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Integration of renewable energies to the power grids in Chile

Regulatory framework, state of affairs and mid term and long term challenges

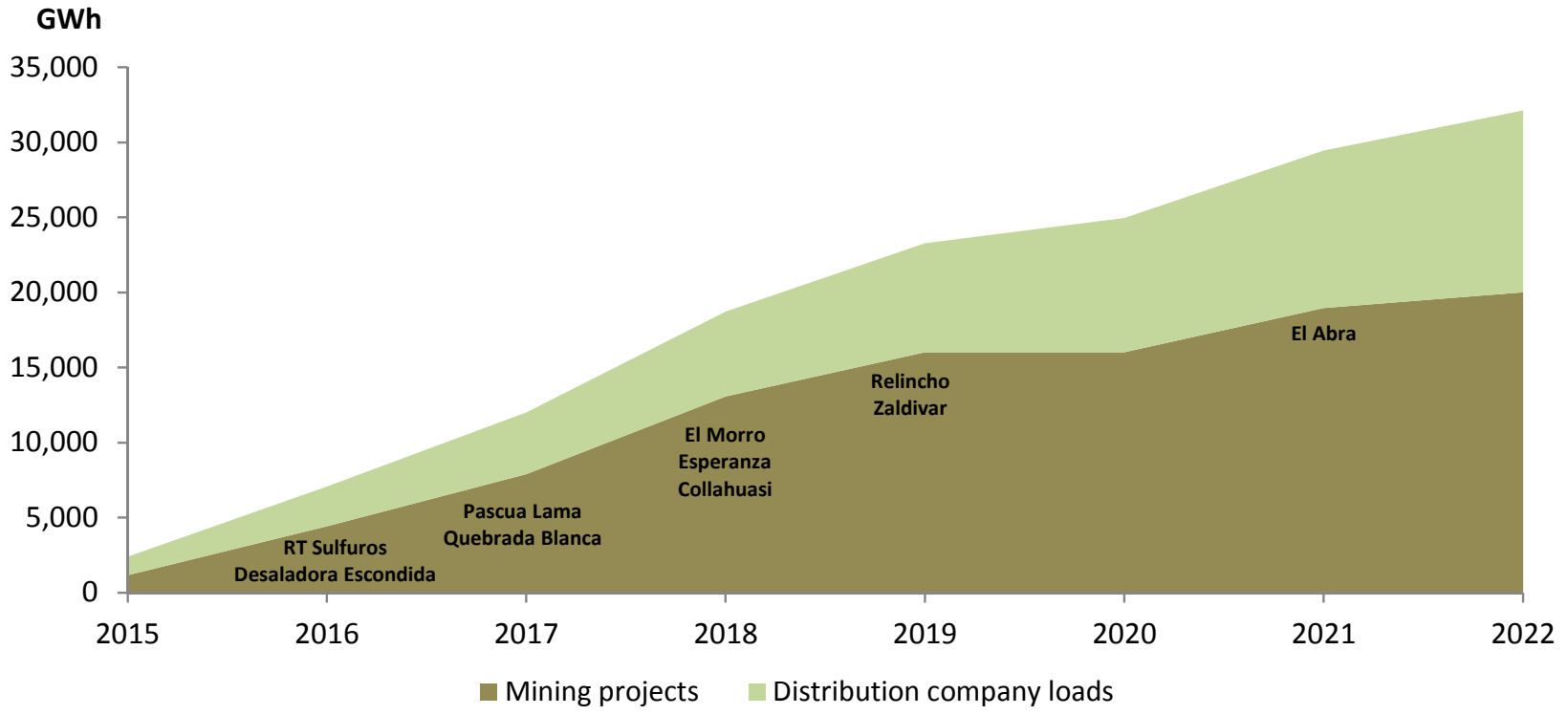
Pacific Economic Cooperation Council

FROM PROTOTYPE TO MARKET: DEVELOPMENT OF MARINE RENEWABLE ENERGY POLICIES AND REGIONAL COOPERATION

24-25 June 2014

Main challenges of electrical expansion

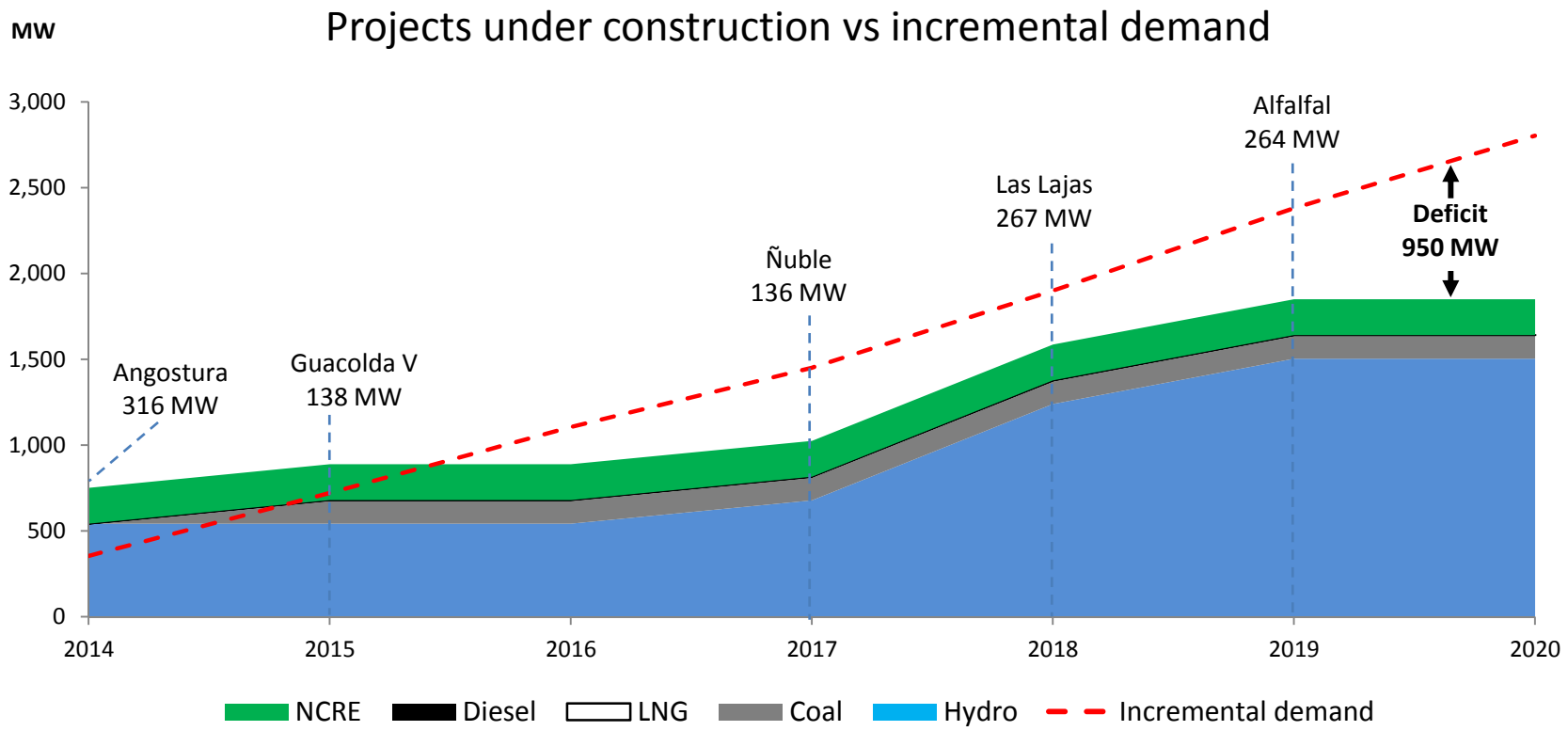
- Chile needs 750 MW a year of new capacity to respond to load growth in the next years.



Assuming a load factor of 80% for mining projects and 60% for distribution company loads.

Source: CDEC, Systep

Main challenges of electrical expansion



Source: CDEC-SIC, Systep

Important offers by renewables

Tema del día

Proyectos por ERNC totalizan 4.222 mw en la región de Ataca

Roberto Miranda

ENERGÍA. *Las iniciativas aprobadas, entre eólicos y solares, suman 2.382 MW y los que están en evaluación unos 1.840 MW.*

cooperativa.cl

Portada | País | Deportes | Entretención y Tendencias | Mundo | Opinión

Tópicos: País | Energía | Generación eléctrica

Gobierno aprobó concesión a para 43 proyectos de energía no convencional

- También seguirán utilizándose medios convencionales mientras respeten medio ambiente.
- Iniciativas sustentables se concentran en la zona norte del país.

Publicado: Sábado 17 de mayo de 2014 | Autor: Cooperativa.cl

La Presidenta Michelle Bachelet junto al ministro Máximo Pacheco, anunciaron esta semana la agenda energética del Gobierno.

Relacionados

09:40 | Pacheco: Usaremos nuestros recursos hídricos

15/05/2014 | Bachelet dio a conocer ejes de la agenda energética

09/04/2014 | [Fotos] Inauguran planta solar fotovoltaica más grande de la Región Metropolitana

Los ministerios de Energía y Bienes Nacionales aprobaron las concesiones por 30 años de 43 proyectos de energías renovables no convencionales, tanto de inversión extranjera como nacional, en una medida que se suma a la difusión de agenda energética del Ejecutivo dada a conocer esta semana.

