CHILE’S SUNNY FUTURE: THE INFLUENCE OF ALLENDE AND PINOCHET ON SHAPING PRESENT DAY CHILEAN ECONOMIC DEVELOPMENT AND ENERGY POLICIES PROMOTING THE USE OF SOLAR ENERGY

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LIST OF ABBREVIATIONS

CCF: Canadian Climate Fund

CER: Centro de Energías Renovables Center for Renewable Energy

CIE: Comité de Inversiones Extranjeras Committee on Foreign Investment

CIFES: Centro Nacional para la Innovación y Fomento de las Energías Sustentables National Center for Innovation and Development of Sustainable Energy

CO₂: Carbon Dioxide

CODELCO: Corporación Nacional del Cobre de Chile National Chilean Copper Corporation

CORFO: Corporación de Fomento de la Producción Corporation for Production Development

CSP: Concentrated Solar Power

DEG: Deutsche Investitions- und Entwicklungsgesellschaft German Entrepreneurial Development Corporation

DHI: Daily Horizontal Irradiance

DNI: Direct Normal Irradiation

ECLA: Economic Commission for Latin America

ENDESA: Empresa Nacional de Electricidad Sociedad Anónima Chile’s once state-owned Electric Company

ERNC: Energías Renovables No Convencionales Renewable Energy

FDI: Foreign Direct Investment

GAIN: Global Agricultural Information Network

GDP: Gross Domestic Product

GHG: Green House Gas

IDB: International Development Bank

IEA: International Energy Agency

IMF: International Monetary Fund
OECD: Organization for Economic Cooperation and Development
PV: Photo Voltaic
SIC: Sistema Interconectado Central Central Connected System
SING: Sistema Interconectado del Norte Grande Big North Interconnected System
T&D: Transmission and Distribution
TT: Technology Transfer
UN: United Nations
USAID: United States Agency for International Development
USDA: United States Department of Agriculture
ABSTRACT

Political unrest in the late 1960s and early 1970s Chile resulted in drastic changes to internal economic configurations. This restructure, from Allende’s nationalization of the copper mining industry, to Pinochet’s implementation of the Chicago Boys’ free market monetarist philosophy, combined to result in a prosperous society in which increasing economic output meant an augmented energy demand, in a country with a dearth of fossil fuel resources. Subsequently, the economic and energy policies set in place during the tumultuous eras of Allende and Pinochet have resulted in an influx of public and private investments in renewable energy infrastructure through partnerships with Chile’s most fundamental industries. Chile’s unique geography results in one of the world’s highest levels of solar irradiance, and a strong emphasis on solar energy has been placed in the energy goals set out by current president Dr. Michelle Bachelet, creating an unprecedented leadership role for Chile in South America, and globally.
Introduction

Chile’s current political and economic systems are the cumulative result of a series of upheavals that took place starting in the late 1960s, which drastically altered the economic structure and output of the country. From the nationalization of what is still present-day Chile’s largest export revenue generator (copper), to the forcible installation of an entirely untested economic structure rooted in Milton Friedman’s monetarist free-market principles, Chile has become a stable, productive, and future-oriented society. The resulting trifecta of economic growth, government stability, and increasing energy demand has resulted in substantial infrastructure investment, and placed Chile in an unprecedented leadership role in South America, and internationally, in the utilization of renewable energy, with an emphasis on solar power.

Chile has experienced exponential economic growth\(^1\) since the latter part of the Pinochet dictatorship in the late 1980s.\(^2\) Behavioral economist at Lund University, Dr. Luis Mundaca, noted in a 2013 *Energy Policy* report that “Chile’s economic model has been widely recognized as a success story by international organizations such as the World Bank, the International Monetary Fund (IMF) and the World Economic Forum. Powered by a neoliberal economic model implemented in the early 1980s, the country has been the fastest-growing, most competitive Latin American economy for many years.”\(^3\) As of 2013, the growth rate of the Chilean economy held steadily at between 4-5% per annum, continually expanding for 15 consecutive years, and measures of per

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capita income had doubled since the 1990s.\textsuperscript{4} This substantial growth has consequently resulted in increased energy demands.\textsuperscript{5}

Economic growth, however, is not without substantial environmental and socio-political consequences. According to Mundaca, direct correlation between “affluence, in the form of GDP per capita, is the most significant determinant of historical CO\textsubscript{2} emissions.”\textsuperscript{6} A 2013 \textit{Energy Policy} analysis by Dr. Ana Pueyo, research fellow at the Institute of Development Studies, University of Sussex, detailed what the IMF has observed in Chile and globally: “emerging and developing economies almost quadrupled growth rates of advanced economies,” and, “this trend is expected to continue for years to come, resulting in increasing energy demand and Greenhouse Gas (GHG) emissions.”\textsuperscript{7,8} Understanding that traditionally, growth has resulted in greater GHG emissions, as well as being aware of the reluctance, or even recalcitrant stances of many emerging economies to address the issue of augmented CO\textsubscript{2} output — oftentimes, there is a misguided belief that GHG “emissions caps would constrain growth and impede the key goal of poverty eradication,”\textsuperscript{9} — Chile’s role as an emerging leader in renewable energy output in the South American energy markets is cause for a greater investigation into how this has come to be.

\textsuperscript{4} Ibid.
\textsuperscript{5} Ibid., 239.
\textsuperscript{6} Ibid.
\textsuperscript{8} Ibid.
\textsuperscript{9} Ibid.
As of 2014, energy costs in Chile per Kilowatt-hour are extraordinarily high, and hold the inglorious title of being the most expensive in all of South America.\(^{10}\) According to *Santiago Times* reporter Eugene Malthouse, “Electrical energy prices have increased considerably in the last decade, doubling since 2006 - without action from the government, Bachelet [Dr. Michelle Bachelet, Chile’s current president] warned that prices could climb by a further 34 percent in the next decade.”\(^{11}\) These elevated energy costs are the result of a two-fold predicament: Chile has a dearth of fossil fuel resources, yet in recent times has relied heavily on energy derived from fossil fuel resources; this makes the country a net importer of energy.\(^{12}\)

Chile’s geographically-induced fossil fuel paucity may also be the way forward in terms of energy output; the same geographic fluke that left Chile starved of this fuel resource is the same landmass that encompasses the driest location on Earth, the Atacama Desert, with an abundant, reliable supply of solar radiation. Chilean academic, economic, and political leaders have become increasingly cognizant of the “evidence that solar technologies can have a major impact on the future energy mix of countries with a high solar resource.”\(^{13}\) Data have proven that “solar energy has resource potential that far exceeds the entire global energy demand.”\(^{14}\)

As a specific influence of the aforementioned series of political events, resulting in a synergistic development and economic policy that is both interventionist (Allende’s

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\(^{11}\) Ibid.


persuasion) and laissez-faire (Pinochet’s persuasion), Chile is becoming a global leader in the utilization of solar energy, developing a portfolio of renewables that spans industries, garnering massive investment capital through public and private sources, and setting standards for other developing nations to emulate.
Chapter 1: Chilean Economies: Allende Through Pinochet

To understand the current Chilean economic state of affairs and augmenting energy demand that Chile is confronting, the roles of a democratically elected Marxist doctor, a coup d’état, the subsequent military dictatorship (that was democratically removed from office by plebiscite), and an elitist academic circle known as The Chicago Boys can’t be over-emphasized. The public, academic, and private institutions that these two presidencies reformed, destroyed, and re-shaped, as well as the consequential development and stability that Chile has almost perennially experienced since this turbulent historical period, is the paradoxical result of a conglomeration of disparate governmental philosophies, that merged to create a stable, transparent, and investment-worthy country that the rest of South America would do well to emulate.

In September of 1973, General Augusto Pinochet co-orchestrated an armed coup d’état that left then-president Dr. Salvador Allende dead (of a much-contested gunshot wound), and installed a dictatorship that would retain absolute power until 1989.\textsuperscript{15} The transition to what former Chilean ambassador to the United Nations Juan Gabriel Valdés called Allende’s “anti-imperialist, anti-oligarchical and anti-monopolistic” government, in which large land masses were expropriated, price controls were imposed, and financial and economic sectors in Chile were nationalized (more than 500 enterprises became state institutions) during a three-year period from 1970-73, resulted in Chile becoming the most-egalitarian society in the whole of Latin America.\textsuperscript{16,17} Allende’s theoretical end

\textsuperscript{16} Ibid.
objective was to give more opportunity to the people of Chile, regardless of social standing, sometimes at the expense of concentrated private ownership by a few financially robust internal and external interests. His political and economic philosophies and practices during his brief time in power resulted in a protectionist role for the state, and included a radical re-organization of production, and eventually, energy sourcing.

It has been argued that a significant part of the Pinochet dictatorship’s success with neoliberal reformation was the decision not to simply dismember the socialist structures implemented by Allende, but to build his economic system on of top these transformed economic, social, and property structures. Protecting such vast resources from outside interests grew Chilean wealth in exponential terms, and has remained a core contributory factor to the Chilean GDP. State ownership of industries is, of course, utterly contrary to the premise of neoliberal economic political philosophy, but in the case of Chile, created the financial basis for the implementation of these political ideals through a reliable, steady, continual value source for state coffers.

Dr. Allende came to office by a tie-breaker Congressional vote, following a narrow 31% victory, in a democratic election, as a representative of the Unidad Popular (Popular Unity) party. The Unidad Popular party was comprised of a coalition of leftist and center-leftist parties, including what United Nations regional advisor Dr. Andrés Solimano describes as, “socialists, communists, and disaffected Christian Democrats,” and Allende was the first Marxist to be democratically elected in the Western world.

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19 Ibid.
His election was scarred by significant economic and financial stagflation. Starting in 1967, there was an observable rise in the underuse of productive capacity; by 1970, inflation had reached 30%. The news was not entirely abysmal, though. By the time Allende was installed as president, the share of wages as a portion of national income had risen to 52%, significant tax reforms had been put in place, and there was 51% percent national ownership in the Northern Chile copper mines (this re-taking of the copper mines from U.S. ownership was accomplished by a unanimous vote in parliament under direction from Allende and has played a vital contributory financial role in the Chilean economy through contemporary times). In late 1970, high international reserves allowed expansionist policy, in which rapidly rising wages and an increased investment in social expenditures facilitated a positive economic response, the consequences of which were an 8% rise in GDP.

As Allende’s time in office progressed, economist Ricardo Ffrench-Davis (a member of the Chicago Boys) noted that, “the [Allende government’s] expansion was carried out with public revenue losses due to drops in real (public) utility rates, appreciating exchange rates, weakening public and private investment, and a rapidly expanding money supply.” Researchers Alejandra (professor of economics at Cal. State, Long Beach, and World Bank Consultant and Sebastián Edwards (Chicago Boy and professor of economics, UCLA) noted that, “also, a number of manufacturing firms were

23 Ibid.
25 Ibid., 9.
26 Ibid.
de facto expropriated through a procedure called ‘government intervention.’”

A continued trend of under-utilization of output capacity, coupled with increased inflation, and the government’s inability to completely control price and trade imbalances resulted in power struggles and infighting, which largely preoccupied the time and efforts of the Allende government, up to the time of the coup.28

Allende redefined the social relationship (area social) the state held with its citizens by offering to share the benefits of the country’s economic output, without a concerted effort to singularly consolidate his own personal power over the country. The changes he instated were not done by his mandate alone in an autocratic manner, but were directed through elected legislative branches. Policies were intended for a re-opening of opportunities related to economic and social participation in basic functions of the state, offering protections that ordinarily would have been limited to Chile’s well-moneyed few; this new approach distressed outside interests, who saw this presidency as limiting many vested financial prospects of the wealthy. As a result, these policies were continually being undermined by external and contrarian influences.

