

The impact of renewable portfolio standard in fast growing countries

The Chilean experience

*Sebastian Mocarquer, Hugh Rudnick, Pedro Miquel,
Jaime Larraín & Javier Ayala*

2014 IEEE Power & Energy Society General Meeting
Charting the Course to a New Energy Future



- **Chilean electricity market context**
 - Electricity system description and characteristics
 - Economical and social challenges
 - Renewable portfolio policy discussion
- **Impact of the increase of renewable portfolio standard policy from 10% to 20%**
 - Investment, operation and transmission costs
 - Final consumer prices
- **Final remarks**



Chilean Electricity Systems (June 2014)



Power & Energy Society®

		Gross Capacity (Dec-2013)	Electricity Generation (2013)	Maximum demand (2013)	Population
SING <i>Sistema Interconectado Del Norte</i>	Arica y Parinacota	3,966 MW	17,229 GWh	2,243 MW	5.7%
	Tarapacá	20.8%	25.2%		
	Antofagasta				
SIC <i>Sistema Interconectado Central</i>	Atacama	14,968 MW	50,820 GWh	7,283 MW	92.6%
	Coquimbo				
	Valparaíso				
	Región Metropolitana				
	Lib. Gral. Bdo. O'higgins				
	Bío-Bío				
	Araucanía				
	Los Ríos				
SEA <i>Sistema de Aysén</i>	Los Lagos	50 MW	155 GWh	25.3 MW	0.6%
	Aysén				
SAM <i>Sistema de Magallanes</i>	Magallanes	112 MW	291 GWh	51.7 MW	1.1%

Taltal

Chiloé

Source: CNE, CDEC, SysteP

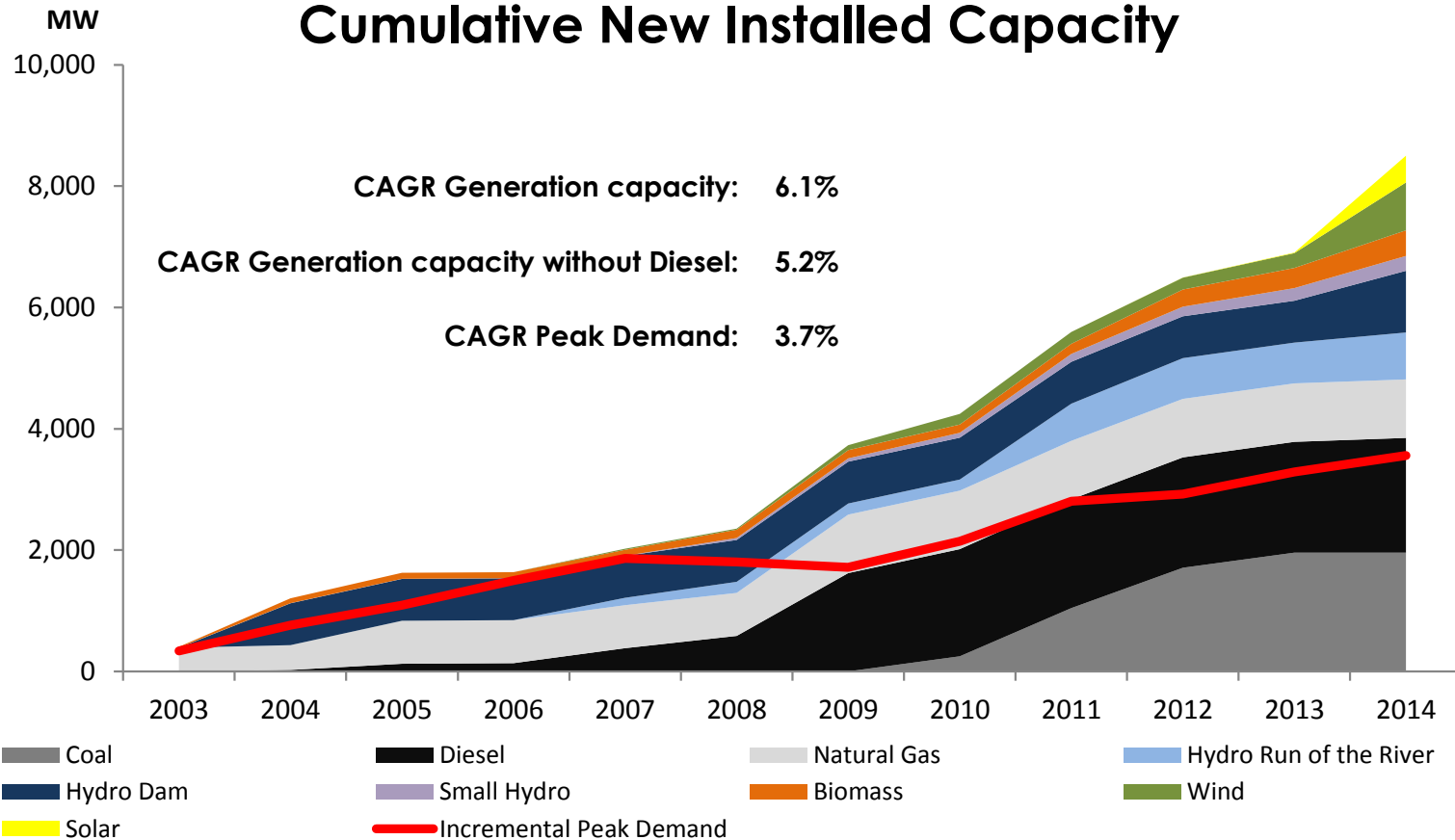


SIC investments last 10 years



Power & Energy Society®

Cumulative New Installed Capacity



Cumulative New Installed Capacity 2003-2014 (MW)									
Coal	Diesel	Natural Gas	Hydro Run of the River	Hydro Dam	Small Hydro	Biomass	Wind	Solar	Total
1,958	1,892	964	774	1,017	245	422	790	441	8,503

