CHILE LEVELISED COST OF ENERGY

PRESENTED TO NRDC

TYLER TRINGAS, ENERGY ECONOMICS

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INTRODUCTION

- Bloomberg New Energy Finance (BNEF) is a leading provider of industry information and analysis to investors, corporations and governments in the clean energy and carbon sectors. BNEF has a dedicated global network of 125 analysts, based across 10 offices in Europe, the Americas, Asia & Africa that continuously monitor market changes, deal flow and financial activity, increasing transparency in clean energy and carbon markets.
- Natural Resources Defense Council (NRDC) commissioned Bloomberg New Energy Finance to prepare an assessment of the levelised cost of energy (LCOE) for various generation technologies in the Chilean power sector and commissioned Valgesta Energía to provide Chilean data.
- Where the Chilean experience or data was limited or lacking, BNEF drew upon its global database. Where indicated, BNEF conducted independent research in Chile which also supplements the information provided by Valgesta.

OBJECTIVES

- The analysis first compares the levelised cost of energy (LCOE) for conventional and renewable energy sources in Chile in 2011, 2020 and 2030 to show the evolution of the costs of non-conventional renewable energy technologies.
- The analysis then shows the impacts of the costs of transmission, fuel and pollution control investments on the LCOE.
- Finally, the analysis presents a scenario showing the possible impact of non-conventional renewable energy on peak energy prices.

LEVELISED COST OF ENERGY MODEL DESCRIPTION



The levelised cost of energy represents a constant cost per unit of generation computed to compare the generation costs of different technologies.

The specific LCOE is the power price, in USD/MWh, in year 1 that, escalating with inflation through the project life, exactly returns a IRR (in this case, 10%).

By indicating the price at which a technology can profitably sell electricity, the technique allows the LCOE to be representative of a competitive tendering process for actual power contracts.

FIGURE 1.1: 2011 LCOE CHILE LEVELISED COST OF ENERGY



Today, on an LCOE basis, a wide range of nonconventional renewable energy (NCRE) technologies, including biogas/landfill gas, small hydro, biomass, onshore wind, geothermal are competitive with the *new build* cost of Chile's mainstay energy sources of large hydro, natural gas and coal.

Energy prices are from CNE data and calculated as the average of 1st quarter 2011 and the last three quarters of 2010.

Note: Large Hydro are non-Aysen projects, small hydro are less than 20MW.

Source: Bloomberg New Energy Finance, Valgesta Energía

Chile Levelised Cost of Energy, April 2011

FIGURE 1.2: 2020 CHILE LEVELISED COST OF ENERGY

249

300

187

174

143

159

169

179

169

133

108

121

121

137

137

102



NCRE LCOE Conventional LCOE

200 100 △ Central Scenario ·····SIC Power Price -

128

110

131

91

92

USD/MWh

400

SING Power Price

450

590

By 2020, utility scale PV and solar thermal systems will be competitive sources of energy without subsidies.

With increasing thermal fuel prices and decreasing costs for renewables. several technologies such as wind, biomass, geothermal and small hydro will in some cases be a cheaper option for new energy capacity than conventional technologies.

Energy prices are based on PRIEN* 2008 forecast to 2030, "dynamic" case.

Note: Large Hydro are non-Aysen projects, small hydro are less than 20MW.

*Programa de Estudios e Investigaciones en Energia - Instituto de Asuntos Públicos en Energía Universidad de Chile. Diesel fuel prices beyond 2030 not modelled

hile Levelised Cost of Energy, April 2011

FIGURE 1.3: 2030 CHILE LEVELISED COST OF ENERGY



Note: Large Hydro are non-Aysen projects, small hydro are less than 20MW.

*Programa de Estudios e Investigaciones en Energia - Instituto de Asuntos Públicos en Energía

Universidad de Chile. Diesel fuel prices beyond 2030 not modelled

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FIGURE 2: IMPACT OF TRANSMISSION COSTS ON LCOE

Diesel utilty-scale PV cSi commercial cPV two-axis tracking utilty-scale PV cSi utilty-scale STEG tower + heliostat utilty-scale STEG trough utilty-scale Geothermal binary utilty-scale Coal utilty-scale CCGT utilty-scale Geothermal flash utilty-scale Wind onshore utilty-scale Biomass all feedstocks utilty-scale Large Hydro Large Hydro Aysen Small Hydro **Biogas/Landfill utilty-scale**

> ■ NCRE LCOE △ Central Scenario

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Except for distributed generation (not connected to the grid), new generation sources require some transmission build out unless built adjacent to existing transmission.

Renewables and large hydro must be located where resources are found and therefore have a wide range of possible costs.

Transmission costs for stand-alone coal and gas facilities will depend heavily on where local regulations permit project siting and could vary significantly for an individual project.

FIGURE 3: 2011 LCOE WITH CCS



Note: Assumes Valgesta Central coal scenario and CNE SIC gas price forecast.

CCS technology is expensive because it has not yet been commercialized. In addition to incremental CAPEX, it reduces a plant's operating efficiency lowering capacity factors.

As a consequence, in 2011 CCS could increase the LCOE by a factor of 2.

BNEF does not predict widespread deployment of CCS until 2030, with costs reductions in excess of 25% only occurring in 2050.

FIGURE 4.1: FUEL PRICE FORECASTS TO 2030



Future thermal prices are very uncertain for Chile and forecasts range widely. These forecasts have a large impact on future LCOE.

Valgesta created a weighted-average coal forecast methodology which is our base case assumption although some forecasts are substantially higher.

The CNE forecast for SIC from 2012 was used as the base case for natural gas.