El ministro Máximo Pacheco recordó que para el año 2025 se espera que el 20 por ciento de la matriz deberá corresponder a energías renovables, aunque esto no dejará de lado los sistemas convencionales que respeten el medio ambiente y las comunidades

"Hoy estamos alrededor del 7 por ciento, de manera que **tenemos mucho que hacer en materia de energías renovables no convencionales**. El otro 80 por ciento va a salir de los recursos hídricos del sur de Chile", sostuvo la autoridad ministerial.

"También el país va a continuar usando recursos provenientes del gas y se continuará con los planes de obras de termoeléctricas", agregó.

Mechanisms for renewable insertion
Historical evolution of incentives for renewables

Law 20,257
2008

From January 1, 2010, generators must certify that during the calendar year, 5% of the energy supplied came from NCRE.
Then, from year 2015, it will increase by 0.5% per year to reach 10% by 2024.
That percentage should be maintained in the future.

Project "**Law 20/20**"
2010

An obligation to be set of 5% for the years 2010 to 2013, increasing by 2% annually from 2014 through 2019; and increasing by 3% in 2020, reaching 20% by 2020.

Law 20/25
2013

By 2014 the obligation will be 5.5%, to reach 20% of the energy sold by 2025. applicable to contracts signed after the enactment of the law.

Energy Agenda

"Raise barriers in the country for non conventional renewable energy (NCRE), compromising that 45% of electricity generation capacity to be installed in the country between the years 2014-2025 comes from such sources"

Commitment of 20% NCRE by 2025

Energy Agenda
Goals

Stimulate integration of NCRE to fulfill the renewables law (20/25)

Confront the barriers that limit a greater participation of NCRE in the electricity market:

-Consider the particularities of NCRE in actions in the Agenda.