Source: CNE, CDEC, July 2014

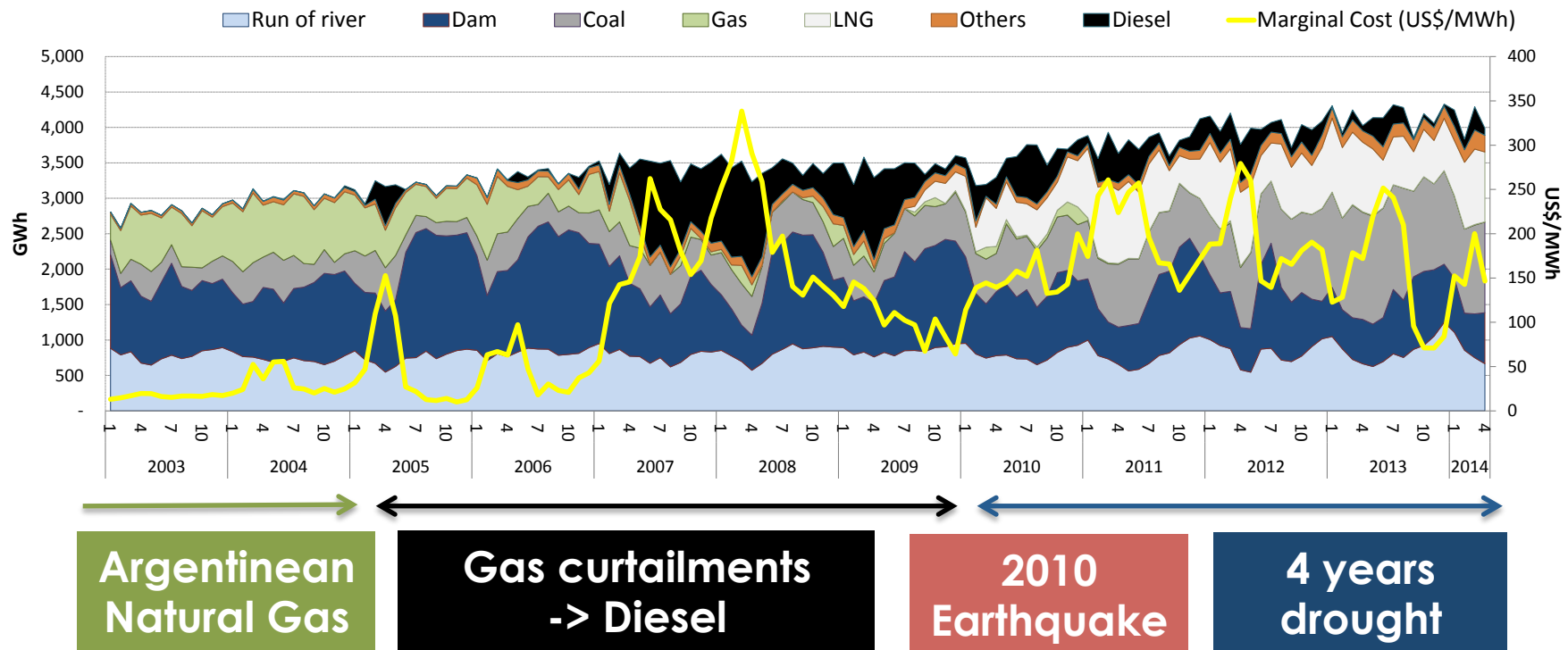


2004-2014: Gas crisis, earthquake and dry hydrologies



Power & Energy Society®

- High energy prices for the past seven years.
- Perfect storm or market failure?



Source: CDEC-SIC, July 2014



Social rejection and litigious scenario



Power & Energy Society®

Several or most energy projects from different technologies have been trapped in approval processes, and most end up in the judicial system.

- Coal:
 - Castilla (2,100 MW)
 - Pacífico (350 MW)
 - Barrancones (540 MW)
 - Punta Alcalde (740 MW)
 - Bocamina 2 (357 MW)
- Hydro:
 - HidroAysén (2,750 MW)
 - Cuervo (640 MW)
 - Neltume (490 MW)
- Wind:
 - Chiloé (100 MW)
 - Arauco (100 MW)