The United States, in particular, having lost massive financial stakes in the Chilean mining industry (US corporations controlled 80 percent of Chilean copper production at the time), and in other financially beneficial undertakings (such a development loans), partook in policy mandates to undermine Allende’s policy agenda.29

In their 1975 book, The United States and Chile, researchers Drs. James Petra and Morris Morley described how the US played a twofold role in impacting Allende’s downfall by

28 Ibid.
implementing, “a combination of severe economic pressures whose cumulative impact would result in internal economic chaos, and a policy of disaggregating the Chilean state through creating ties with specific critical sectors (the military).”

Further complicating Allende’s retaking of national ownership of the copper mines was the fact that nearly all means for extraction and processing of copper were controlled by US machinery companies, who managed nearly 95% of all replacement parts, and were essentially the single-source supplier for the means of production. With the resources to influence market wellbeing based on export purchase power, the US also endeavored to destabilize Chile’s ability to compete in other non-US export markets. The Kennecott Copper Corporation, which held a 49% interest in Chile’s El Teniente mine, which at the time was the world’s largest underground copper mine, managed to persuade Chile’s copper buyers to place heavy financial penalties on each export transaction with them. For example Kennecott secured escrow requirements on a copper shipment to France, and an extremely lengthy shipping embargo on copper exports to West Germany, Chile’s largest copper procurer; this was all undertaken through direct collaboration between Kennecott and US government officials, largely within the US Security Council.

Allende’s presidency was ill-fated from the beginning, having to not only attempt to ameliorate the internal strife of being an umbrella party candidate, but also having inherited the impossible task of attempting to manage a continual manipulation of economic outcomes by external interests. At every turn, attempts to create a state of expanded economic opportunity for the Chilean populous were impeded by Allende’s

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31 Ibid.
32 Ibid.
33 Ibid.
government being forced to deal with the residual consequences of external interference through the legacy of debt that existed when Allende took power, and the inability to compete fairly in the global marketplace by US government-backed corporate aggressions related to the core export commodity Chile produced.

Pinochet’s military takeover of Chile marked a time in Chilean history in which a new economic system was forcibly installed, at the sacrifice of democracy and fundamental human rights, and with nominal input from the Chilean populace at large. The multi-lateral orchestration of Pinochet’s coup would later be revealed as having its origins and undertaking in a trans-national agenda, in which hegemonic principles were a guiding force, oftentimes violently shaping a financial legacy that influences economic outcomes even today.
Chapter 2: The Chicago Boys, Neoliberalism, and the Growth of Public-Private Partnerships as a Means to Further Development

Neoliberalism, as a political and economic system, is a structure that relies on the absolute primacy of capitalist market forces as the means by which growth can and must occur. It is oftentimes portrayed as self-regulating, and is a system that prefers very little state intervention in the social or economic spheres, therefore possibly tending to ignore or minimize market responsibility in terms of potential or real detrimental social/and or environmental outcomes. Like many economic systems, policy results favor distinct beneficiaries, and in doing so, also create groups of disenfranchised individuals.

Milton Friedman, the founder of free-market economic theory and monetarist philosophy, exemplified the neoliberal model through the promulgation of the idea that economic autonomy in markets is the best way to apportion economic resources to a population. Friedman's ideology also espouses the philosophy that economic efficiency can be achieved without government intervention in economic output or financial interactions.34 His economic model has been described by Drs. Michael MacDonald and Darel E. Paul as existing to encourage the "banishment of the state from the economy."35

Free-market/monetarist theory was disseminated as an accounting identity, which economists Drs. Sarwat Jahan and Chris Papageorgiou of the IMF describe as the idea that fiscal policies should be directed at matching money supply with the GDP growth

35 Ibid.
rate, based on the belief that economies were, as a propensity, stable and self-regulating, and government interference with a market’s natural, cyclic balancing process was problematic.\textsuperscript{36} Chile’s idiosyncratic, distinguishing version of neoliberalism developed through a masterful series of steps that incorporated a Friedman-laden version of neoliberal practices during the time of Pinochet’s dictatorship.

After the 1973 coup d’état, the structural changes that Allende had designed and implemented — ones that Dr. Marcus Taylor of the Department of Global Development Studies, Queen’s University, Ontario, describes as, “a government that acted under the banner of moving towards socialism,” in which, “the restructuring served to deepen that state’s economic role and expand redistribution within a capitalist framework,” — the Pinochet regime began reforms with a “relatively gradualist approach to macroeconomic management that sought to normalize—but not fundamentally change-Chilean economic structures.”\textsuperscript{37, 38, 39} With this approach, however, inflation increased to triple digits, and Pinochet eventually became inextricably dependent on a group of Chilean neoclassicist economists based at the Catholic University (\textit{La Universidad Católica}).\textsuperscript{40} Pinochet didn’t simply take the presidency, but he also took the entire country as his personal laboratory; the Chilean economy was his and the Chicago Boys’ grand experiment in neoliberalism, which drastically usurped many legal precedents domestically and globally, including the production, storage, and distribution of electricity.

\textsuperscript{38} Ibid.
\textsuperscript{39} Ibid.
\textsuperscript{40} Ibid.
Pinochet structured his economic system through a series of pre-established relationships that Chile had begun to cultivate prior to his dictatorship, but which he conspicuously sustained and strengthened. Starting in 1955, a partnership between the University of Chicago and the Catholic University began what would result in the issuance of more than 100 Ph.D. and Master’s Degrees in the United States to a group of economic scholars who would be dubbed “The Chicago Boys.”\textsuperscript{41} This assemblage was the result of two distinctive, synergistic academic partnerships, in which a program developed by the United States Agency for International Development (USAID) educated 26 students, who largely continued their academic careers to obtain terminal degrees, and returned to Chile, specifically to the Catholic University, to teach economics; this served to establish the dominance of monetarist theory in Chilean academia. A continuation of this international training partnership was funded by the Ford Foundation, which underwrote a group of about 100 students, of which 26 received Ph.D.s and 74 received economics MAs.\textsuperscript{42} Interestingly, their role and influence outside of academia was nominal until the Pinochet dictatorship was firmly established; their monetarist and free market ideals were in absolute contrast to the structuralist and Marxist economic propensities that permeated the majority of Chilean thought and society in the time of Allende’s presidency.\textsuperscript{43}

The advisory role of the Chicago Boys came into existence through a Chilean presidential tradition to partner with an economic consultative body. This was chiefly established with former Chilean President Eduardo Frei and the ECLA (Economic

\textsuperscript{42} Ibid., 113.
\textsuperscript{43} Ibid., 115.
Commission for Latin America) in 1964. The ECLA was founded in 1948 under the auspices of the United Nations (UN), and was based in Santiago, Chile. The organization was widely lauded for its UN origination, and was not viewed as an agency with a highly-politicized agenda.

The Chicago Boys did not initially involve themselves in the Pinochet advisory realm. In the nascent period of his dictatorship, Pinochet depended on an economic team he compiled, which was comprised of a group of economists that were amenable to a nationalistic political ideal that sought to “reduce tariffs, free prices, devalue the exchange rate, and privatize companies.” After a period of unimpressive economic outcomes by the end of 1974, including an inflation rate “around 375%,” Pinochet instigated a concerted search for alternative economic advisors. The Chicago Boys served the purpose of offering a distinctive economic ideology, the majority of which was garnered from the theoretical concepts of Milton Friedman, and his unwavering argument that “the market, not the state, should be the regulator of the economy.”

Prior to both Allende’s presidency, and Pinochet’s dictatorship, the Chilean economy had been established as largely copper-centric. This would be a defining element in the frameworks that both men and their respective governing associates would restructure during their respective tenures. The Chilean dependence on copper exports in the mid 1960’s, which nearly comprised 75% of the export earnings of the country,

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46 Ibid.
47 Ibid., 120.
48 Ibid.
served as one of the major factors influencing the implementation of the neoliberal economic model.  

Falling copper prices and high-tariff protectionist policies in the internal Chilean marketplace augmented the stagnating economic outlook; the failing economic structure resulted in more individuals needing state support, and diminished means by which to accomplish the structuralist development model intended to stimulate the stagnating economy, which would have provided the economic means by which to supply the aforementioned support.  

The Pinochet regime responded by lowering price and wage controls, and social spending was cut by more than 20%. In describing the outcome of Pinochet’s rule, *The Economist* wrote, “Like most Latin American dictators, General Pinochet was instinctively an economic nationalist. But he saw the ‘Chicago Boys,’ a group of free-market economists, as a means to consolidate his personal dictatorship.” By the 1980s, the “Friedman-prescribed policies had caused rapid de-industrialization, a tenfold increase in unemployment and an explosion of distinctly unstable shanty towns. They also led to a crisis of corruption and debt so severe that, in 1982, Pinochet was forced to fire his Chicago Boy advisors and nationalize several of the large deregulated financial institutions.” Throughout these drastic reshuffles, changing leadership, and economic structures, the basis of the Chilean economy remained intimately tied to the copper mining industries in the north of the country, and these industries then, and in present times, require massive quantities of energy infrastructure. Because the Chilean economy has for decades prior to, during, and after Allende and Pinochet’s rules demanded such large energy input, energy production, and the means of

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51 Ibid.
52 Ibid., 187
production have remained at the forefront of Chilean development priorities, making it distinct in its development from other emerging nations over the last 50 years.

Amongst the institutions that Pinochet and the Chicago Boys manipulated in the early 1980s, the power sector was one of the largest-scale. Cambridge University researcher Dr. Michael Pollitt emphasized in his 2004 analysis that, “Chile’s electricity sector cannot be disassociated from the rest of the Chilean economy.” The utilities had been nationalized under Allende, and Pinochet dismantled this structure entirely. By the late 1970s, Pollitt noted that, “large state owned companies, such as electricity companies, were being forced to trade on a commercial basis. State owned companies as a whole were breaking even by 1979 and into the 1980s electricity companies in particular were showing improving rates of return on capital.” Pinochet’s dismantling of what had been long-established, basic institutions run by the state, in order to abruptly allow for privatization, set a precedent for Chile in terms of establishing itself as a country open to outside investment in infrastructure, particularly energy utilities.

This transformative period of private ownership, overtaken by state ownership, and ensuing re-privatization of the utilities in Chile was (and in present day, still is) critical to the development of energy sourcing, creation, storage, and distribution. Allowing, and subsequently encouraging external capital influx in development projects in the energy sector, set Chile apart in its electrification progress, compared to neighboring South American nations. Dr. Carl Bauer specifically addresses the role of neoliberal politics in the energy sector, recognizing that, “Chile has been an international

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56 Ibid.
57 Ibid.
leader and paradigmatic case of neoliberal law and economics since the late 1970s. These characteristics are true both at the macro level and in the specific sectors of water and electricity. Alluding to this macro-level consequence, Pollitt elucidates the peculiar outcome of a 1985 law allowing for the Pension Fund Management Companies, which are Chile’s state-run pension funds, to invest internally (within Chile) in private corporations and specifically, in utilities; this led to a flush state of capital investment within the utilities sector, and the “electricity industry remained largely domestically owned until the latter half of the 1990s.”