Source: Bloomberg New Energy Finance, Valgesta Energía

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FIGURE 4.2: IMPACT OF COAL PRICE FORECASTS



NCRE follow a predictable path for price reductions in the longterm. However, future thermal prices depend on very unknown fuel prices.

This makes the point of parity with other fuels very uncertain but possibly very near.

FIGURE 5: LEARNING CURVE, CAPEX ASSUMPTIONS: USDM/W



Crystalline silicon PV modules, fall in cost by 25% for each doubling of global capacity.

Wind turbine prices in Chile are historically very high but in the medium term we expect them to quickly converge with our global averages.

Learning effects ultimately slow as global markets mature and capacity doubles less frequently.

Tech	2010	2015	2020	2025	2030	% Δ2020	% Δ2030
Coal	3.17	3.17	3.17	3.17	3.17	0%	0%
CCGT	1.51	1.51	1.51	1.51	1.51	0%	0%
PV cSi residential roof	3.76	2.20	1.68	1.45	1.35	-55%	-64%
PV cSi commercial/BIPV	3.48	2.08	1.61	1.38	1.29	-54%	-63%
PV cSi utilty-scale	2.98	1.84	1.43	1.23	1.15	-52%	-61%
Wind onshore utilty-scale	2.62	2.02	1.66	1.50	1.36	-37%	-48%
Solar Thermal	4.61	3.00	2.58	2.22	1.90	-44%	-59%

FIGURE 6: GLOBAL PV EXPERIENCE CURVE





Using inflation-adjusted data back to 1976 from Paul Maycock, Bloomberg New **Energy Finance estimates** the industry learning rate at 25%. This figure shows blue and purple points representing the actual data points from the historical dataset, and the line is a fit to the experience curve formula. Cumulative volume is on the x-axis and cost is on the y-axis, both on a log scale to make the relationship display as a straight line.

Source: Bloomberg New Energy Finance Solar Price Index, Paul Maycock, Solarbuzz

FIGURE 7: GLOBAL WIND TURBINE PRICE INDEX



Our Wind Turbine Price Index includes analysis of approximately 100 turbine contracts globally, including Latin America. encompassing around 20% of the global annual wind market. Because onshore wind turbines represent a mature technology, the learning curve is essentially flat. Offshore wind turbines, by contrast, represent an emerging technology whose costs are expected to decline 15% in the period up to 2030.

Source: Bloomberg New Energy Finance

Wind Turbine Price Index

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FIGURE 8: LEARNING CURVE LCOE FORECAST BY PROJECT COMMISSIONING DATE



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FIGURE 9.1: SIMPLIFIED TIME OF DAY MULTIPLIERS FOR CALIFORNIA SHOWING PEAK ENERGY VALUE



This analysis only looks at a constant USD/MWh cost, however in reality energy produced at times of peak demand has higher value. For reference, we include a simplified perspective of the "value multipliers" used by California utilities to represent this time of day value. Customized multipliers would have to be developed for Chile.

These multipliers are used to adjust power contracts based on time of day the project delivers power.

Source: Bloomberg New Energy Finance, California Public Utilities Commission

FIGURE 9.2: SIMPLIFIED DAILY OUTPUT PROFILE OF SOLAR TECHNOLOGIES



This figure shows a typical daily output profile of solar technologies,also using California as a reference.

By multiplying the curves in Figures 9.1 and 9.2, power from PV and solar thermal are worth 1.3 – 1.5x the nominal USD/MWh paid.

We would expect results to be roughly similar in the SIC.

FIGURE 10: SOLAR: RESIDENTIAL PV GRID PARITY VS. LCOE: CHILE, MEXICO, BRAZIL POISED TO COMPETE

Retail electricity prices (USD/kWh)



Grid parity differs in each country dependant on the solar resource and avoided cost of retail electricity.

The lines on the graph to the left show how cost declines in solar module prices over time move more countries into grid parity.

Chile is expected to hit retail grid parity by 2014, although sunnier parts of the country will see it earlier.

Note: WACC = 10%; O&M = 1.5% of capex; system degradation = 0.7% per year; project life = 25 years; based on 2010 retail electricity prices; no electricity price increase assumed

FIGURE 11: PROJECTED COST OF POLICY SUPPORT (LCOE MINUS POWER PRICE)



Depending on the energy policy framework Chile puts in place, the costs of scaling up renewable energy will vary.

A rough estimate of the costs of deploying each technology can be made by subtracting the projected power price from the projected LCOE of a given technology.

A result greater than zero indicates the amount of payment required in excess of the projected power price.

AREAS FOR FURTHER STUDY

- The Chilean renewable energy market is still very immature with few data points. Although, the best available data was included in this report, global averages and local analyst estimates were frequently used.
- As Chile's energy matrix evolves, it is very unclear what entities (small or large independent power producers, large corporates, state-backed entities) will actually be building future energy infrastructure. The financing structures and hurdle rates of the each of these entities could significantly change the actual price of energy from projects within a certain technology.
- Renewable resource information was of limited availability at the time of this study. Preliminary analysis indicates Chile has world-class solar and geothermal resources and reasonable wind and biomass resources however there are few projects to have confirmed this output and a lack of detailed and publicly available studies.
- Other relevant costs and benefits are beyond the scope of the study, such as the costs of pollution not related to equipment costs, the costs of integrating variable resources into the grid, the benefits of diversification and other benefits and costs.

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MARKETS

Renewable Energy Carbon Markets Energy Smart Technologies Renewable Energy Certificates Carbon Capture & Storage Power Water Nuclear

SERVICES

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