8,496 MW in projects have been rejected or challenged in court

HidroAysén



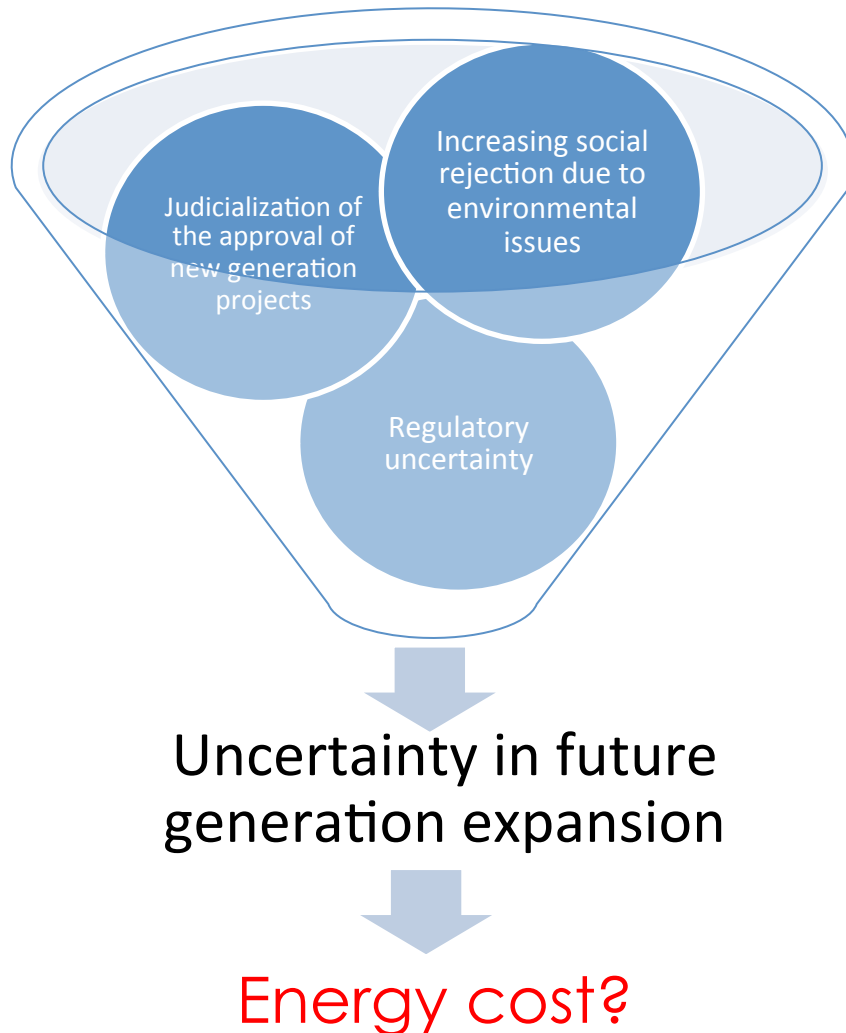
Hydroelectric - 2,750 MW
Investment 3,200 MMUS\$
May 2012

Chiloé



Wind - 112 MW
Investment 235 MMUS\$
July 2011

Source: Systep, press, July 2014



Social Rejection:

Not in my backyard effect

Judicialization:

Environmental permit processes normally end in court

Regulatory uncertainty:

Changes in the market rules
New energy policy to be discussed in 2015



Law 19.940 - Short Law I (2004):

- Decree 244 - Non-conventional and Small Generator Bylaw (2006):
 - Incentives for small generators (less 9 MW, including NCRE).
 - Trunk Transmission toll total or partial exemption.
 - Energy trade through stabilized price option or fixed price

Law 20.257 - NCRE Law (2008):

- NCRE Quota of 10% by 2024 for contracts signed after August 2007, starting with 5% in 2010 and increasing 0,5 % annually from 2014 until 2024.
- Penalty for non-compliance (30 US\$/MWh first time, 45US\$/MWh second time).

Law 20.698 – 20/25 Law (2013):

- Modification of the NCRE Quota (20% for 2025) for contracts signed after July 2013.
- Annual NCRE auctions for the compliance of the quota, when the National Energy Commission foresee NCRE deficit.



Renewable projects in Chile



Power & Energy Society®

Technology	Installed Capacity [MW]	Under construction [MW]	Environmental Qualification Approved [MW] (1)	Under Assessment [MW] (2)
Small Hydro	341	34	290	183
Wind	682	154	4,542	2,099
Biomass/Biogas	461	22	74	66
Solar-PV	184	448	5,809	4,155
Solar-CSP	-	100	760	-
Geothermal	-	-	120	-
Total	1,668	758	11,595	6,503

(1): The projects got the environmental permits (Environmental Qualification Resolution).

(2): In process to get the environmental permit.