Chile’s economic upheavals, from Allende’s short-lived presidency and socialist repatriation of core Chilean economic sectors, to Pinochet’s eighteen-year dictatorship that saw the blunt re-privatization of economic strongholds under a neoliberal economic model, resulted in energy systems that have (literally) powered the economic outcomes of the country, even today. The continued Chilean reliance on energy-heavy industrial sectors to support internal development, has resulted in sustained growth in energy demand, and has consequently formed a solid history of synergistic public-private partnerships in the energy sector, resulting from the melding of policy extremes from each of the two men’s disparate economic models.

Chapter 3: Sourcing, Pricing, and Privatization of the Energy Sector in Chile

The structural background for any energy system is founded in the legal framework that a country utilizes to demarcate generation, sourcing, storage, and distribution. The current-day interconnectivity of the Chilean economy and energy sector is the result of what Pollitt describes as “an interesting case study of electricity reform.” He continues, stating that, logically, the “demand for energy has been growing as the country approaches development,” and wattage output has steadily risen as well. “In the first years of the 1980s they [Pinochet and the Chicago Boys] designed the legal framework established in the 1982 Electricity Act, which is still the most important legislation governing the sector.” Other changes in the electricity sector have, of course, held lofty significance too, especially regarding energy sourcing, though with regards to offering-up Chile to outside investors to foster development in the energy sector, these reforms were key.

In 1982, according to the US Energy Information Administration, Chile’s total electricity installed capacity in millions of kilowatts was 3.344, while in 2012 the number had increased to 18.16, a nearly six-fold growth. Even with this growth, by developed world standards, electricity consumption per head is low. This persistent increase in

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61 Ibid.
63 Chilean installed electrical capacity data, accessed September 2, 2015, http://www.eia.gov/cfapps/ipdbproject/iedindex3.cfm?tid=2&pid=2&aid=7&cid=regions&syid=1982&eyid=2012&unit=MK. Note: 2012 was the most recent year the data was available at time of publication.
demand has resulted in a policy which, according to researchers Felipe del Sol, formerly of Enlasa Energy, et al., “generation companies receive a capacity payment for their installed power capacity, if it is considered that they contribute to the energy reserves in case of a contingency.”

This shift in energy production and consumption is the outcome of a concentrated series of reforms that restructured the country in terms of economic, and consequently electrical output. Mundaca summarizes the transformative period of the early 1980s:

Chile began the liberalization of its electricity market in 1981, well ahead of many IEA [International Energy Agency] members. High inflation in the early-mid 1970s, combined with high fuel prices and price controls, resulted in large losses and lack of investment in publically-owned electricity utilities. These factors provided the foundations for the liberalization of the sector and the Electricity Law was enacted in 1982. The liberalization and subsequent privatization of the electricity market, including a successful rural electrification program provided nationwide access to electricity. In 1982 only 62% of the country had access to the grid, by the late 1980s this had increased to 98%.

The consequences of an energy market that was amenable not only to domestic investment, but also open to outside investment, ensured its steady expansion. This in turn promulgated a view to outsiders that reflected favorably on Chile in terms of stability.

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for other types of investments that may not necessarily be relegated solely to the energy marketplace.

The far-reaching nature of the modifications that Chile underwent regarding electricity reform has remained a germane topic for development analysis. Fifteen years post-transformation, the Chilean energy system as a whole was retrospectively described by the World Bank in its June 1996 publication Public Policy for the Private Sector as, “The first experiment in transforming a government-owned and-operated power industry,” into a privatized system from 1986-89, in which internal and external investments were made possible.67,68 The implementation of the 1982 law was regarded to have unfalteringly, “restructured the sector and defined basic regulations.”69 Reformations in the electricity sector post-1982 remained nominal for the remainder of the 1980s and ’90s. Eventually, a drive for restructuring came about in 2000, when, as Pollitt describes it, “a substantial revision of the Electricity Act was debated but this proved to be too controversial and too complicated to be enacted. However in the summer of 2003 another new law, the so-called Ley Corta (or Short Law), was debated in parliament. This was passed in January 2004.”70 From 1982 through the 2004 passage of the Ley Corta, regulatory frameworks focused primarily on allowing private enterprise to manage and invest in the energy sectors, but did not focus comprehensively on the specific details of energy sourcing. After a series of energy crises, however, Chile began a concerted effort to analyze and address the legal frameworks that would create explicit

68 Ibid.
69 Ibid.
stipulations on energy sourcing, with a profound focus on renewable energy opportunities.

As of 2010, the traditional energy mixture in Chile was comprised of 76% non-renewable sources; renewable energy sources were largely hydroelectric and wood-based biomass fuel.\textsuperscript{71} During this same time period, coal-fired power plants were a sizeable part of the non-renewable equation; natural gas and coal combined made up between 30% and 16% of the non-renewable energy equation, respectively.\textsuperscript{72,73} Natural gas historically played a huge role in Chile’s energy needs, but was also subject to the socio-political caprices of its largest natural gas provider, Argentina.\textsuperscript{74} In 2004, Argentina was undergoing internal political strife, and reduced its exports of natural gas to Chile between 30-80%; following this crisis in 2004, natural gas exports to Chile were reduced by 90%.\textsuperscript{75} This resulted in an average energy cost increase that was threefold the typical pricing, and Mundaca noted that, “by 2007, the export of natural gas from Argentina to Chile had almost completely ended. The Chilean response to this abrupt supply termination resulted in the construction of large-scale liquefied natural gas (LNG) terminals.”\textsuperscript{76} Mundaca also asserts that pricing will be influenced because the LNG suppliers are not neighboring countries with abundances of supplies, (due to ongoing border disputes), but rather global trading partners such as Russia and Yemen.\textsuperscript{77}

\textsuperscript{72}Ibid.
\textsuperscript{75}Ibid.
\textsuperscript{76}Ibid.
\textsuperscript{77}Ibid.
For Chile to obviate an increased price that inevitably came with imported energy resources from distant locales, this necessitated the sourcing of less-expensive alternatives. Initially, this internal source was hydroelectric power. Hydroelectric dams had been in place since the 1970s as a product of ENDESA (Chile’s then state-owned National Electricity Company, Empresa Nacional de Electricidad Sociedad Anónima), though Chile’s first hydroelectric power plant, Chivilinga, was fully operational nearly 100 years earlier, in 1897.\(^{78}\)\(^{79}\) However, in 1981, as Mundaca explains, “The military government implemented a Water Code that introduced private property rights for water, promoted the emergence of water markets and greatly reduced the role of the state. Water property rights were created as a fully marketable commodity and given to owners of hydropower dams in the form of ‘non-consumptive’ water permits.”\(^{80}\) During this time between the late 1970s and early 1980s, hydro power provided 80% of electricity generation for Chile, which became highly problematic during periods of drought, causing blackouts nationwide.\(^{81}\)

Dr. Bauer’s publication also alluded to another impediment to dependence on hydro power, explaining that, “climate change will make water supplies more uncertain, more variable, and scarcer in many regions, which will undermine power generation.”\(^{82}\) A 2013 OECD [Organization for Economic Cooperation and Development] publication stated that from 1979-2006, there was an “observed change and trend,” that resulted in the “rise in temperature in the Central Valley and the Andes Mountains (where most of

\(^{81}\) Ibid., 242.
Chile’s water resources are stored),” and that during that same time frame, glaciers were in retreat.\textsuperscript{83, 84, 85} The same report delineated the implications of these changes: “Retreat of glaciers will have a significant impact on water supply, as glaciers act as strategic water reserves, not only supplying water to river basins in summer, but providing the single most important source of replenishment for rivers, lakes, and groundwater in arid regions during periods of drought.”\textsuperscript{86} Understandably, this is extremely dysfunctional, and may continue to be so, due to the uncertainty of ongoing climate change, since Chile has traditionally tied electricity generation so intimately with the use of hydropower.

Along with the uncertainty of climate change hampering the efficacy and general stability of hydroelectric power, the consumption of this source of power has weighty socio-political baggage as well. Bauer also proffers analysis with regards to the privatization of water access, and explains that, “Chile’s 1981 Water Code is the world’s leading example of a free-market approach to water law and economics — the textbook case of treating water rights not merely as private property but also as a fully marketable commodity.”\textsuperscript{87} The continuity of this approach seems to be losing footing, however, and the people of Chile have become more outspoken in their general discontentment with an expanding reliance on hydroelectric power, and especially with the continued commodification of the water itself.

\textsuperscript{84} Ibid.
\textsuperscript{85} Ibid.
\textsuperscript{86} Ibid.
\textsuperscript{87} Bauer, Carl J. “Dams and markets: Rivers and electric power in Chile.” \textit{Natural Resources Journal} no. 49 (2009): 596.
Understandably, allowing vast, private control of massive swaths of natural resources is a prickly arrangement, and in recent times, the creation of more dams has come under greater scrutiny by the Chilean populace, not only by those interested in protecting indigenous peoples’ land and water rights, but those by those who are interested in seeing water as a public good, as well as environmentalists. The irrevocable repercussions of re-shaping the immense acreage of land and water resources that, in large, define the Chilean environmental identity, would not be given-up to private interests as readily as hydroelectric power investors hoped. A brief Associated Press blurb in the *New York Times* in June of 2014 detailed the public viewpoint with regards to expanded use of hydroelectric power:

A government commission rejected an $8 billion proposal to dam Patagonian rivers to meet growing energy demands, handing a victory to environmentalists who praised the ruling on Tuesday. The commission, including the ministers of agriculture, energy, mining, economy and health, voted unanimously to reject the HidroAysén plan, which would have tamed two of the world's wildest rivers, the Baker and Pascua, and built more than 1,000 miles of power lines to supply energy to central Chile. Patricio Rodrigo, executive secretary of the Patagonia Defense Council, called the decision ‘the greatest triumph of the environmental movement in Chile.’ Chile is strapped for energy, but most Chileans opposed the plan.90

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90 Ibid.
This determined response, the result of outspoken, everyday Chileans, was reflected up to the Chilean Congress, and served to define the socio-political sentiment of the nation at the time. Chileans have become more active in the analysis of sourcing options as the country continues to develop, and hydroelectric sourcing is no longer a default solution to meeting growing energy needs.

Fully understanding the context in which Chilean energy is sourced, as well as the terms of its regulation and distribution, has been the impetus for Chile to seek greater energy autonomy, largely under the directive of a publically-fueled environmental protectionist viewpoint. This has resulted in a focused effort to source power from non-traditional resources, and Chile’s leadership role in this regard cannot be overlooked on a regional, and even global scale. Chile is learning to balance the open-market concept of energy infrastructure investment: In the free market system, capital should theoretically flow to growth opportunity sectors, which, in Chile’s case, it does, but by shaping the type of growth opportunity sectors within the energy segment available for investment, the public still has a role in designing infrastructure investments. The thrust to rely on power sourcing that is void of hefty socio-political implications (relying on gas imports from outside countries, obliterating natural resources), and that isn’t intrinsically dependent on climatic traditions (climate changes may transform rain patterns that have almost perennially filled dam waters for hydro), has inspired Chilean leadership to seek-out non-traditional sourcing, and in doing so, has focused on technologies that are extremely low-carbon.