-Reinvigorate the tools to support pre-investment and access to financing for NCRE projects, aimed at integrated generation into the electricity market.

Promote the development of geothermal energy for local development

- Law project to improve geothermal concessions.
- Implement schemes to reduce the risk of drilling deep wells in the geothermal exploration stage.

Energy Agenda
Goals

Adequacy of the operation rules of interconnected systems for the efficient and safe incorporation of NCRE.

- Provide greater operational flexibility to the SING and SIC, for the efficient and safe NCRE incorporation.

- The parameters defined for the thermal power dispatch, automatic generation control and prediction of NCRE generation will be reviewed.

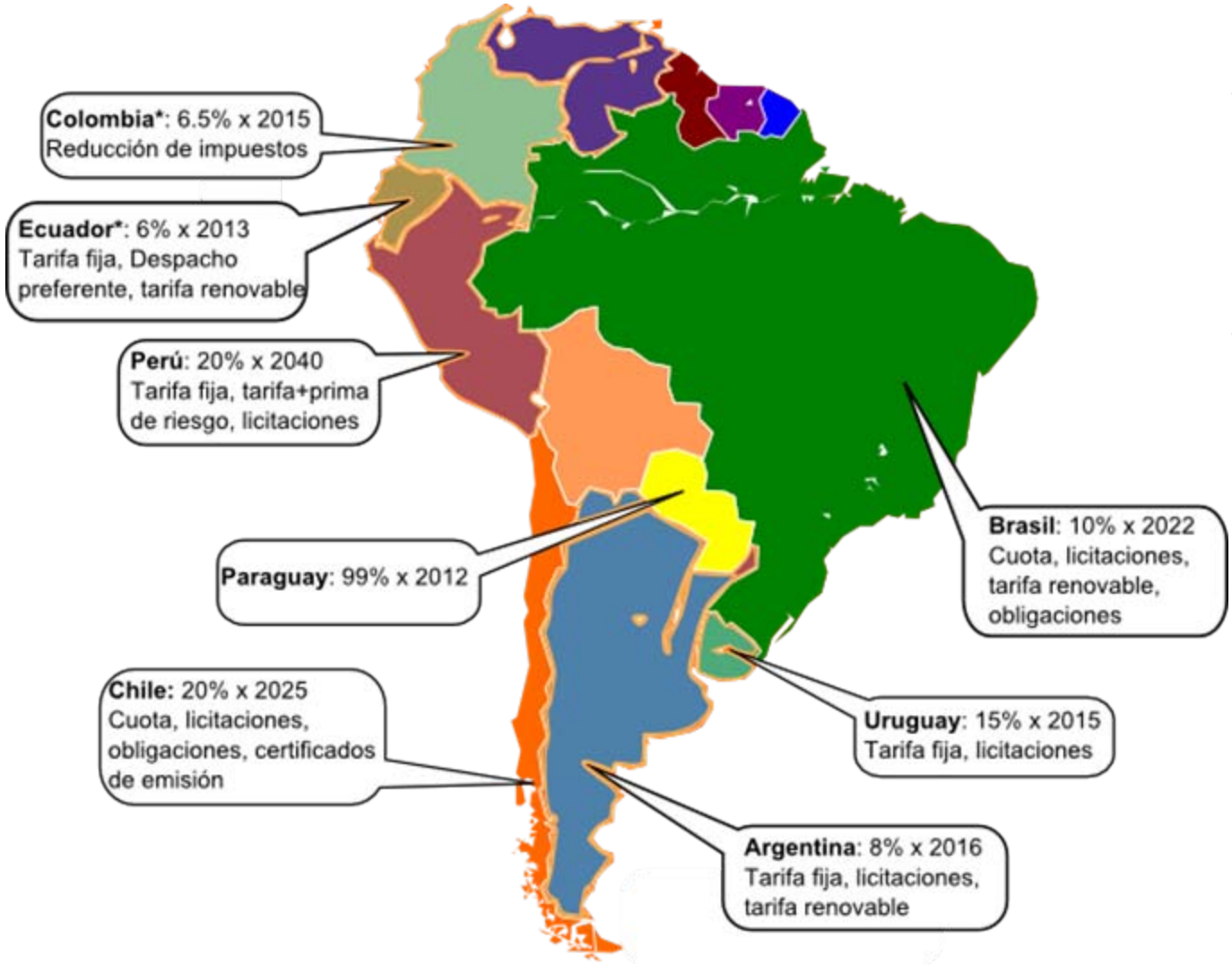
Reform of the Independent System Operators (CDECs)

- The legal nature and governance of CDECs, according to the new reality of a national grid, will be reviewed.

Enhance human capital, science and energy innovation

- New features will be added to the current Renewable Energy Centre, making it the National Center for Development and Innovation in Sustainable Energy.