Source: SEIA July 2014

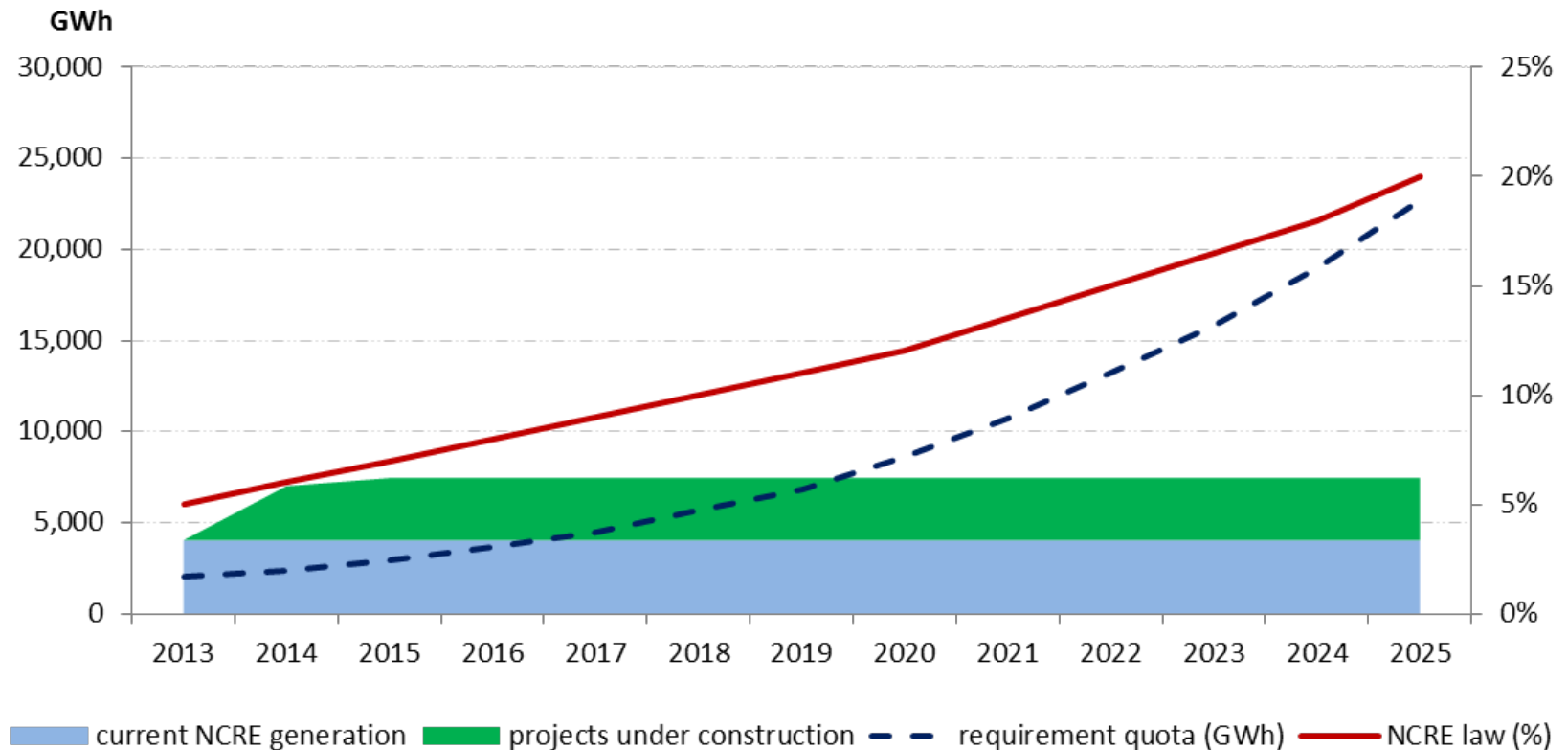


Renewable Portfolio Standard in Chile

Current and projected quota fulfillment



Power & Energy Society®



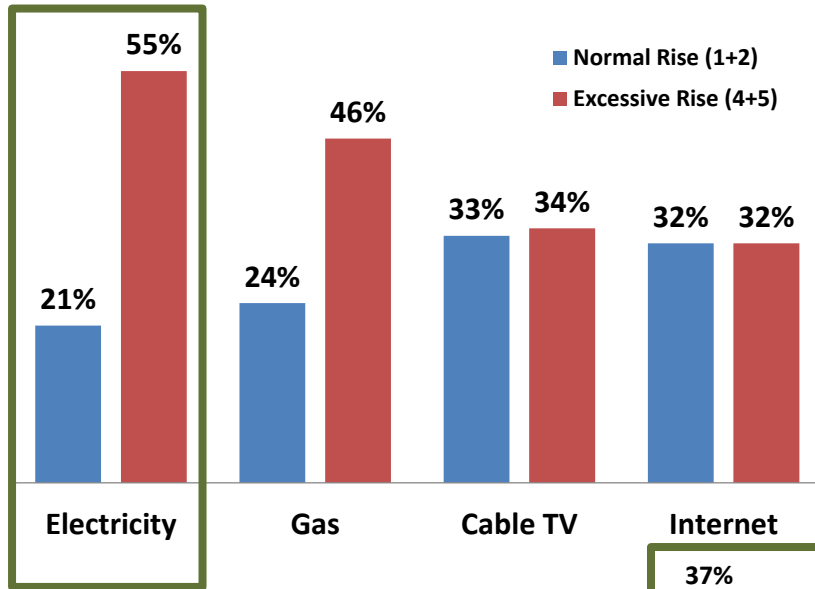
Source: CER, SEIA,
Systep, July 2014



Society's perception of energy costs



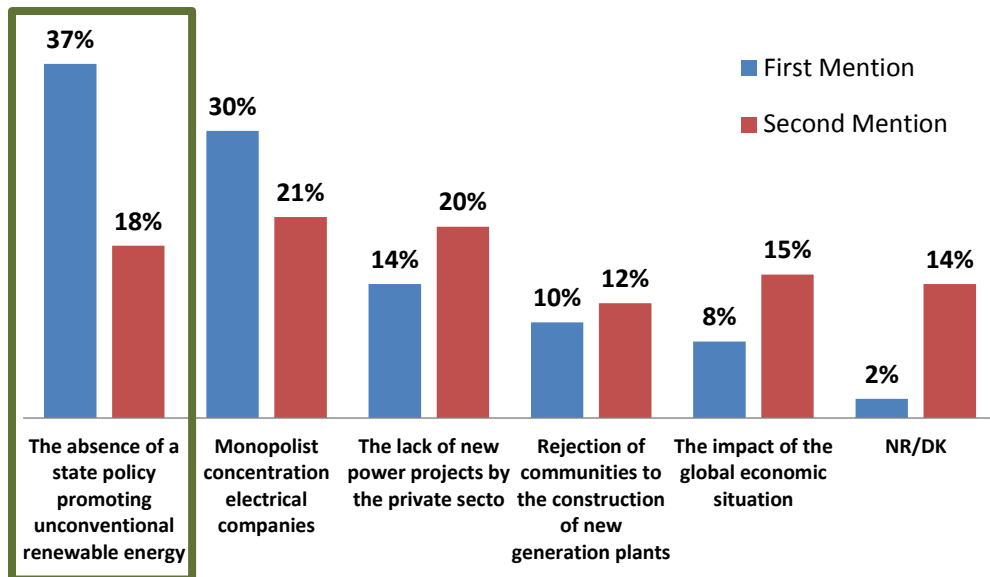
Power & Energy Society®



Would you say that in the last time the price of the following basic services in Chile have had normal rises?