Pueyo emphasizes the synergistic benefits of a stronger reliance on these types of technologies, reinforcing that, “Low carbon technologies allow not only climate change
mitigation but also energy security, one of the main concerns of developing countries.”

Solar energy, in particular, based on the geographic idiosyncrasies of Chile, is a renewable energy technology that is rapidly expanding into the country’s energy mix, and has become a socio-political and environmental protectionist priority in the economic development of the country. This sage emphasis on solar is not unfounded, especially as data from multitudes of studies show the abundant benefits solar energy provides. To quote University of Toledo researcher Dr. Vijay Devabhaktuni et al.’s 2013 publication, “some studies have indicated that roughly 1000 times the global energy requirement can be fulfilled using solar energy; however, only 0.02% of this energy is currently utilized.”

Chapter 4: Un-integrated Power Grid System: SIC, SING, Aysén, Magallanes

Chile’s geographic layout provides for a disjointed set of power grid systems to serve the long, narrow country. Each grid serves a different part of the country, and these systems are dependent on different types of sourcing. The primacy of geography in determining the type of energy sourcing selected is imperative. The northern part of Chile is exceptionally arid, and contains the Atacama Desert. The mid-country is a little greener, since, traditionally, seasonal water flow from the Andes keeps the area a bit less tree-nude; the middle of Chile is the location of Santiago, Chile’s capitol city. The mid-lower region of Chile is a green, lush, lake-covered zone, in which rain and clouds are the norm for many seasons of the year. And, at the very bottom of the country, in the Tierra de Fuego (Firelands Region) the climate gives way to tundra and glaciers. The entire country is bordered by the Pacific Ocean on the west, and the Arctic Ocean at the extreme south. The Andes Mountains run as a spine through the country, largely on the eastern side.

The power networks that Chile utilizes in its different geographical regions are described by researchers del Sol, and Sauma describe as, “four independent power networks: (i) the Northern Interconnected System (SING), providing energy to the north zone, where the main mining industry is located, (ii) the Central Interconnected System (SIC), providing energy to the central and south regions, where most of the population lives, (iii) the Aysén System, a small, isolated system in the extreme south of Chile, and
(iv) the Magallanes System, which covers another isolated area in the extreme south of Chile.”

Intriguingly, this disjointed series of power grids in Chile make an ideal basis for solar energy integration, since having the solar project near to the point of distribution is an efficient way to supplement and, in select cases, even usurp grid-connected energy sources altogether.

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Figure 1: The regions of Chile, and the potential for different renewable energy projects in each section

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95 Source: (Center for Renewable Energy, Chilean Government Office of CER, Centro de Energias Renovables)
Each region is geographically primed for a greater integration of renewable energy because of the distinctive topographical characteristics that define each portion of land. For example, there is nearly four thousand kilometers of Chilean coastline that can be utilized for wind turbines and wave turbines. However, due to constant energy demand from the mining sectors, partnered with abundant solar radiation, the northern portion of Chile is becoming an increasingly important focus for the country in terms of launching renewable energy projects, with an emphasis on solar energy.
Chapter 5: Power Consumption by Economic Sector:

Mining

In Chile, even decades before the time of Allende or Pinochet, mining was the industrial powerhouse for the country. The absolute importance of the mining industry has given rise to certain governmental agencies to further develop primary economic contributory industries, as well as foster the well-being and growth of outside (though often inter-related) industries within the Chilean economy. CORFO (Corporación de Fomento de la Producción, Corportion for Production Development) Chile’s government agency, founded in 1939, whose mission to “improve the competitiveness and the productive diversification of the country by encouraging investment, innovation and entrepreneurship, strengthening in addition the human capital and technological capabilities to achieve a sustainable and territorially balanced development,” has been actively engaging with specific industries that are both pillars of the Chilean economy, as well nascent and small and medium enterprises to facilitate synergistic solar energy partnerships.96 97 Focusing investment opportunities in Chilean ERNCs (Energías Renovables No Convencionales, Non-Conventional Renewable Energy) has come about from fostering partnerships with the precise industries that will be the beneficiaries within the Chilean economy. Investment partnerships have also shown success in providing divergent means of integrating solar energy into a sector’s energy mix; these two options can result in the form of solar energy integration into the four main power grids (SING, SIC, Aysén, Magallanes), as well as non-grid connected systems. Chile’s partnership-

facilitating agencies, such as CORFO, thus far, have definitively influenced the allocation of resources from partnering governmental investments with private investors.\textsuperscript{98}

The concepts of dependence (dependencia) and autonomy (autonomía) in the copper mining industry continue the shape the Chilean economy today. Dependence was the model of being dependent on multi-national corporate control of Chilean copper mining assets, and autonomy referred to the Allende impetus and subsequent securing (through congressionally approved means) of the Chilean mining resources once again.\textsuperscript{99} Because of Allende’s re-taking of autonomía of the copper mining industry, and subsequently, Pinochet’s marketing-opening policies, the core of the Chilean economy is still built largely on this finite resource, which as recently as 2012, made up 70\% of Chilean exports, and accounted for nearly 19\% of total government revenue.\textsuperscript{100, 101} As of 2013, the world’s largest copper mine, the Escondida mine, located in the Atacama Desert, provided of 5\% of the global copper supply.\textsuperscript{102} The Economist also reported that in 2013, “Chile produces a third of the world’s copper.”\textsuperscript{103} The mining companies in the north of Chile utilize electricity provided by the SING grid system, and as of 2013, 99\% of the electrical generation from SING was thermoelectric, generated from fossil fuels; solar only comprised 0.02\% of the grid’s annual output.\textsuperscript{104, 105}

\textsuperscript{98} Ibid.
\textsuperscript{101} Katia Moskvitch, “Sun to keep Atacama Desert’s grapes growing,” BBC, April 15, 2012.
\textsuperscript{103} Ibid.
\textsuperscript{104} Ibid.
Polytechnic University of Madrid researcher Dr. Jorge F. Servert et al. described the interrelationship between mining and energy usage: "The activities that encompass mining in northern Chile grow an average 5% annually, and require large volumes of electricity."\textsuperscript{106} Data compiled as of December of 2013 are indicative of Northern Chile’s overwhelming dependence on coal energy in this economic sector. Researchers Matías Hänel, et al. noted in their 2013 publication that, "Consumption centers in the northern part of the country are mostly mining industries, which consume the highest share of power generation with fundamentally constant demand."\textsuperscript{107}

The impact of the mining industry in the mass consumption of energy has been acknowledged in the past by the Chilean government, and in the 2014 Energy Agenda, it was addressed specifically.\textsuperscript{108}CODELCO (Corporación Nacional del Cobre de Chile, the National Chilean Copper Corporation) competes with private mining firms, and has somewhat lacked in investments until a 2010 corporate governance change took effect.\textsuperscript{109} The goal, as stated, was to remain as a competitive industry, both in the public (CODELCO), and private mining sectors, and to do so by becoming more energy efficient through the incorporation of ERNCs into the energy grid in the north of Chile (SING) that the mining industries rely on.\textsuperscript{110}

Since Chile’s grid system is not entirely interconnected, opportunities exist for highly-localized projects; Chile has a grand advantage in that the solar energy production


\textsuperscript{110} Ibid.
sites are largely located nearby the greatest use-demand sites (the upper mining regions of Chile). World Bank senior research economist Dr. Govinda Timilsina et al. describe this advantage by explaining that, “as a distributed energy resource available nearby load centers, solar energy could reduce transmission and distribution (T&D) costs and also line losses.” Localized projects also offer benefits in other regards as well. For example, having a cross-trained workforce that could perform basic maintenance and upkeep of solar components, as well as perform duties within the economic sectors (such as mining) benefiting from localized energy generation, would have potentially large cost savings, versus having to have a maintenance team brought in for requisite service from other locales.

The following graphic, designed and published by Green Tech Media in 2013, indicates the general proximity at which mining operations are geographically to major solar power projects. Transmission lines also zig-zag across the region, (the region being the northern Chilean mining installations) offering the option for energy integration for grid-connected projects. Opportunities for successful non-grid projects, ones that singularly benefit specific the enterprises that privately invest and manage the own solar energy production, also abound, simply due to the extraordinary levels of solar radiation found in the region.

Figure 2: Graphic representation of the 2013 mining region of northern Chile\textsuperscript{113}

\textsuperscript{113} Source: (http://www.greentechmedia.com/articles/read/chiles-solar-sector-poised-for-strong-growth)
Other Significant Economic Contributors: Chilean Wine and Grapes

A substantial portion of the Chilean economy is comprised of agricultural exports, especially wine and grapes.\textsuperscript{114, 115} The USDA Foreign Agricultural Service GAIN Report published in 2013 indicated that, “Chile has an estimated 8,000 producers of wine grapes,” and the “planted area has increased over 70% in the previous eight years.”\textsuperscript{116, 117} As of 2010, Professor Christian Felzensztein of the University of Adolfo Ibañaz, reported that Chile exported around 70% of its wine, “making it the world’s most globalized wine industry;” Chilean wines are consumed in 170 different countries.\textsuperscript{118, 119} With a global reach, and a Wines of Chile industry trade group growth goal of transforming Chile into the “Number One producer of premium, sustainable, and diverse wines of the New World by 2020, increasing the value of bottled wine exports over the course of the decade to US$3 billion,” the role of grape and wine producers is at the forefront of economic priorities.\textsuperscript{120}

The modern-day opportunities to trade Chilean-owned and cultivated goods in a global marketplace also tie to the strangely synergistic relationship that resulted between Allende’s nationalistic policies, and Pinochet’s neoliberal ones. Allende’s fiercely protectionist policies, believing in the abilities of the Chilean people to transform the country’s resources into internal wealth, without multi-national ownership stakes, defines

\textsuperscript{120} Ibid.
how the Chilean grape and wine industries have developed. Allende’s open and free-market policies freed Chile to find new buyers for internally-produced goods, and on a far-greater scale than solely-domestic consumption markets can provide. This scion between two immensely-disparate socio-economic ideologies has resulted in an extraordinarily lucrative agricultural sector, which, as an aggregate, is second only to mining in terms of economic importance in Chile.121

In analysis garnered from the 2012 GAIN data, “Chile became the seventh largest wine producer in the world,” and that has been sustained through 2014.122, 123 With the economic prominence that the Chilean wine and grape industry now occupy, protecting and growing these businesses, which 2014 data from the GAIN report, wine exports were responsible for economic contributions of more than $1.841 billion USD, has recently become a priority for more growers and processors.124 Researchers Michelle Reneé Mozell and Liz Thach of the Sonoma State University Wine Business Institute describe what growers and oenophiles alike know very well: “premium winegrape production occurs within very narrow climate ranges,” and, within those ranges, “individual winegrape varieties have even narrower climate ranges.”125, 126 Chile’s geographical layout provides for a multitude of mini zones, which are uniquely productive for varietals that other countries, New World and Old World, are unable to coax into becoming

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126 Ibid.
profitable exports, such is the history of the Carménère varietal. These regions are unique on a global scale, and protecting these micro climates has become a prerogative for the country.

Figure 3: Map by Wines of Chile industry trade group showing the micro climates within the Chilean wine growing regions

According to researchers Monica Hadarits, et al., “climate change poses significant challenges and opportunities” within the context of cultivation and production in the viticulture and viniculture industries.\(^\text{129}\) Savvy producers, wanting to contribute to the long-term well-being of the micro-climates in which their varietals thrive, have begun to seek out opportunities to source energy from low-carbon options. The result is than an increasing number of producers have begun to invest in solar for various stages of grape and wine cultivation and production.