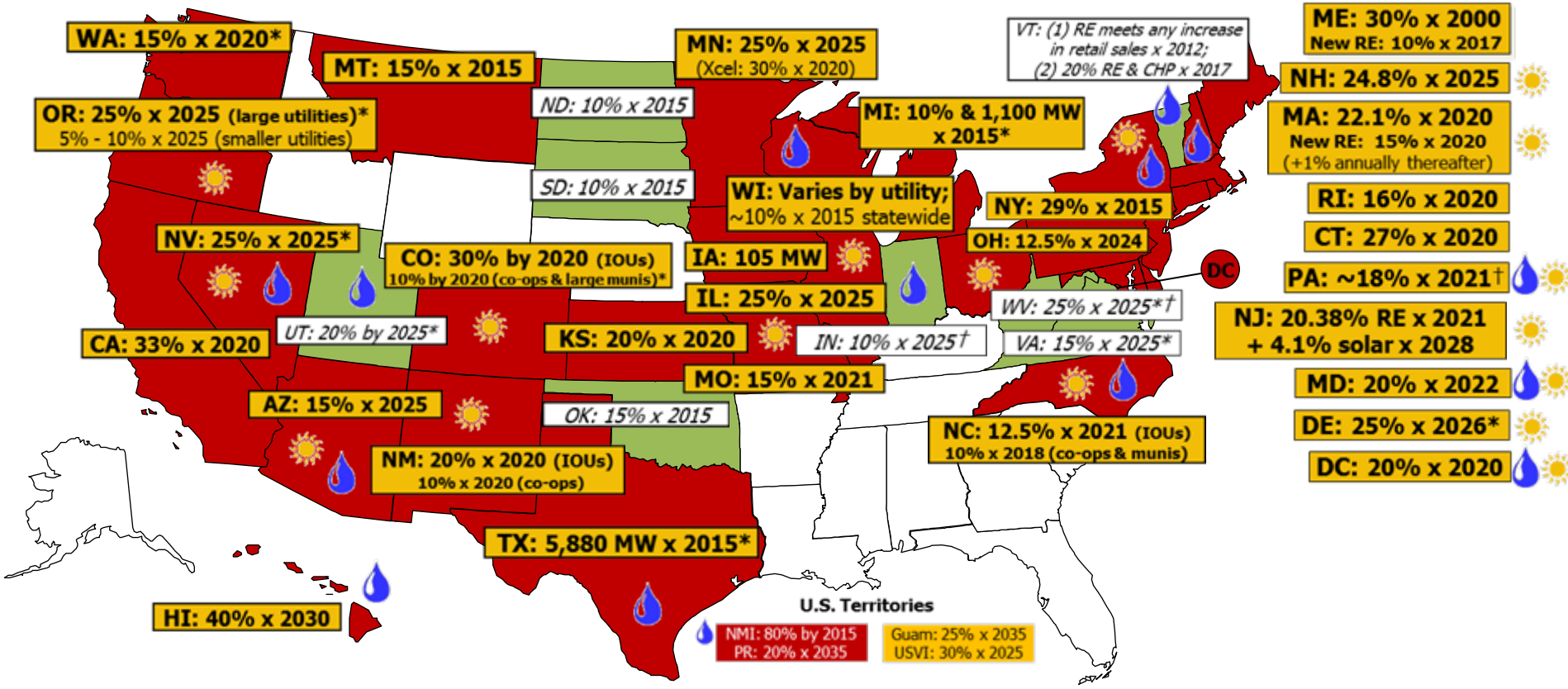
Goals NCRE insertion
South America



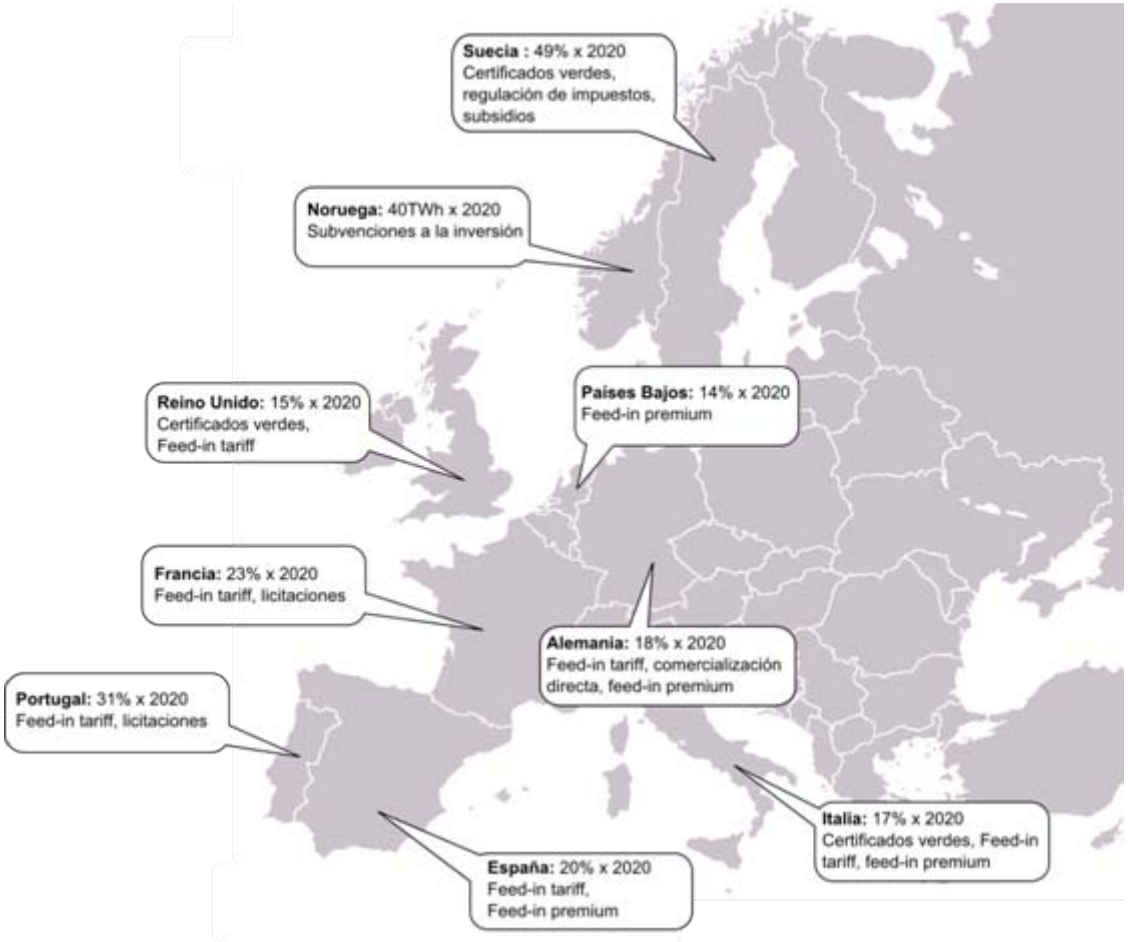
- **In the case of Colombia and Ecuador the percentage is applied to capacity.**
- **The limit for hydro NCRE is variable among different countries (for example in Paraguay there is no limit).**