(On a scale of 1 to 5, where 1 means "a normal rise" and 5 means "an excessive rise")

Which of the following factors is the main responsible of the current cost of electricity?



Source: FeedBack, 2014



Global renewable objectives



Power & Energy Society®



Sources:

- (1) CIDET-Cono Sur SER-GIMEL 2014 "Interconexiones regionales para el desarrollo de una matriz de energía sustentable"
- (2) www.dsireuda.org
- (3) CEER, "Status review of renewable and energy efficiency support schemes in Europe", June 2013



Price structure in Chile

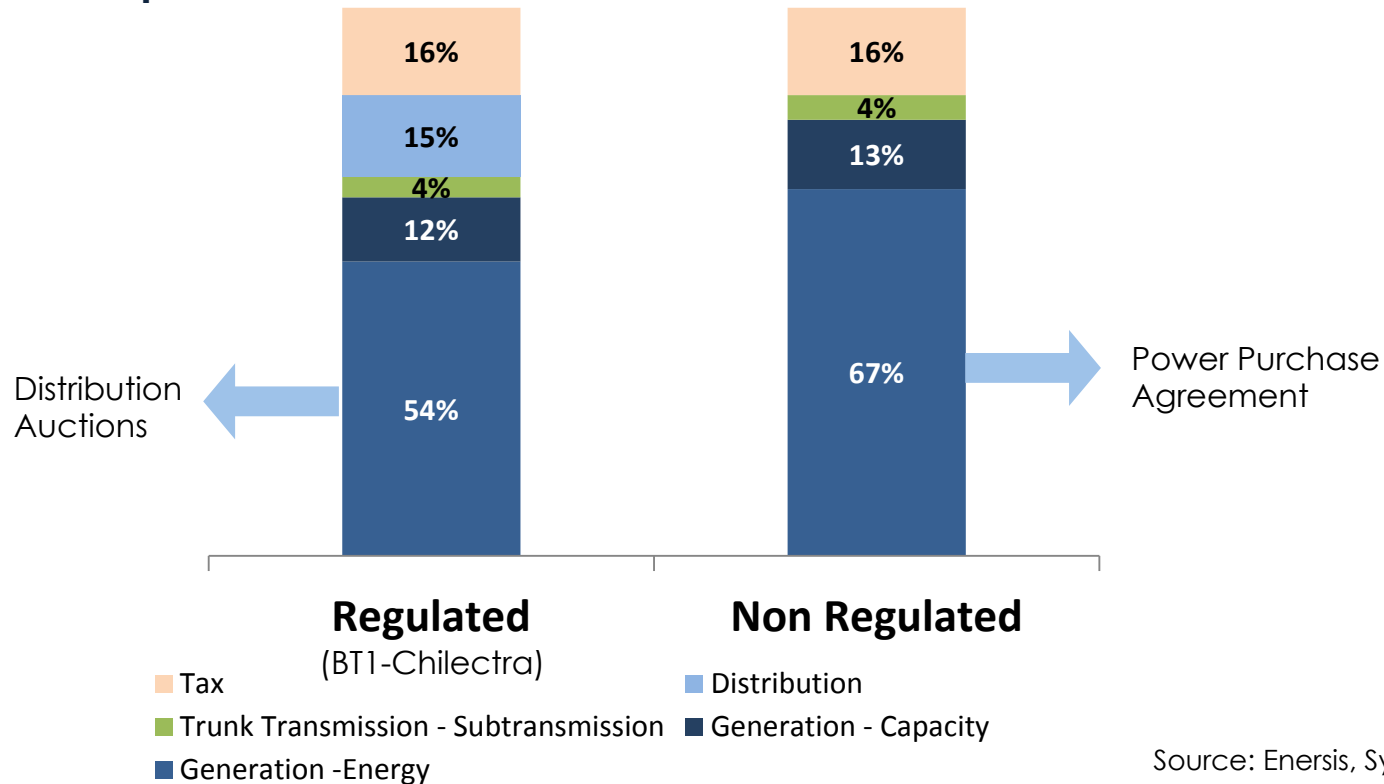


Power & Energy Society®

- Objective: Estimate tariffs for non-regulated and regulated clients in 2025, assuming that capacity payments, distribution tariffs and taxes remain constant