Data published by Drs. Mervyn Smyth, et al., as of 2011 indicated that there were around 258 large-scale winemakers in Chile, (in comparison to only twelve that existed in 1995), and as of that same year, only around seven actively integrated solar energy into cultivation and production.\(^\text{130,131}\) Increasingly, scientific and industry publications in the field of viticulture address the need for producers “to mitigate against global warming,” and to do so by lowering vineyards’ production output of CO\(_2\).\(^\text{132}\)

Chilean growers and producers have progressively begun to invest in a variety of solar energy technologies, and over the past few years, solar energy has been incorporated into wine and grape production at a substantially augmented rate. Within the past three years, Chile has seen an exponentially amplified list of wine and grape producers make the integration of ERNCs an investment priority.\(^\text{133}\) Four of the

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128 Source: (http://www.winesofchile.org/chilean-wine/wine-regions/)
outstanding examples of wineries and grape growers taking a proactive approach to solar energy integration within the last four years include Concha y Toro, Miguel Torres Chile, Hacienda Auraucano, and Subsole (a grower co-op of grapes and other fruits).

The Chilean winery Concha y Toro, which represents 35% of Chilean wine exports to 137 different countries, epitomizes how many of the grape and wine producing businesses in Chile are expanding the use of ERNCs.\textsuperscript{134} It was recognized as the first Chilean winery to actively measure their annual carbon footprint; it maintained this data over a six-year period, and was able to reduce its output by 28%, in part by utilizing ERNCs.\textsuperscript{135} According to the Concha y Toro magazine, “More than 30 thermo-solar panels have so far been installed at the company’s estates, cellars and plants, which has meant a reduction in the use of fossil fuels for heating water in the different industrial processes of Viña Concha y Toro.”\textsuperscript{136} In 2015, Concha y Toro was inducted into the Dow Jones Sustainability Index for Chile, one of only 12 companies recognized as having sustainability practices that exceed those of same-industry peers.\textsuperscript{137}

Other vineyards, such as Hacienda Araucano, have undertaken installation of solar-powered irrigation systems, with admitted initial skepticism, only to realize that a per annum savings of $40,000.00 USD offered by being removed from the power grid would more than return the initial investment, and ameliorate all doubts to the probity of


\textsuperscript{135} Ibid.


ERNCs.\textsuperscript{138} The example of Hacienda Araucano shows what numerous companies that chose solar energy are discovering: over time, the initial costs of the solar energy installation more than pays for itself in terms of cost savings in electrical bills. Hacienda Araucano is also not atypical in an initially dubious reaction to the idea of solar-powered technology being an investment-worthy choice for powering various aspects of the business.

Grape producers have also invested in solar energy sourcing, including the Subsole vineyard in the Copiapo region of the Atacama Desert, which utilized solar-powered pumps to irrigate their grapevines utilizing a pump system that took advantage of a natural underground reservoir.\textsuperscript{139} More often now, the viticulture industry is becoming aware that solar technologies are not simply limited to a scattering of solar panels around farmlands for building and machinery power, and with continued examples of non-traditional solar technology proving beneficial, increased usage will follow.

Not to be outdone, in 2015, Miguel Torres Chile received the prestigious “Renewable Energy Implementation Award” from British trade journal \textit{The Drinks Business}, which was created, “to award those companies showing a reduction of their carbon footprint by using renewable energy.”\textsuperscript{140} This was in part due to a project undertaken with \textit{Universidad de Talca} (Talca University) and \textit{Universidad Diego Portales} (Diego Portales University) that, in partnership with the vineyard, worked to

\textsuperscript{139} Katia Moskvitch, “Sun to keep Atacama Desert’s grapes growing,” BBC, April 15, 2012.
implement a “solar polygeneration system,” (a system designed to both cool and heat by solar energy) designed to substantially reduce GHG emissions.\textsuperscript{141}

Numerous other Chilean wine and grape growers and producers have increased efforts in the search for lower energy cost output, and ERNCs, especially solar, have begun to occupy a more substantial role in the Chilean agricultural community. Recently, a new prestige has become associated with idea of sustainability as an emerging concept within the Chilean viticulture and viniculture communities. The Wines of Chile industry trade organization has officially created a certification for wineries that follow sustainable business models, and their list of participants now boasts fifty-two wineries that have been deemed “Certified Sustainable Wines of Chile.”\textsuperscript{142} For a vineyard to receive the label, a standard of sustainability must be achieved, which is audited biannually, and based on the concept of “a long-term vision, based on a combination of environmental principles, social equity and economic viability”\textsuperscript{143} As consumers seek out products that reflect personal values in purchases, a label that is indicative of a rigorous, tested, and proctored agrarian practice, especially one which integrates renewable energy into the production process, will doubtlessly help expand Chile’s export market reach.

Chapter 6: Types of Solar Power Systems, Requisites, and Technologies

Globally, solar power growth has been exceptionally brisk since the early 2000s. According to Devabhaktuni et al.’s 2013 publication in Renewable and Sustainable Energy Reviews, data they have aggregated show that, “PV [photovoltaic] production has been doubling every two years, increasing by an average of 48% each year since 2002, making it the world’s fastest-growing energy technology.”\(^1\) Parallel to this growth, and understandably part of the equation that plays into this growth, is the fact that the cost of PV cells continues to decline, and the cost is expected to follow this trend of dropping costs.\(^2\)

Internationally, many leaders of developing economies are recalcitrant regarding caps for greenhouse gas emissions, based on the flawed argument that bringing as many people out of poverty as quickly as possible should be the primary economic goal, and the repercussions of energy sourcing are therefore irrelevant. This being said, there are two fundamentally disparate outcomes that can result from the energy choices a country decides to select: a) if GHG emissions are not constrained and reduced during this growth process, then inevitably, large groups of once-impoverished individuals will again find themselves in the same socio-politically precarious predicament of limited resources because of climate change increasing resource scarcity and decreases in livable landmass availability, along with environments that are exceedingly polluted, or b) if GHG emissions are constrained through a thoughtful development process, in which ERNCs such as solar are integrated into the sourcing energy plan, growth can continue, but in a

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\(^2\) Ibid.
\(^3\) Ibid., 559.
way that doesn’t undermine the poverty-alleviating development progress made, and the well-being (environmentally, socio-economically, and otherwise), of future generations. Chile has proven itself an exemplar model of option “b,” and has not simply offered hollow rhetoric about low-carbon development, but is striving to make its development model one in which both South American and other global economies would be wise to emulate, making especially great advances in the last five years.

As recently as 2013, researchers Matías Hänel of Cambridge University, and Dr. Rodrigo Escobar, director of Energy Engineering at Catholic University, Chile, admitted that, “Solar energy development in Chile is small, mostly focusing on water heating applications for the residential sector. The total contribution of solar energy to the primary energy consumption of Chile is negligible.”\(^{147}\) That being noted, however, researchers Felipe del Sol, formerly of Enlasa Energy, and Dr. Enzo Sauma, professor of industrial engineering at the Catholic University, attest that, “Chile has one of the best worldwide conditions for the generation of electrical energy from solar resources, having an annual average Direct Normal Irradiation [Irradiance (sic)] (DNI) of 9-10kWh/m\(^2\) /day.”\(^{148}\) The map below shows Chile’s paramount position, compared to the rest of the globe, as measured by a standard called Global Horizontal Irradiance, GHI. GHI is comprised of DNI and Diffuse Horizontal Irradiance, DHI, which is, “the amount of radiation received per unit area by a surface (not subject to any shade or shadow) that does not arrive on a direct path from the sun, but has been scattered by molecules and


particles in the atmosphere and comes equally from all directions.\textsuperscript{149} The atlas is indicative of how uniquely Chile is positioned on the planet to harness and utilize the abundant solar energy it receives from the combined DNI and DHI measurement, the GHI.

Figure 4: 2015 map from Vaisala, a Finnish environmental measurements company, illustrating Chile’s outstanding quantity of solar irradiance, designed by aggregating high-resolution visible satellite imagery observations over a period of 10 years\textsuperscript{150}

Solar energy can be integrated into the four Chilean grid systems, or function as an independently-managed, off-the-grid system, as well. This is particularly

\textsuperscript{150} Sources: (http://www.vaisala.com/Vaisala\%20Documents/Scientific\%20papers/Vaisala_global_solar_map.pdf, and http://www.3tier.com/en/support/solar-prospecting-tools/how-was-data-behind-your-solar-prospecting-map-created/)
advantageous for Chile since the country’s grid systems are not completely interconnected. Geographic considerations may also influence the utility, feasibility, and efficiency of each solar energy generation option. For example, being able to generate energy off-the-grid is particularly beneficial for agrarian businesses that are in rural or remote areas, such is the case with numerous vineyards, which are frequently acres upon acres of cropland that may not be readily accessible to grid-connected systems.

The details about the particular benefits and functionality of the systems are described by researchers Timilsina et al.: “There are two types of PV (photovoltaic) systems in current markets: grid connected, or centralized systems and the off-grid or decentralized systems.”\textsuperscript{151} These two systems can be further broken down by the means by which energy is generated: “Solar technologies that transform the solar radiation in electric energy can be grouped in two families: Thermal and Photovoltaic. Solar thermal technologies use irradiation as a source of heat to raise the temperature of a fluid. To minimize the land usage and maximize the efficiency, the sunlight is concentrated onto receivers. Electric energy can be generated via a steam turbine or a heat engine connected to a generator. Solar photovoltaic technologies convert solar radiation into direct current due to the photovoltaic effect.”\textsuperscript{152} Timilsina et al. also noted another benefit of these technologies: “Solar technologies like PV carry very short gestation periods of development and, in this respect, can reduce the risk valuation of their investment.”\textsuperscript{153}

The multitude of options for generating energy through solar systems will doubtlessly


\textsuperscript{152} Ibid.

\textsuperscript{153} Ibid., 455.
prove to be utilitarian for the diverse range of businesses scattered throughout the distinctive geographical regions of Chile as the country’s development progresses.

Many researchers, both public and private, have now focused on the distinctive solar energy systems that would be most advantageous for Chile, and a variety of data collection efforts have ensued. Raw measurement data, sought out by government agencies, private investors, and business owners, in order to facilitate a baseline analysis to encourage and inform solar energy investments, include a network of ground stations that are designed to measure solar radiation. These attempts to get accurate baseline surface radiation measurements in Chile were found to be only partially as effective when compared to the utilization of both satellite and surface measurements; the addition of satellite data has proven to be a far more-accurate means of measurement, as the ground data is not always as reliable. Five-year data sets can help establish long-term averages, but a 15-year data set gives a more-precise view into inter-annual patterns, which is helpful in determining which specific type of solar energy production should be invested in. Both have their own series of virtues and shortcomings in contributing to an analysis of potential outcome of solar investment projects: “ground measurement campaigns, although accurate are expensive and prone to equipment failure,” while, “satellite estimation is cheaper yet sufficiently accurate.”