Source: CIDET-CONOSER-GIMEL 2014 “Interconexiones regionales para el desarrollo de una matriz de energía sustentable”

Goals NCRE insertion
United States



Goals NCRE insertion
Europe



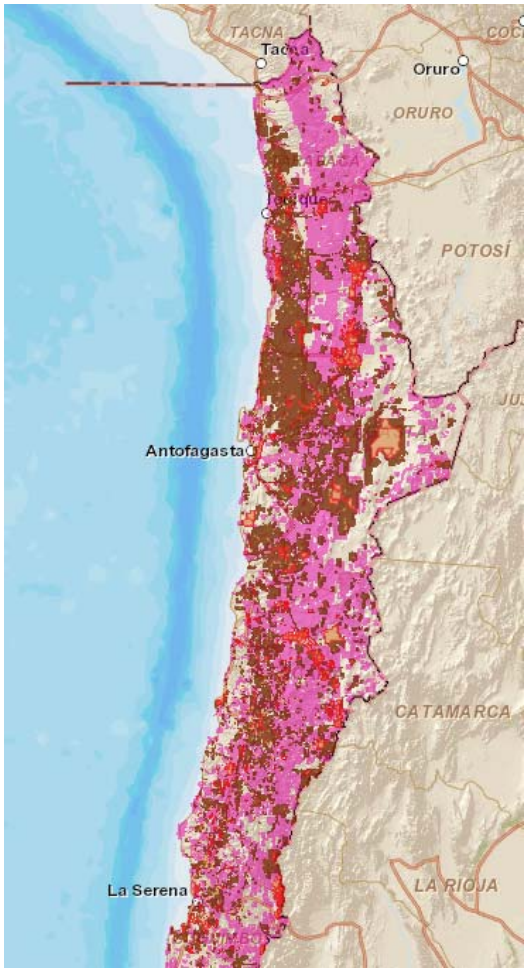
- Environmental targets set by the European Union.
- Countries taking the lead in supporting renewable generation are Portugal (24.9%), Spain (20.1%), Germany (13.1%) and Sweden (11.6%).

Source: CEER, Status review of renewable and energy efficiency support schemes in Europe, June 2013

Difficulties for NCRE insertion in Chile
Challenges in short & mid term: land use

- Pieces of land north of the SIC, who are near substations are scarce right now and there is a great demand for them. The NCRE projects that can not negotiate their connection to the system and decide to build their own connections (substation and transmission lines) will be delayed until 2017-2018

- Conflict with mining concessions
  - Under Chilean law, the land given by the authorities as mining concession can not be used by others and can only be bought if the owner agrees to sell the granting land rights.