April 2014 prices 160 US\$/MWh

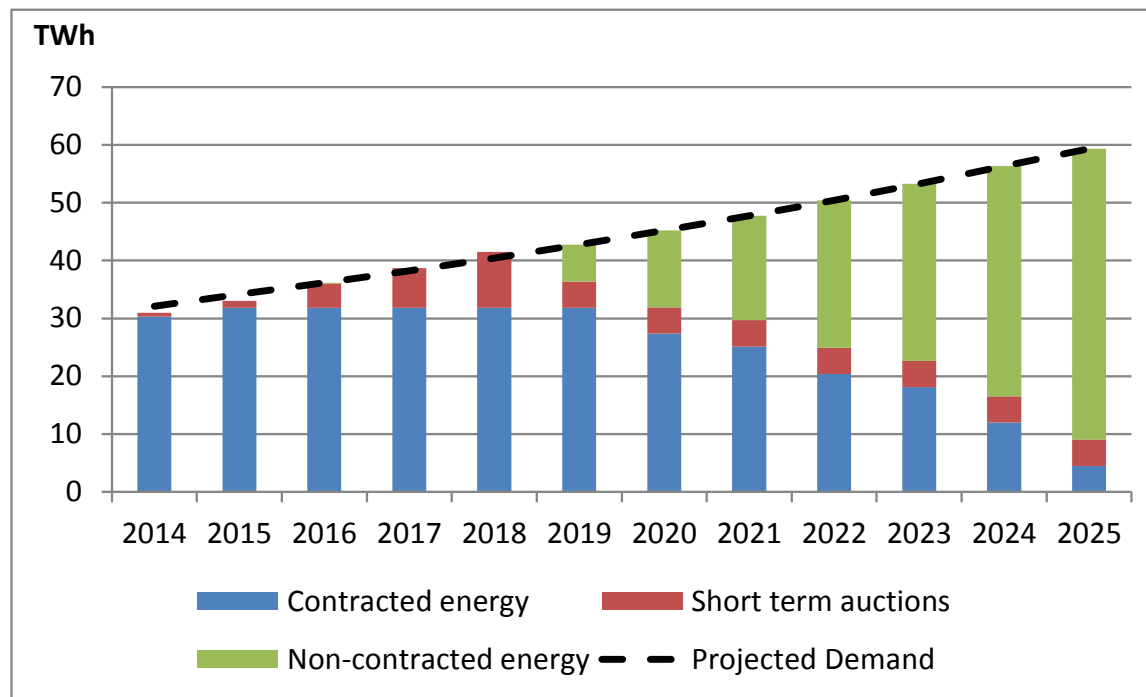
134 US\$/MWh



Source: Enersis, SysteP, April 2014



- Energy price for **regulated** clients by 2025 will be affected by two factors:
 - Current contracts expiration
 - NCRE quota (only when NCRE require an overprice)
- Assumption: all new contracts by 2025 fulfill the NCRE quota of that year (20%)
- Both tariffs could experience an additional overprice due to additional **transmission** and **spinning reserve** requirements



Source: Enersis, Systep, April 2014



- Simulation of system expansion up to 2025 with two quota schemes
- Consideration of private generation driven expansion
 - Scenario 1: Coal based expansion
 - Scenario 2: LNG based expansion
- Hydrothermal simulation of SIC, multi-nodal and multi-dam representation of the SIC.

Item	Coal	LNG – Combined Cycle
Unitary investment	2,400 – 2,800 US\$/kW	1,000 – 1,200 US\$/kW
Capacity factor	85% - 90%	50% - 80%
Fuel prices	100 – 130 US\$/Ton	11.0 – 13.0 US\$/MMBtu
Variable cost	37.0 – 47.5 US\$/MWh	78.2 – 91.8 US\$/MWh
Debt-equity rate	70%/30%	70%/30%
Levelized cost of energy (LCOE)	76.5 – 96.4 US\$/MWh	74.4 – 115.0 US\$/MWh

Marginal costs not affected by 10 or 20% penetration levels, defined by private investment decisions, and resulting as those from conventional coal or LNG driven expansion.



Simulation assumptions

NCRE supply curve



Power & Energy Society®

- NCRE supply curve:
 - What is the price for a given amount of NCRE?
 - Given a long term price, what is the amount of NCRE that would be installed?
- Assumptions:

Technology	Investment [US\$/kW]			Load factor			Levelized cost [US\$/MWh]			Available Capacity [MW]
	Min.	Ave.	Max.	Min.	Ave.	Max.	Min.	Ave.	Max.	
Biomass	1,750	2,200	2,710	75%	80%	90%	33.5	43.6	57.6	91
Geothermal	3,480	5,750	6,600	88%	90%	92%	65.1	105.4	122.5	96
Small hydro	3,510	4,210	4,910	50%	60%	70%	69.0	93.2	127.2	261
Wind	2,000	2,250	2,500	25%	33%	40%	66.5	88.3	123.2	2,370
Photovoltaic solar	1,960	1,990	2,500	20%	25%	35%	73.2	102.3	155.4	5,248
Concentrating solar	7,380	7,310	8,530	70%	80%	90%	120.9	132.0	167.2	320

- Normally, effective installed capacity is less than the reported capacity in the environmental studies, therefore only 80% of the reported capacity of each project is considered
- Monte Carlo method is used to evaluate levelized costs of future projects
 - The future set of projects is defined using SEIA information
 - Investment costs and load factors of those projects are modeled as random variables using independent truncated normal distributions.