Ground stations typically have fewer problems with inaccuracy, but only when stations are positioned within a certain distance of one another, and on days with “irradiation lower than 3kWh/m²/day

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155 Ibid., 325, 326.
156 Ibid., 325.
157 Ibid.
158 Ibid., 327.
the satellite-derived data overestimates systematically the actual solar resource.”¹⁵⁹ The numerous data collection processes and subsequent analyses demonstrate how Chile is taking a pragmatic, measured approach to solar energy integration, and the continued focus on data-supported analysis is one way that investments made in solar energy projects are able to maximize efficiency and output.

In global terms, the installation of solar energy technologies has grown exponentially; solar energy worldwide represents the largest source of renewable energy supply.¹⁶⁰ Connecting emerging technologies with the existing energy mix in Chile is imperative for the successful growth and implementation of current and projected future solar energy projects.

Chapter 7: Investments in Solar Energy

Regarding carbon emissions, until quite recently, Chilean energy policies related to CO₂ emission increases tended to correspond with what Mundaca described as, “neoliberal economic policies, which aim to maximize affluence via economic growth and give little consideration to environmental protection and regulatory frameworks.”¹⁶¹ The Pinochet-era economic models that promoted the primacy of growth, with as little regulatory oversight as possible, resulted in a nearly two decade span in which little policy attention was paid to the environmental repercussions of business decisions. Mundaca continues by explaining that, “Chile has no legally binding commitments under the Kyoto Protocol, and emissions doubled between 1990 and 2007.”¹⁶² In 1990, Chile emitted 32.21 metric tons of CO₂, and by 2007 emitted 67.94 metric tons of CO₂.¹⁶³ By comparison, the global aggregate of CO₂ emissions in metric tons for 1990 was 21,713.14, and by 2007 totaled 36,798.76.¹⁶⁴ Mundaca further explains that, in terms of legal protocol, “As a whole, results show that the decarbonization of the energy mix has historically been a major policy challenge for the country.”¹⁶⁵ According to the CIE (Comité de Inversiones Extranjeras), Chile’s Committee on Foreign Investments, “The country’s projected economic growth implies increased demand for electricity which is

¹⁶² Ibid., 240.
¹⁶⁴ Ibid.
forecast to rise by around 5% a year through to 2020, creating opportunities for
investment in generation and transmission.”

Chile’s geographic advantages and relatively stable economic position currently
have meant that investors have begun to take note of opportunities to launch solar
projects. A 2014 analysis from The Guardian declared that, “there is sound economic
rationale for building solar PV plants in Chile.” The Chilean government plays a
critical role in the concentration of ERNC investments in Chile. Dr. Ana Pueyo describes
this role further: “Economists and policy makers advocate a fundamental shift towards
low-carbon growth based on higher participation of renewable sources in the energy mix
and increased material, resource and energy (MRE) efficiency. The development,
transfer, and implementation of low-carbon technologies play a fundamental role in this
proposed path towards climate change mitigation.”

The current Chilean government seemingly concurs with this conclusion; policy initiatives have been indicative of such.

The Bachelet administration touts certain financial, investment, development, and
 technological support instruments to encourage investment partnerships with renewables.
 What was once CER, (El Centro de Energías Renovables, The Center for Renewable
Energy), an agency within the government of Chile, was usurped and revamped to create
a hybrid organization with CORFO, called CIFES (Centro Nacional para la Innovación y
 Fomento de las Energías Sustentables). CIFES has a singular goal: “The Centre for
Innovation and Promotion of Sustainable Energy is an institution that strengthens the

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content/uploads/2015/04/ENERGY.pdf.
167 Christian Roselund, “Chile’s solar market is leading the way in South America,” The Guardian, June 5, 2014.
168 Pueyo, Ana. “Enabling frameworks for low-carbon technology transfer to small emerging economies: Analysis of
efforts of the Republic of Chile to develop non-conventional renewable energy (NCRE), through the support of CORFO in the design, implementation, tracking, evaluation and the promotion of programs and strategic projects, with public finance, that foment sustainable energy and innovation.”\(^{170}\) This served as a substantial step in proving the administration was committed to fostering partnerships to promote and grow sustainable energy development, including solar energy projects.

As of 2010, the Chilean government began to take a more proactive approach to grow the percentage of energy generated by renewables, including solar. A law passed in 2010 “requires electricity distributors to provide 5% of their energy sales from renewable energy sources, at average bided prices, increasing the contribution to 10% by 2024.”\(^{171}\) This was later revised upward, the previous goal of 10% was expunged, and Chile’s recently updated renewable energy standards reflect the move toward increased sustainable production, including a goal of 20% of the total electricity production to be renewable by 2025.\(^{172}\) This doubled the previously-established goal of 10% of electrical energy being sustainably-sourced by 2024, and serves to encourage the growth of renewables in the energy mix.\(^{173}\)

This drive to promote ERNC investments in the country developed initially at a sluggish pace: BBC reporter Katia Moskvitch explains that even as recently as April 2012, “only 4% of Chile's energy needs are met by non-conventional renewables like

\(^{170}\) Ibid.
\(^{173}\) Ibid.
solar, wind, geo-thermal, biofuels and wave power.”\textsuperscript{174} However, with an assertive goal to increase investments, Chile has exceeded the 10\% ERNC goal a full 9 years ahead of schedule. In a report published by CIFE on August 19\textsuperscript{th}, 2015, ERNCs officially comprised 10\% of the registered energy generation in the month of July, with 6.163GWh in total registered energy output, and 617Gwh comprised of ERNCs.\textsuperscript{175}

![NCRE projects in Chile](attachment:image.png)

**Figure 5:** A depiction of the state of renewable energy projects in Chile for August 2015\textsuperscript{176}

The Bachelet government has been conspicuously active in pursuing projects, with public input being requisitioned from the Chilean populace, and through an active ERNC policy agenda in the pursuit of energy investment partnerships. In 2015, the Chilean government, under the auspices of CIFES, launched what they called “Energía 2050,” (Energy 2050). The plan would follow a specific path to fruition, and that path was not simply to go forward as a country to invoke new ERNC policies, but to involve the people of Chile to shape the policy path by which the country would move forward.

\textsuperscript{174} Katia Moskvitch, “Sun to keep Atacama Desert’s grapes growing,” BBC, April 15, 2012.
\textsuperscript{175} ERNC goals for Chile, accessed October 14, 2015, http://cifes.gob.cl/en/blog/2015/08/ernc-inyectan-el-10-de-la-generacion-total-del-sistema/.
\textsuperscript{176} Source: (http://subscriber.bnamericas.com/Subscriber/en/features/electricpower/why-chiles-70-renewable-goal-is-attainable/)
The entire project, in fact, was designed and prefaced on the idea that the people of Chile, who would be living with the consequences of energy policy decisions, should be involved in the shaping of those decisions to decide what they wanted the Chilean renewables mix to look like over the next 35 years. The involvement of the Chilean people by the current administration harkens back to Allende’s time, in which the belief that that Chilean people should have a voice in the economic well-being and development of the country, and in which the resources of Chile should benefit the people of Chile (in this case, the abundant solar energy opportunities). This is juxtaposed with the very Pinochet-reflective economic philosophy, however, that markets should be open to outside investments. The resulting mix is the present-day duality of these two polar political philosophies being blended together in a way that modern policies that reflect an portion of each: Chilean resources (in the case of ERNCs, the abundant potential that Chile’s geography affords the country in solar energy potential), and open markets (the present-day policies designed to attract foreign investments to partner with Chilean enterprises) comingle to benefit the Chilean people.
Many data and media sources have begun to notice Chile’s increasing visibility to investors in the solar energy sector. Christian Roselund of *The Guardian* describes this leadership in solar energy growth as a system which, instead of setting the price of electricity from solar PV, similarly to the way that other solar leaders such as Germany, Spain, and Japan have, Chile has created an investment environment in which stability, financial security greater than any other Latin American country, and an easily-navigable regulatory environment encourage solar energy investment. Data published by Ash Sharma, senior director for solar research at IHS Global Information Company reflect Chile’s growing global prominence in solar energy: “While the top three largest markets in 2015 will be the same as in 2014 — China, Japan and the U.S. — a couple of new entrants will get into the top 10. Chile, which IHS predicts will install more than 800 MW...”

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177 In English: Figure 1: Process to Formulate the Long-Term Energy Policy for Energy 2050. Step 1: Energy Agenda, Technical Months (August to December 2014), Step 2: Vision and Path Forward for 2050 (January to September 2015), Construction of a Vision by Consultative Committee, Delivery of the Path Forward to the Ministry, Step 3: Energy Policy (October to December 2015), Creation of the Policy by the Ministry, Public Consultation Pre-Policy, Delivery of the Policy to the President of the Republic, Source: *(Hoja al Ruta 2050, http://www.energia2050.cl/registro_consulta)*

of new PV capacity in 2015, will become the ninth largest market globally. Chile is quickly becoming the engine of growth in the expanding Latin America solar market.”

Figure 7: Chile’s growing global prominence in solar PV installations

In Chile, and elsewhere, oftentimes the role of the state is imperative to ensure the existence and completion of ERNC projects. In a 2014 publication by Servert et al., the concept of state-funded incentives was addressed, with a focus on the importance of incentivizing ERNC investors: “Fiscal and financial incentives can help the promoters to reduce the final price of electricity required to make Non-Conventional Renewable Energy (ERNC), and particularly solar, projects economically feasible, and contribute to the quick and steady development of said projects.” There are many financial incentives that Chile has the opportunity to utilize, and, in a very Allende-influenced

manner, the state is stepping in, to try and incentivize project participation. In Chilean
tradition, however, in which both Allende’s and Pinochet’s development perspectives are
merged in modernity, and in a Pinochet-influenced manner, project participation is being
requested through outside, oftentimes private, investment.

Timilsina et al. discuss that as of 2012, “Subsidies are the primary instrument to
support solar energy development in almost every country in the world. A subsidy could
be investment grants or capacity payments, output or production based payments or soft
loans (e.g. interest subsidies).”¹⁸² A more current analysis completed by The International
Energy Agency’s (IEA) World Energy Investment 2014 Special Report findings also
stated that, “Reducing the cost of capital could have major implications for low-carbon
technologies, given that many are capital intensive and require significant upfront
investment.”¹⁸³ The analysis continued, proffering a policy recommendation that
suggested, “Lower capital costs would also help less mature and (presently) costlier
technologies attractive to investors, thereby reducing costs and fostering employment.”¹⁸⁴
ERNC development has been the direct beneficiary of a number of these ideas have been
adapted into Chilean policy initiatives to encourage solar investment partnerships.