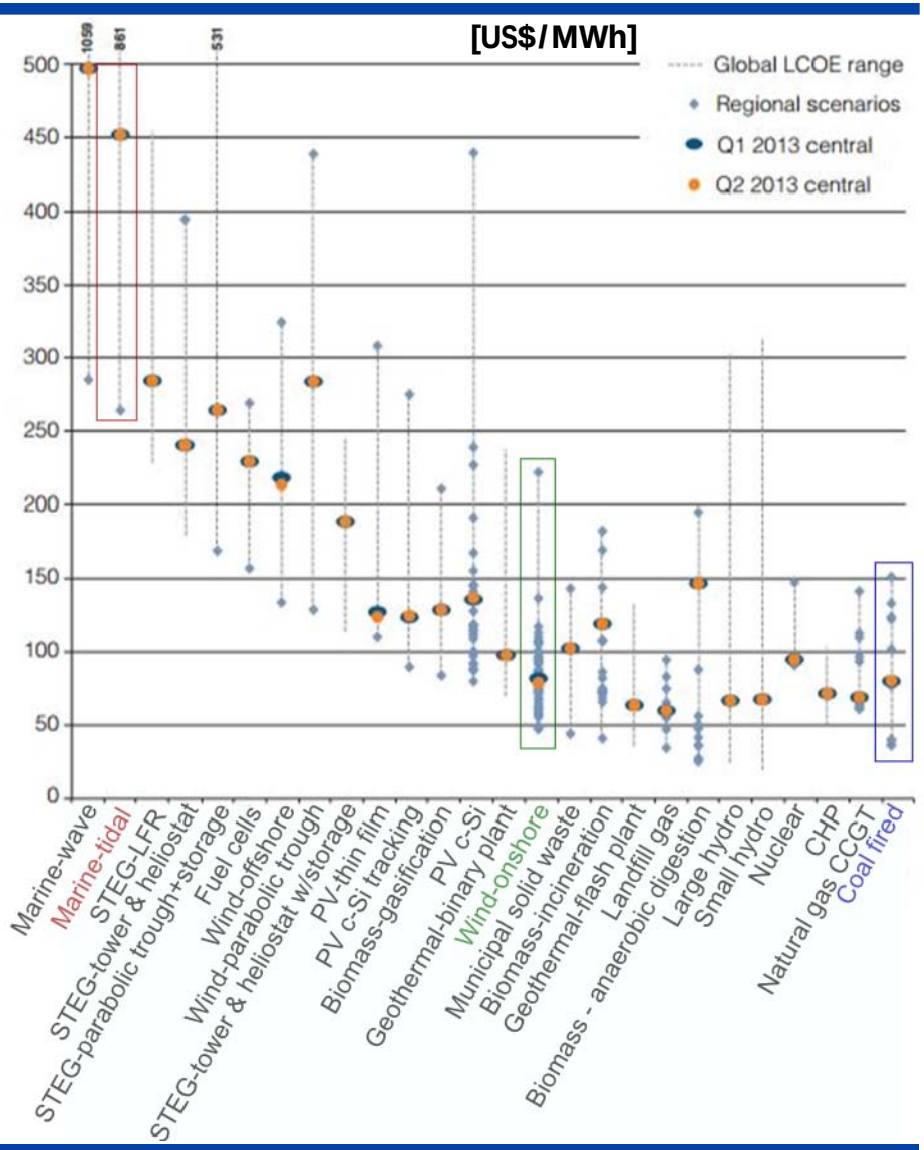


Source: http://www.geoportal.cl/Visor/

Difficulties for NCRE insertion in Chile

Prices per technology worldwide

- Mature clean technologies such as hydro and **wind**, when in a good location, have prices close to those of **traditional technologies**, while new technologies such as **tidal** still have high costs associated with their development.



Source: World Energy Perspective: Cost of Energy Technologies

Difficulties for NCRE insertion in Chile
Base technology to support NCRE expansion

- **Cost of development by technology in Chile**

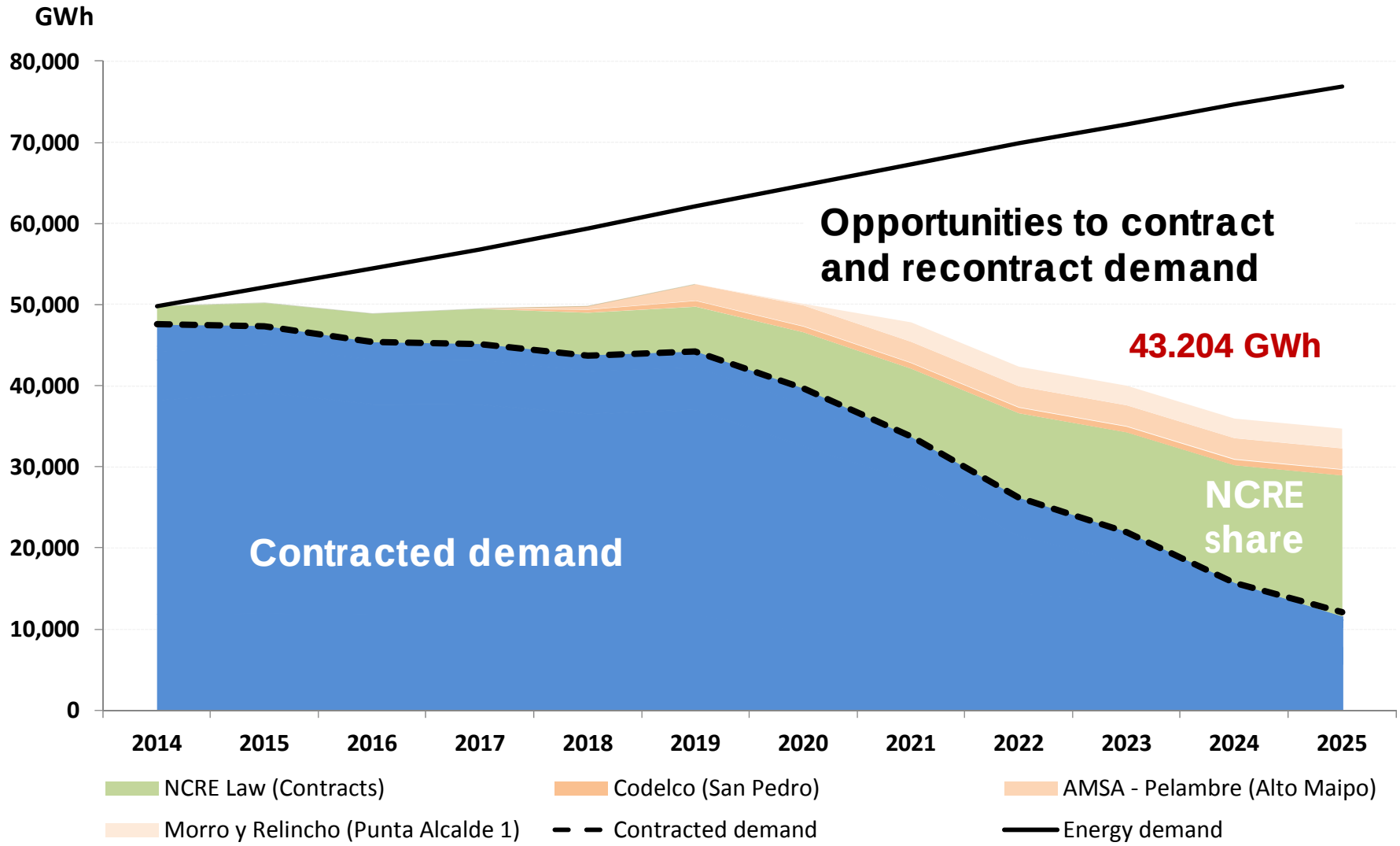
Technology	Unit investment cost [US$/kW]	Variable costs [US$/MWh]	O&M fixed costs [US$/MWh]	Plant factor [%]	Development cost [US$/MWh]		
					Minimum	Average	Maximum
Run of river hidro	2,670 - 4,000	2.0 - 5.0	-	50 -60	66.3	82.4	112.1
Reservoir	2,750 - 3,650	2.0 - 5.0	-	55 - 65	66.1	84.3	98.8
Wind	2,000 - 2,500	7.7	-	25 - 40	66.5	88.3	123.2
Coal	2,400 - 3,000	37.0 - 47.5	37	89	84.6	94.2	108.4
PV solar	1,960 - 2,500	3	18.1	20 - 35	73.2	102.3	155.4
Geothermal	3,480 - 6,600	-	2.0 - 12.5	88 - 92	65.1	105.4	122.5
LNG CC	1,000 - 1,200	74.5 - 88.1	10.0 - 15.0	50 - 80	100.7	115.4	129.9
CSP Tower with 8 hr storage	7,378 - 7,841	21.5	36	70 - 90	120.9	132.0	167.2
Diesel	390 - 860	149.1 - 223.7	10	15	178.6	220.5	262.4