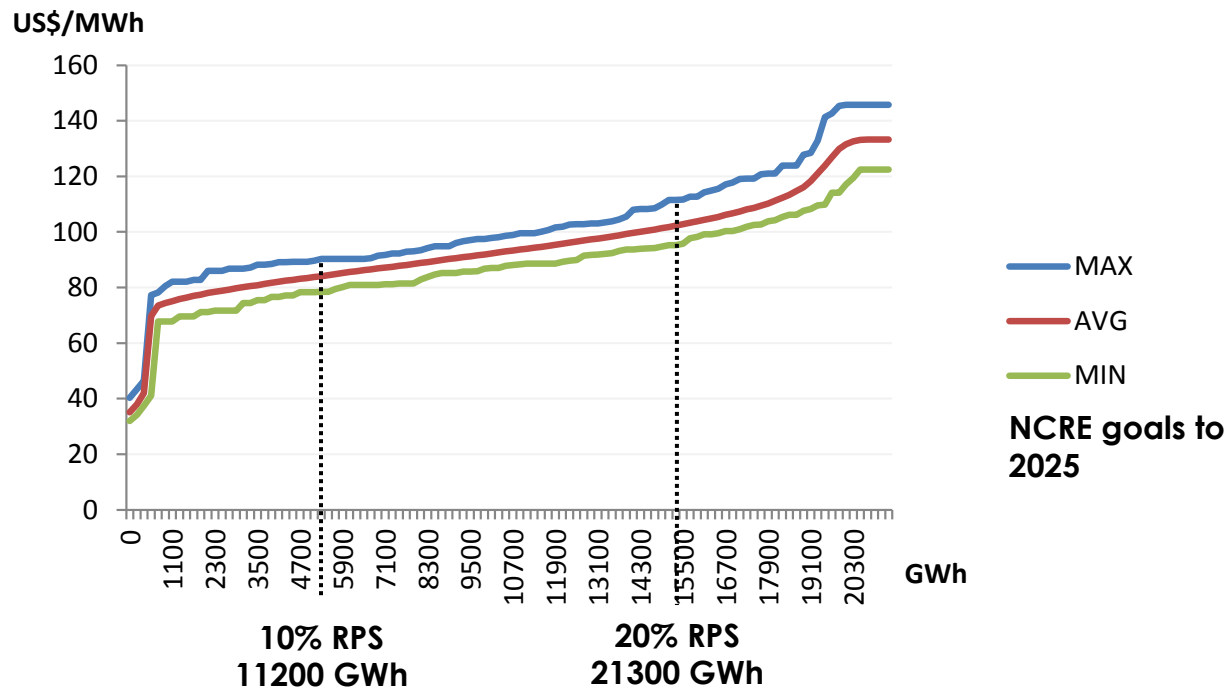
Simulation assumptions

NCRE supply curve



Power & Energy Society®

- Results for 1.000 Monte Carlo draws

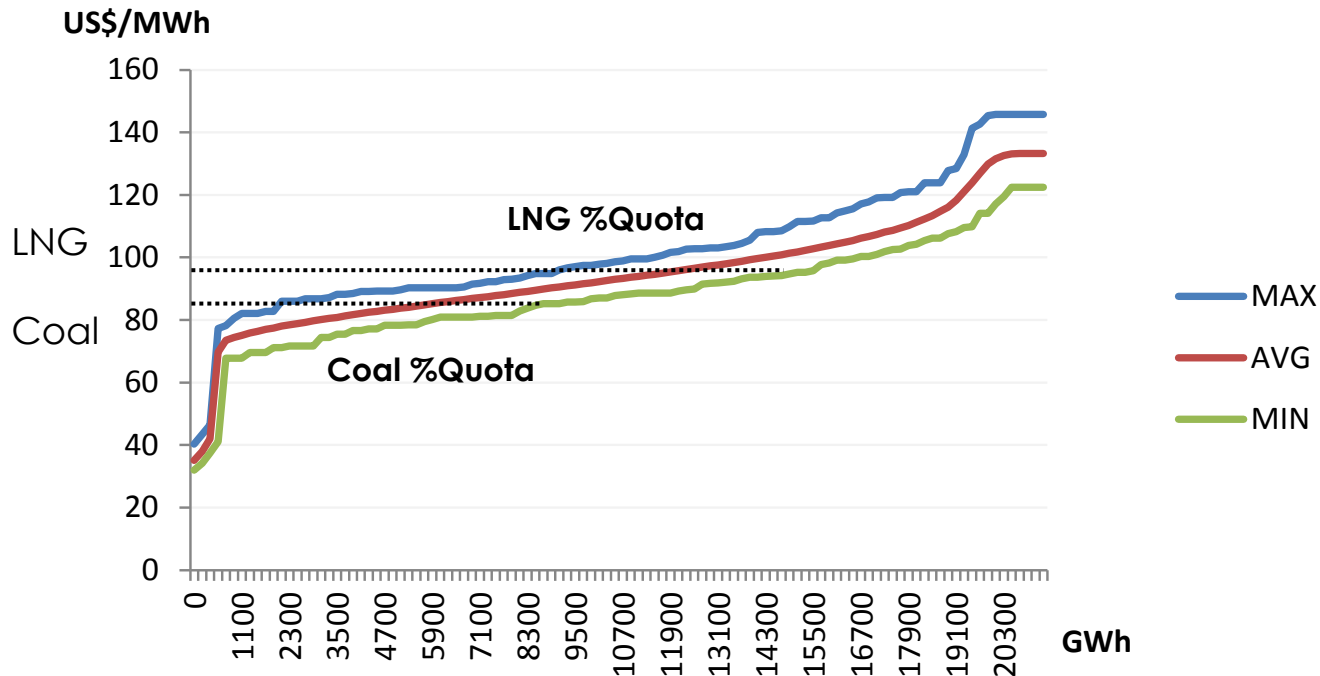


- Future investment decisions of projects installed after 2014
 - NCRE energy up to 2014: 6,150 GWh



What would the efficient renewable quota be?

- Depending of the expected price, given by the generation expansion scenarios, the NCRE quota constraint could be active or no



Item	Coal scenario			LNG scenario		
	Min.	Ave.	Max.	Min.	Ave.	Max.
Efficient NCRE Quota in 2025	8%	11%	14%	15%	18%	20%



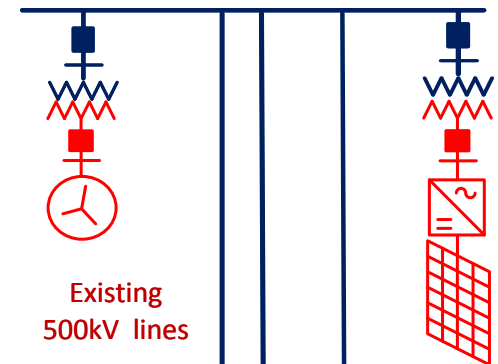
■ Methodology

- Base transmission expansion plan considers all existing transmission lines and future lines considered in regulated expansion (source: CNE, CDEC-SIC, CDEC-SING)
- Power flows are calculated for each scenario (10 and 20% RPS, coal and NLG)
- Expansions are added to satisfy power flows