As recently as 2012 again, Timilsina et al. described financing of solar projects as
a “critical barrier” for many projects to come to fruition.¹⁸⁵ This has changed
dramatically, even within the last two years, as more foreign investors view Chile as an

¹⁸³ World Energy Investment Outlook Special Report 2014, accessed April 22, 2015,
¹⁸⁴ Ibid.
apt locale for solar projects, and the Chilean government continues to concentrate efforts to reduce barriers to investors in public-private partnerships.\footnote{http://cifes.gob.cl/sobre-el-cifes/ Accessed 9-30-15.}

A tradition of Chilean interest in learning from outside cultures in order to amplify economic success, a concept that both Allende and Pinochet utilized, continues today. Allende’s quest for economic security was very technologically-centric, with his attempt to create Synco, a pre-Internet electronic system designed to provide real-time analysis of economic output to be able to better manage productivity.\footnote{Medina, Eden, “Designing Freedom, Regulating a Nation: Socialist Cybernetics in Allende’s Chile,” \textit{Journal of Latin American Studies} 38 (2006): 572.} The team he assembled to manage the project was British, including the designer of the five-tier system, Stafford Beer, and the founding developers of Cybernetics, Norbert Wiener, Julian Bigelow, and Arturo Rosenblueth, were, respectively, US-born, and Mexican.\footnote{Ibid., 573.} Pinochet, in turn, also depended on outside ideas for structuring of economic outcomes, though more for intellectual technology, than for physical technology. This was, of course, the US-born Milton Freidman, and the American educational institution, the University of Chicago. Once again, present day Chilean economic growth, aided through this concept of technology transfer (TT), the practice of transferring new technologies and or philosophies from the originating source to developing economies to boost economic output, is the end result of a mixture of the two Chilean leaders’ drastically different economic philosophies. Pueyo explains that, “Pre-existing technological knowledge coming from Chile’s competitive industrial sectors was cited as one of the main enablers for the provision of local inputs to processes of TT.”\footnote{Pueyo, Ana. “Enabling frameworks for low-carbon technology transfer to small emerging economies: Analysis of ten case studies in Chile,” \textit{Energy Policy} 53 (2013): 377. doi:10.1016/j.enpol.2012.10.078.} These factors have
contributed to increasing examples of Chile’s leadership success in the solar energy market; the Council on Hemispheric Affairs noted that, “within the fourth quarter of 2014 alone, Chile installed two times the amount of solar energy projects than all of Latin America’s solar PV total from 2013.” Technology transfer as a means to foster investment partnerships has been crucial to Chile’s growing use of ERNCs.

Investment opportunities can also be influenced by a country’s role in academia; Chile’s understanding of the government’s role in academic life came into enormous prominence, of course, with Pinochet’s history with the Chicago Boys. Dr. Ana Pueyo describes that not only financial incentives, but human capital in the form of a well-educated populace can encourage ERNC investments: “Most countries cannot develop on their own the portfolio of low-carbon technologies required to bring about this change [enough low-carbon tech to greatly diminish energy-dependence on outside nations for sources of energy] and often do not have the capabilities to implement, operate, maintain and repair them. International technology transfer (TT) to developing countries is therefore a key aspect of low-carbon growth. The private sector has indicated that appropriate national enabling frameworks are needed to accelerate climate change technology diffusion to developing countries. This recommendation is particularly relevant as the private sector owns most climate change mitigation technology and is responsible of more international TT through trade and foreign direct investment (FDI).”

Fundamental to those series of incentives are Chile’s strong academic partnerships (both public and private) with outside and internal organizations which offer

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learning and sharing environments that investors laud. Pueyo continues by explaining that, “Factors promoting investment can be enhanced through sound macro-economic policies and solid institutions, while factors promoting cooperation can be enhanced, for example, through trade openness, regional integration or the government brokerage of TT processes.”

A recent example of Chile’s academic partnership and TT building was launched in 2014: a scholarship program was set-up through the Chilean government, in partnership with Germany, to train individuals in renewable energy technologies, with collaborative, on site experiential training offered globally. The importance of human capital to foster financial capital, as well as cultivating an educated, technologically-savvy populace is absolutely a factor in attracting large-scale investments in ERNC.

The Chilean government is promoting Foreign Direct Investment [FDI] in the energy sector by self-endorsing as one of the top recipient countries for FDI. As of 2013 (the most-recent data published on the CIE Website and sourced from the United Nations Conference on Trade and Development), Chile ranks globally as 11th in billions of dollars received in FDI, and is the second-ranked in all of Latin America, behind Brazil. Early on in Chile’s solar development stages, partnerships with development banks, including the World Bank’s International Finance Corporation, and the US’s Overseas Private Development Corporation kickstarted numerous projects. Financing flexibility also lends to a greater propensity of developmental capital influx. The IEA stated that, “Compared with traditional financing, an increase in the use of public capital (through

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192 Ibid., 372.
195 Christian Roselund, “Chile’s solar market is leading the way in South America,” The Guardian, June 5, 2014.
debt or equity) can reduce the weighted average cost of capital (WACC) for renewable energy technologies.”¹⁹⁶ Philosophically, the aforementioned organizations have traditionally been seen as neo-liberal institutions, though Chile has in recent times re-shaped the working relationship with these organizations to utilize investment opportunities that benefit the whole of Chilean society (as well as the rest of the globe with the eventual lowering of CO₂ output) with ERNC production, creating a very Allende-esque reframing of their purpose. In the Energía 2050 plan statement of goals, the role of the state and the role of private enterprise is succinctly demarcated: “Private roles and roles of the State. Private investment will maintain its protagonist role in the development of the sector, with an active role of the State in strategic decisions such as legislation, the definition of taxes or incentives, standards, removal of barriers and transmission planning.”¹⁹⁷ This goal defines the duality of the roles required for the successful partnerships (state together with private) requisite for the large-scale development of ERNC projects; the same document also decrees that by 2050, a minimum of 70% of the energy matrix should be comprised of ERNCs.¹⁹⁸

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¹⁹⁸ Ibid.
Figure 8: A projected mapping of Chilean energy sources to 2050, with a minimum goal of 70% ERNCs\textsuperscript{199}

\textsuperscript{199} From top to bottom: Wind, Solar, Geothermal, Mini-Hydro, Conventional Hydro, Fuel Oil, Biomass Liquor Fuel, Diesel, Natural Gas, Coal, Source: (http://www.energia2050.cl/registro_consulta)
Chapter 8: Policy Evolution in Investment Priorities and Goals

Over the past few years, the importance of the government in creating investment opportunities in ERNCs has become more-prominent in policy goals. The Chilean Ministry of Energy, and other government bureaus are seemingly cognizant that not investing in ERNCs will become a real impediment in terms of growth and financial investments. Researcher Hänel reiterates that, “The successful deployment of renewable energy in the country will depend on providing an adequate investment environment, which in turn is affected by the availability and quality of the renewable energy resources.”\(^{200}\) Timilsina et al. reinforce the idea of creating public-private financial partnerships to expand ERNCs: “One of the main drivers of solar energy development in developing countries is public investment. Many developing countries host a number of government and/or donor-funded projects to support solar energy under their rural electrification programs.”\(^{201}\) Chile is moving vigorously toward increasing ERNC output, and again renewables seem to be the common denominator in uniting both Allende and Pinochet’s political philosophies; outside investment is tethered to an active role by the state.

Gabriel Rodriguez, director of energy, science, technology and innovation at Chile's Ministry of Foreign Affairs stated in 2012 that, “We [Chile] need to double our electricity-supply capacity over the next 10 years.”\(^{202}\) ERNC legislation had been enacted prior to Rodriguez’ analysis, but had been meek in setting hefty ERNC output goals.


Policy shifts since that declaration have been swift and potent, and have re-shaped the legal framework in which the electric providers operate.

After taking office in 2010, then “President Sebastian Piñera outlined an energy plan, pledging to increase renewable-energy use by as much as 20% by 2020.”

CORFO [Corporación de Fomento de la Producción de Chile, Corporation for the Development of Chilean Production], the Chilean agency responsible for both seeking and distributing capital investment to promote economic growth, has worked largely in conjunction with other ministries to boost start-up capital for renewable investments. As of January 2014, CORFO had announced that, “More than USD 2.3 million is available for financing NCRE projects connected to the grid in 2014 and other USD 4.2 million will be available by companies committed to energy self-supply systems based on renewable sources. These resources are part of the programs launched during the first half of 2014 by the Centre for Renewable Energy (CER) of the Ministry of Energy-CORFO, which released its work plan to promote clean energy.”

Five months later, and within the first three months of the inauguration of President Michelle Bachelet to a second term in office, as part of the first 100 days initiative, the Ministry of Energy published a 123 page document outlining the “Metas y Objectivos de la Agenda de Energía” (Goals and Objectives of the Energy Agenda). Listed under these objectives were the following goals, including: “Reduce the marginal costs of electricity during this period of government by 30% in the Central

203 Ibid.
Interconnected System (SIC), so that the average marginal cost of 2013 U.S. $151.36 MWh less than U.S. $105.96 MWh in year 2017, “Lift barriers for ERNC (Non-Conventional Renewable Energy) in the country, ensuring that 45% of electricity generation capacity to be installed in the country between 2014-2025 will come from these types of sources, thus fulfilling the goal of a 20% sourcing of ERNC in our electricity system by 2025, under current law,” and, “New functions will be added to the current Renewable Energy Center, transforming it into the National Center for Development and Innovation in Sustainable Energy and will focus on the objective of the Strategic Innovation Programs in Energy and promoting renewable energies, in conjunction with CORFO.” Also being implemented, amongst other programs, will be public-private partnerships to develop applications for distributed generation and smart grids integrating different technologies, as a strategic program in innovation and industrial development in solar energy. For Bachelet to make a sweeping change in the ERNC goals during the initial period of her presidency sets a new precedent for making a reduction in GHG a top priority for Chile.

The Chilean solar energy transition, stemming from this massive-scale revamping of the country’s legal framework for energy sourcing, includes a notable increase in public-private partnerships for project funding; legislation specifically encourages active partnerships between public and private sources. Chile has proactively designed institutional opportunities for transition from non-renewable to renewable energy

207 Ibid.
sourcing, and financing opportunities have been designed to incentivize potential large-scale investors and start-ups alike.

Since that time, Chile has continued to proactively promote the use of ERNCs, such as solar installations, and again addressed the need for expansion in the 2014 Energy Agenda, making directly-stated verbiage requiring the utilization of solar energy. Declaring the academic and TT goals would remain an enhanced priority to promote this aforementioned increase in ERNCs, the 2014 agenda stated, that Chile, “will stimulate innovation and industrial progress with solar energy, with the consolidation of the solar research centers and by implementation in the country; the promotion of associations between industries and research centers, and a focused cluster in the development of the providers of goods and services.”

This hard push created measurably significant outcomes in 2014; at the beginning that year, “Chile’s Center for Renewable Energy (CER) reported only 6.7MW-AC of completed PV projects, and number which has increased by 50-fold by December to 326 MW-AC.”

Chile has stepped up efforts to use a plethora of options to install energy systems that require less GHG output. Government incentive options are plentiful, too. Researchers Servert et al. suggested that there are five main mechanisms that can be put in play to incentivize solar investment in Chile:

The Customs Duty or “Impuesto al Comercio Exterior” (CE) is an indirect tax levied on imports. The tariff is calculated as a 6% of the result of adding the cost

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of goods, insurance premium and freight value. Several countries have signed bilateral commerce treaties with Chile which include partial or total exemptions from this tax. The Value-Added Tax or “Impuesto al Valor Agregado” (IVA) is an indirect tax levied on consumption. Companies act as collectors of this tax, balancing the amounts paid and charged on this concept with the government. The rate of this tax is 19%. The Corporate Tax or “Impuesto a las Utilidades” (IU) is a direct tax levied on the income earned by commercial, industrial, mining and service companies. It is applied on the basis of the net profits earned by the company. The rate of this tax is 20%. The Municipal Tax or “Impuesto de Patente Comercial” (PC) is a direct tax levied by municipalities on companies that develop commercial or industrial activities in their territory. The yearly amount is calculated on the basis of the equity capital of the company, and the rate ranges between 0.25 and 0.50%, at the municipality’s discretion. It is limited to 8,000 UTM/year where UTM stands for “Unidad Tributaria Mensual”, a figure in Chilean tax law which value changes monthly according to the Consumer Price Index. It has ranged between 40,005 and 40,286 CLP (Chilean pesos) during the first half of 2013. The Additional Tax or “Impuesto Adicional” (IA) is a direct tax levied on the same basis as the Corporate Tax, but it applies to income obtained in Chile by individuals or legal entities neither domiciled nor resident in Chile, when this income is sent abroad. The rate of this tax is 35%, but the amounts already paid on the same basis (e.g. Corporate Tax) are deducted.\textsuperscript{210}

New solar investments have left the sluggish ways of the past, and are coming online at a rapid-fire pace; international partnerships have become the new standard for ERNC large scale investments. Principally related to the need for energy in the mining sectors, these projects epitomize the scope of the global partnerships that define solar growth within Chile. Wine and grape producers are also beneficiaries of international collaborations to jumpstart ERNC installations, but not on the same scale as the mining industry, thus far. Between 2010 and 2015, a number of Chile’s solar energy capacity expansion made headlines.