Geothermal technology does not include exploration costs
The investment cost includes the costs of grid connection

Source: Fraunhofer 2013, IEA 2012, SEA 2014, CNE 2014, SYSTEP 2014

Difficulties for NCRE insertion in Chile

Opportunities for PPAs (contracts) for existing and new agents



Source: CDEC-SIC. Systep

Difficulties for NCRE insertion in Chile

NCRE with contracts

Central	Propietario	Tecnología	Potencia [MW]	Energía promedio [GWh]	F. Planta promedio [%]	Empresa que contrató la producción de energía
Laja	Energía Verde S.A.	Biomasa	17	131,5	90,0%	AES Gener
Constitución	Energía Verde S.A.	Biomasa	13	105,6	90,0%	AES Gener
Loma Los Colorado	KDM Energía y Servicios S.A.	Biomasa	2	15,8	90,0%	AES Gener
HBS Energía - Los Á	HBS Energía	Biomasa	2	17,3	90,0%	Generadora ON GROUP
Loma Los Colorado	KDM Energía S.A.	Biomasa	10	77,3	90,0%	AES Gener
ANCALI 1	Agrícola Ancali Limitada	Biomasa	2	15,0	90,0%	AES Gener
Canela 1	CENTRAL EOLICA CANELA S.A.	Eólica	18	28,7	18,0%	ENDESA
Canela 2	CENTRAL EOLICA CANELA S.A.	Eólica	60	128,2	24,4%	ENDESA
El Rincón	Sociedad del Canal de Maipo	Hídrica	0	1,5	61,0%	Sociedad del Canal de Maipo
Chiburgo	Colbún S.A.	Hídrica	19	103,7	61,0%	Colbún S.A.
San Clemente	Colbún S.A.	Hídrica	6	31,5	61,0%	Colbún S.A.
Puclaro	Hidroeléctrica Puclaro S.A.	Hídrica	6	29,9	61,0%	Empresa Eléctrica Guacolda S.A.
Ojos de Agua	ENDESA ECO S.A.	Hídrica	9	48,1	61,0%	ENDESA
El Tártaro	Wenke y CIA Limitada	Hídrica	0	0,7	61,0%	ON GROUP S.A.
Trueno	Hidroeléctrica Trueno S.A.	Hídrica	6	30,4	61,0%	Empresa Eléctrica Guacolda S.A.
Los Corrales	Agrícola Alejandro Ponce E.I.R.L.	Hídrica	1	4,3	61,0%	Empresa Eléctrica Capullo S.A.
Guayacán	Energía Coyanco S.A.	Hídrica	12	64,1	61,0%	AES Gener
Los Corrales II	Agrícola Alejandro Ponce E.I.R.L.	Hídrica	1	5,5	61,0%	Empresa Eléctrica Capullo S.A.
Don Walterio	Generhom Ltda.	Hídrica	3	15,8	61,0%	Arauco Generación
ERNC con contrato (informado catastro CDEC)			187	854,9	-	-

