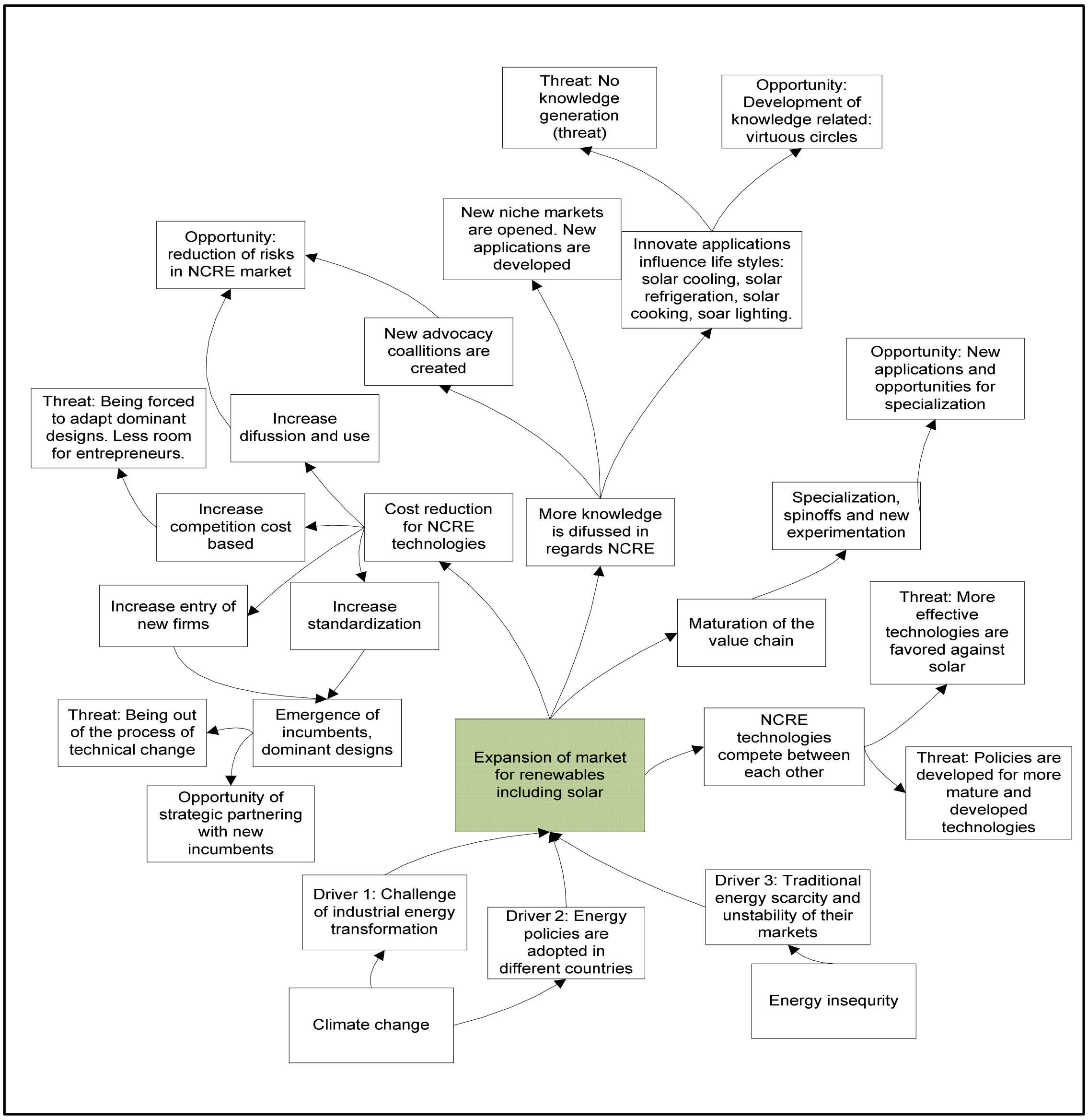
Figure A.0.1. Trends and critical uncertainties in scenario analysis method.
Source: Magnusson (2010), presentation of the institute of management of innovation and technology.

Afterwards, factors with more importance are selected. Those factors with low degree of uncertainty become trends and those with high uncertainty become critical uncertainties. As for this study, critical trends and uncertainties are:

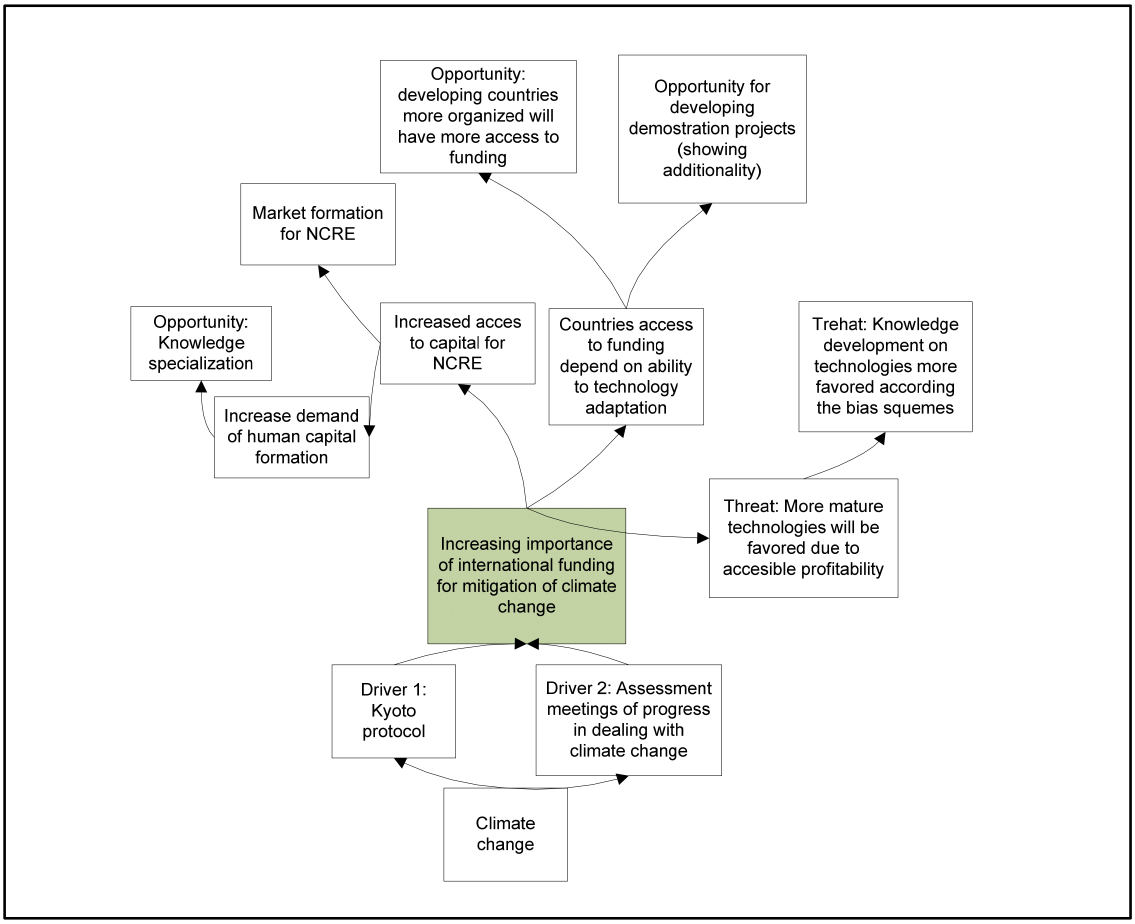
- Internal trend 1: Increasing Water scarcity
- Internal trend 2: Increasing Energy Scarcity and Insecurity
- Internal trend 3: Increasing Demand of Energy
- Global Trend 1: Expansion of the market for renewables, including solar
- Global Trend 2: Increasing importance of international funding for mitigation to climate change
- Critical uncertainty 1: Carbon lock-in in industrialized countries becomes relevant
- Critical uncertainty 2: CSP competes on costs with NG by 2015

Step 5: Identify opportunities and threats developing “trees” of consequences from the critical trends. The trend is represented by the trunk and the consequences by the branches. For example, for the trend "expansion of markets", consequences are identified by asking: what is a consequence of that trend?. Consequences can be of first, second or third order. In this appendix are presented trees of consequences for external critical trends.

Opportunities and threats for global trend 1: Expansion of the market of renewables including solar.



Opportunities and threats for global trend 2: Increasing importance of international funding for mitigation of climate change



APPENDIX 4: Sample Questionnaire (Codelco)

Exploring importance of technological innovation in corporate strategies

1. In the last few years, Codelco has allocated between 2.5% and 3.5% of total investments, and less than 0.4% of total revenues into R&D, collaborations and technological subsidiaries.
    a. How important is R&D in the corporate strategy?
    b. Do you expect this to grow?
    c. How important is technology development (new products) for the corporate revenues?
    d. How important are networks for the corporate revenues?
2. Present our awareness of their activities in technology development, adoption and regarding R&D investments and networks (collaborations):
    a. What are the main drivers for these activities?
3. Regarding technological subsidiaries:
    a. What are the main drivers for these activities?
    b. How innovative are these subsidiaries?
        i. What is the rate of new product development (could be based on revenues)?
        ii. Is R&D investment growing?
        iii. What is the importance of intellectual capital assets?
        iv. How much do these subsidiaries contribute to the total revenue of Codelco?
        v. What areas are you
4. Is there any connection between your technology subsidiaries and NCRE related projects?

Exploring importance of NCRE technologies in corporate strategies:

5. Regarding the company's current activities that involve NCRE technologies:
    a. What are the drivers that support these activities?
    b. In which stage are these projects? Are there bottlenecks?
    c. Why is Codelco pursuing electricity generation rather than leaving these activities to established generation companies?
6. Which NCRE technologies are most interesting to your company? Why?

a. What is your perception of the opportunities of solar driven technologies, in regards to solar thermal power generation, PV, and solar heating?

7. How do you perceive the role of NCRE technologies in the next 10, 20, 30 years?

8. How do you perceive the recently implemented **Non-Conventional Renewable Energy policy** and Law 19.940?
9. How do you perceive other policy instruments that aim to support NCRE technologies? Is Codelco aligned with the current policies?
10. How do you perceive the role of NCRE policies in the next 10, 20, 30 years?
    d. Could you describe policies that would better support the development and adoption of NCRE in Chile, and would be more favorable for Codelco?

Exploring importance of internal and global trends in corporate strategies:
Presentation of relevant trends: energy insecurity, water scarcity, market expansion of NCRE and solar technologies, external funding to climate change mitigation, lock-in complex and solar energy costs.

11. Is your company aware of these trends (Y/N)?
    a. **If yes**... Do these trends influence your company's strategies (Y/N)?
        i. **If yes…** What opportunities or threats does your company address within its strategies?
            1. What are the **implications** of addressing these opportunities and threats?
        ii. **If no…** Why not?
    b. **If no**… (this is unlikely) what are the key trends or drivers that influence your company's strategy in regards to innovation and energy?

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