In 2013, Power Finance and Risk reported a new partnership between France, Spain, Canada and Chile that will result in new financing of solar energy projects to benefit Chile. “The CCF [Canadian Climate Fund] is a C$250 million ($246 million) fund set up by the Canadian government and managed by the IDB, which backs private sector climate mitigation and adaptation projects in Latin America that need concessional financing to become viable.”211 Together with Proparco, the private investment unit of the French Development Agency with a mandate of “procuring private investment for developing countries, related to growth, sustainable development, and assist countries in attaining the United Nations’ millennium development goals,” the IDB, and Spanish solar company Solarpack, a debt package was approved to fund 26.5MW of solar projects in the Atacama Desert.212 213 Describing the projects in more detail, Power Finance and Risk reporter Nicholas Stone explained the details of the partnership: “The $84 million series of projects include the 25.4 MW Pozo Almonte 2 and Pozo Almonte 3 photovoltaic

212 Ibid.
213 Ibid.
facilities, which are under construction, and the 1.1 MW Calama Solar 3, which has been operational since April 2012. Electricity from the facilities will be sold to Santiago, Chile-based mining companies Codelco and Collahuasi. Solarpack has signed a contract with Compania Minera Dona Ines de Collahuasi for the construction, development and management of the solar power plants.”

Euro-Chilean partnerships abound as well. German and French energy companies have partnered with Chile to build a 5 MW thermal solar concentrated power plant that will supply the 150 MW Mejillones coal plant in the north of the country. “GDF Suez announced it had partnered with Solar Power Group, [a] German renewable energy company” to create the partnership to install a solar boiler that will link to a coal-fired power plant that will utilize steam to drive turbines, even after sunset, and diminish the requisite coal to power the plant, resulting in diminished GHG emissions.

In January of 2014, the Chilean Minister of Energy announced a massive projected investment in solar energy generation projects; at the time of the announcement, the prior four years had shown an aggregate approval for developments totaling 703 MW. This package of investment partnerships included Amanacer Solar, part of the US firm SunEdison in partnership with the Chilean iron mining company CAP. An additional 2,662MW of solar investment projects was under review.

“SunEdison has closed a $260.5 million debt package backing the 100MW Amanacer

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216 Ibid.
217 Ibid.
218 Diana Hristova, “Chile’s Atacama set to attract USD 7.5bn in solar power investments,” See News Renewables January 15, 2014.
219 Ibid.
220 Ibid.
solar project near Copiapo in the Atacama Desert in Chile. The deal consists of $212.5 million non-recourse tranche from the International Finance Corp. and the U.S. government’s development finance institution the Overseas Private Investment Corp. The IFC provided $65 million of debt, while OPIC provided $147.5 million. Rabobank also lent a Chilean Peso VAT facility of $45 million.”221 The recipient of this massive projected energy output would be mining and steel company CAP, “which is the largest steel producer in Chile.”222

The common element in each of the partnerships that were designed to bring ERNC investment projects on line in Chile is the creation of state-steered partnerships with open-market, outside investment partners. The two political ideologies that this ironically embraces include the neoliberal model, undertaken by shock economics under the constraints of Pinochet’s dictatorship, which sought an open marketplace in which to conduct business, and Allende’s unaltering belief that the role of the state was to ensure the economic well-being of all its populace, while ensuring the country’s resources were equitably distributed. Of course, the natural geographic resources that power ERNCs, especially solar installations, will be of benefit to all Chileans, not simply for the economic benefits afforded to the businesses who utilize ERNCs, but to all Chileans, who, in turn have cleaner air to breathe, lower electricity costs, and, with any persistence in increased ERNC usage, the possibility to mitigate even more irrevocable climate changes.

222 Ibid.
For financing of solar projects, investment has been opened up to private and public investors, both domestic and international. “The Chilean government is actively seeking to promote the deployment of renewable energy plants by a mandatory quota system and also financial incentives.” According to the OECD, “The government of Chile has provided funding for managing climate change, enabling the creation of permanent working groups charged with addressing climate change from within their ministries and the allocation of budgets to implement their activities.” The cost of investment in solar technologies has declined drastically since photovoltaic (PV) cells were first invested in Bell Labs in 1954. “The application of fiscal and financial incentives can lead to a price reduction in the electricity from solar sources such as CSP [Concentrated Solar Power] and PV. Fiscal incentives can be assessed in terms of efficiency, where incentives with high efficiency would be more advisable from an economic point of view.” “The mechanism with which an incentive is applied can affect its efficiency...mechanisms that improve the investor’s cash flows during the earlier years of the project reach the best efficiencies for a given impact on price.”

According to a 2013 US Department of Commerce report, “Local Chilean banks have been slow to invest in Chile’s renewable energy industry, limiting the sector’s

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227 Ibid., 1886.
growth potential over the previous decade. The exception has been the Chilean Government’s Corporación de Fomento de la Producción (CORFO), which has disbursed roughly $12 million for the renewable energy industry and is one of the key incubators for the renewable energy industry in Chile.\textsuperscript{228} The International Finance Corp (IFC) and the German Development Bank (DEG) have also been instrumental in financing solar expansion in Chile.\textsuperscript{229} “14 million is coming from the IFC-Canada Climate Change Programme, financed by the government of Canada,” and “Germany’s DEG is providing the operating company SPS La Huayca [solar park] with a loan of $18.5 million to cover the necessary investment” of and expansion up to 30.5 MW of photovoltaic production installed in the Atacama Desert.\textsuperscript{230}

The financial well-being and stability of Chile for sustained periods of time has come with certain financial perks from a variety of finance agencies. “From the mid-1970’s onwards, the country enjoyed privileged treatment from the International Monetary Fund (IMF) and the commercial banks.”\textsuperscript{231} Other investors in Chilean ERNCs thus far have included the Inter-American Development Bank (IDB), the European Investment Bank (EIB), “as well as several private sector investors from the United States, Europe, and China [that] often find Chile a great place to do business thanks to its well-functioning capital markets and business-friendly culture.”\textsuperscript{232,233,234} The lesson in

\textsuperscript{230} Ibid.
\textsuperscript{232} Ibid.
\textsuperscript{234} Katia Moskvitch, “Sun to keep Atacama Desert’s grapes growing,” BBC, April 15, 2012.
solar financing economics again pieces together neoliberal tidbits from Pinochet, from a lesson to look to outside market forces to secure economic footing, but also an economic motivation from Allende, to ensure that the benefits originating from Chile are enjoyed by all segments of Chilean society, and to consolidate the will of the people to move the government to action.
Conclusion

Renewable energy has the potential to become a core power goal for a thriving Chilean future. Geographically, the country is privileged with irradiance that is unparalleled in the rest of the world. Researchers Timilsina et al. stated the paramount importance of solar in their 2012 publication, declaring that, “Solar energy is expected to play a crucial role in meeting future energy demand through clean energy resources.”

Chile’s turbulent, and politically tense decades during the Allende and Pinochet years have also molded the Chilean future with regards to ERNC growth. Despite two disparate ideologies, Allende’s belief in socialist principles, and Pinochet’s eventual steadfast belief in monetarist and neoliberal policies, both perspectives have evolved over time to reflect a Chilean economic outlook that embraces the sapient principles each philosophy offered: from Allende, the idea that Chile belongs to the Chileans, including its vast natural resources, the idea that the state has a role in managing economic practices, and that access and opportunity for financial well-being should be available to all Chileans, and from Pinochet (though not an endorsement in the least for how his philosophies were implemented or enforced), the idea of open, free trade, in which businesses are permitted to create their own unique path to growth through both internal and external investment opportunities. The melding of these two ideologies has given the Chilean people an opportunity to develop in a way that no other South American country has, and has afforded the country new opportunities in ERNC leadership.

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Chile’s history of fossil fuel and non-renewable energy dependence has made it a country that is precariously susceptible to energy supply interruptions, as well as resulted in the highest energy prices in all of South America.\textsuperscript{236} Chile’s dependence has made it vulnerable to price and supply fluctuations, as well as makes it politically beholden to countries which may not share the same socio-political and philosophical ideologies that this democracy holds. Many publically and privately-funded investors, as well as CORFO, have shown substantial financial commitments to the Chilean energy market, which is plagued by continually augmenting demand.\textsuperscript{237} Solar energy’s benefits include what Devabhaktuni et al. describe as “the simplicity, versatility, reliability, and low environmental impact” which are believed to “help PV systems to become highly utilized sources of economical, premium-quality power over the next 20-30 years.”\textsuperscript{238} With sustained state initiatives, such as Energía 2050, designed with specific, aggressive, unprecedented 70\% renewables goal, including specific policy ideas on how to integrate more ERNCs, especially solar, into the four Chilean power grids, tangible emissions reductions goals are being attempted, and successfully achieved.\textsuperscript{239, 240}

Christian Roselund of The Guardian reported that as of summer 2014, “In Latin America, Chile has grown into the region’s leading solar market.”\textsuperscript{241} According to Melanie Diaz, a research associate at the Council on Hemispheric affairs, Chile continues to excel in a leadership role for the utilization of solar energy: “In 2014, out of the three leading solar countries, Chile made the most developments, with three-fourths of the total

\textsuperscript{236} Ib\textsuperscript{id.}
\textsuperscript{237} Ib\textsuperscript{id.}
\textsuperscript{241} Christian Roselund, “Chile’s solar market is leading the way in South America,” The Guardian, June 5, 2014.
of Latin America’s solar market increase (370 percent) powered by its facilities.”²⁴² Chile has thus far been a leader in South America for the utilization of ERNCs, and, if a continuation of this momentum is sustained, carries the real possibility of becoming not only a regional, but a global leader in the utilization of solar energy to sustain and grow its economy.²⁴³

The benefits of solar energy integration in Chile are numerous, including the social benefits through reductions of GHG pollution, health benefits of lower particulate pollutants in the air, economic growth with vastly reduced energy costs, and political, no dependence on outside suppliers for energy sourcing. Even as early as 2013, James Montgomery, associate editor of Renewable Energy World, noted that there were indications of growing Chile’s ERNC success: “Chile has become one of the planet’s most promising solar markets, leading a wave of regions that will begin achieving grid parity, where solar is at equal cost or cheaper than traditional energy sources, in the near future.”²⁴⁴ The energy and developmental path appears abundantly clear: Chile has a very sunny future.

²⁴⁴ Ibid.
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Vita

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