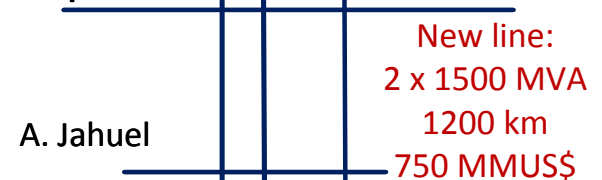
■ Results

- 10% RPS: No additional lines required
- 20% RPS: Additional lines required in 2022 due to high wind and solar penetration
- Total annualized cost: 79.6 MMUS\$

P. Azúcar



Polpaico



A. Jahuel

Ancoa

Charrúa





- SIC requires a spinning reserve between 5% and 8% of the peak demand (source: CDEC-SIC)
- Hydro dam power plants must increase their spinning reserve, reducing their energy generation and triggering more LNG use.
- Methodology
 - Intermittent renewable power is identified for both 10% and 20% RPS scenarios in **2025**
 - LNG generation equals intermittent renewable power (MW) multiplied by spinning reserve (%)
 - Annual generation is calculated using LNG fuel cost
- Assumptions
 - Intermittent NCRE coincidence factor: 100%
 - LNG power plants replace hydro power for 8 hours a day, 365 days a year
 - LNG variable cost: 78 US\$/MWh

Item	RPS 10%			RPS 20%		
	Min.	Ave.	Max.	Min.	Ave.	Max.
Spinning Reserve	5%	6.5%	8%	5%	6.5%	8%
Intermittent generation [MW]	2,793			6,057		
Additional spinning reserve [GWh]	408	530	652	884	1,150	1,415
Annual costs [MMUS\$]	32	41	51	69	89	110



Regulated consumer final tariff



Power & Energy Society®

Regulated consumer tariff 2025		Coal Scenario						LNG Scenario					
		RPS 10%			RPS 20%			RPS 10%			RPS 20%		
		Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max
Final tariff	US\$/MWh	175.9	176.0	176.5	177.6	178.9	180.6	188.7	188.7	188.7	188.4	189.4	191.1
Additional Transmission	US\$/MWh	0	0	0	0	0.46	0.69	0	0	0	0	0.46	0.69
Incremental Operational cost	US\$/MWh	0.28	0.36	0.44	0.60	0.78	0.96	0.27	0.36	0.44	0.60	0.78	0.95
Total tariff	US\$/MWh	176.2	176.4	176.9	178.2	180.1	182.2	189.0	189.1	189.2	189.0	190.6	192.7
Difference (RPS 20%-RPS 10%)	US\$/MWh	2.0	3.8	5.3				0.0	1.6	3.6			
% Change (RPS 20%/RPS 10%)		1.1%	2.1%	3.0%				0.0%	0.8%	1.9%			

- Total expected increase is within 3%
- Coal scenario has a larger increase due to the cost competitiveness of coal fired power plants



Large consumer energy price



Power & Energy Society®

Large consumer energy price 2025 (Tx and other costs excluded)		Coal Scenario						LNG Scenario					
		RPS 10%			RPS 20%			RPS 10%			RPS 20%		
		Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max
Energy Price	US\$/MWh	85.6	85.7	86.7	87.5	88.8	90.7	98.7	98.7	98.7	98.4	99.5	101.4
Additional Transmission	US\$/MWh	0	0	0	0	0.46	0.69	0	0	0	0	0.46	0.69
Incremental Operational cost	US\$/MWh	0.28	0.36	0.44	0.60	0.78	0.96	0.27	0.36	0.44	0.60	0.78	0.95
Total	US\$/MWh	85.9	86.1	87.2	88.1	90.1	92.3	99.0	99.1	99.2	99.0	100.7	103.0
Difference (RPS 20%-RPS 10%)	US\$/MWh	2.2	4.0	5.2				0.0	1.6	3.8			
% Change (RPS 20%/RPS 10%)		2.6%	4.7%	5.9%				0.0%	1.7%	3.9%			

- Total expected increase is within 5,9 %
- Coal scenario has a larger increase due to the cost competitiveness of coal fired power plants



1. Current renewable portfolio standard has a limited impact in final energy tariff:
 - Regulated residential consumer: max. increase 3.0 %
 - Large consumer: max. increase 5.9 %

2. Limited impact due to:
 - Renewables are competitive given high generation cost in Chile
 - Abundant solar and wind efficient resources

3. Energy prices expected to rise due to renewal of existing contracts and more costly conventional thermal technologies
 - Regulated residential consumer: max. increase 18.9%
 - Large consumer: max. increase 9.4%



4. For a 20% renewable quota to have a limited impact, the following challenges need to be addressed:
 - Transmission access
 - Renewable participation in regulated supply tenders
5. Further ongoing work to further assess impact in operational and transmission costs through better long term modelling of system operation
6. Further increase of renewable quota needs to be assessed carefully and these results can not be extrapolated.
 - Discussion of 30 % target



Further reading

More information of the Chilean electricity market:

- Publications

www.systep.cl/?page_id=23

- Monthly reports

www.systep.cl/?page_id=21



The impact of renewable portfolio standard in fast growing countries

The Chilean experience

Sebastian Mocarquer, IEEE Member (smocarquer@systep.cl)

Hugh Rudnick, IEEE Fellow (hrudnick@systep.cl)



Washington, July 27-31, 2014