Source: CDEC-SIC, Systep

Difficulties for NCRE insertion in Chile

NCRE with contracts

Central	Propietario	Tecnología	Potencia [MW]	Energía promedio [GWh]	F. Planta promedio [%]	Empresa que contrató la producción de energía
Bioenergía Lautaro	COMASA S.A.	Biomasa	25	197,1	90,0%	Colbún S.A.
Arauco	Celulosa Arauco y Constitución S.A.	Biomasa	39	307,5	90,0%	Celulosa Arauco y Constitución S.A.
Licantén	Celulosa Arauco y Constitución S.A.	Biomasa	8	63,1	90,0%	Celulosa Arauco y Constitución S.A.
Nueva Aldea III	Celulosa Arauco y Constitución S.A.	Biomasa	49	386,3	90,0%	Celulosa Arauco y Constitución S.A.
Viñales	Celulosa Arauco y Constitución S.A.	Biomasa	31	244,4	90,0%	Celulosa Arauco y Constitución S.A.
Mapocho Trebal	Aguas Andinas	Biomasa	8	65,2	90,0%	Aguas Andinas
Monte Redondo	Eólica Monte Redondo S.A.	Eólica	48	112,7	26,8%	CGE Distribución
Punta Colorada	Barrick Chile Generación Ltda.	Eólica	20	14,0	8,0%	Barrick Chile Generación Ltda.
El Arrayán	AMSA/Pattern/Ashmore	Eólica	115	327,4	32,5%	AMSA
Punta Palmeras	Acciona Energía	Eólica	66	187,9	32,5%	Colbún S.A.
Talinay Oriente	Enel Green Power	Eólica	90	237,3	30,1%	Spot + Contrato regulado (Panguipulli)
Taltal	Enel Green Power	Eólica	99	282,7	32,6%	Contrato Regulado (Panguipulli)
Llano de Llampos	Amanecer Solar Spa	Solar	101	290,5	32,9%	CAP
Emelda Solar	Enel Green Power	Solar	36	103,8	32,9%	Contrato Regulado (Panguipulli)
Andacollo	SolaireDirect	Solar	1	2,1	20,2%	Minera Andacollo
Esperanza	RTS Energía Limitada.	Solar	3	7,1	28,0%	Coldelco
ERNC con contrato			739	2.829,0	-	-
Total ERNC con contrato			**926**	**3.683,9**	**-**	-

Source: CDEC-SIC, Systep

Difficulties for NCRE insertion in Chile

ERNC selling at spot market

Central	Propietario	Tecnología	Potencia [MW]	Energía promedio [GWh]	Fp. promedio [%]
Los Cururos	EPM Chile	Eólica	110	312,2	32,4%
Totoral	NORVIND S.A.	Eólica	46	81,8	20,3%
Negrete Cuel	Aela Eólica Negrete SpA	Eólica	33	90,2	31,2%
Ucuquer	Energías Ucuquer S.A.	Eólica	7	20,8	32,9%
Cristoro	Cristalerías Toro S.A.C.I.	Eólica	4	9,9	31,9%
Tambo Real	Ingeniería Térmica Kaltemp Ltda	Solar	1	1,9	20,2%
San Andrés	San Andrés Spa	Solar	51	137,4	31,0%
El Salvador	Etrion/TOTAL/Solventus	Solar	68	196,0	32,9%
ERNC Spot			**319**	**850,1**	-

Tipo	MW	GWh	(%)
Contrato	1.182,8	5.334,2	78,5%
Spot	547,0	1.457,2	21,5%
Total	**1.729,9**	**6.791,4**	**100%**

- % contracted by technology (related to average generation):
  - Biomass 90% (cogeneration)
  - Wind: 80% of its average energy generation
  - Solar: 65% of its average energy generation
  - NCRE Hidro: 90%
  - Geothermal: 90%

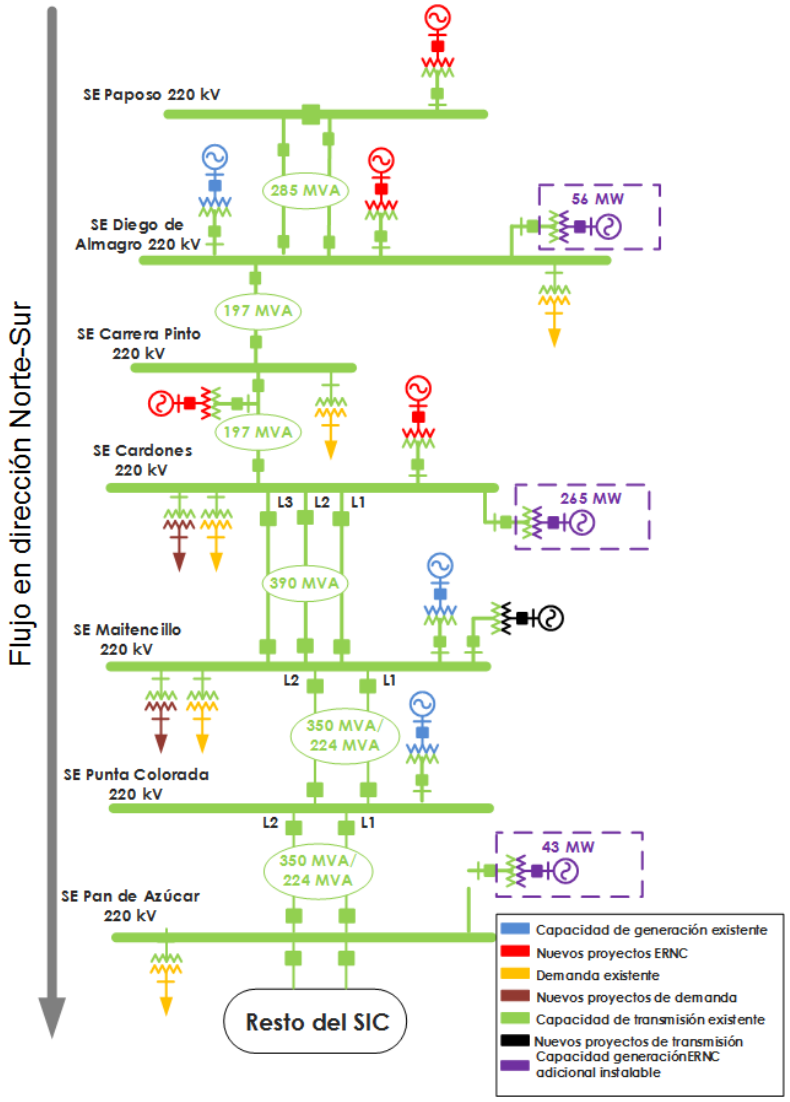
Source: CDEC-SIC, Systep

Difficulties for NCRE insertion in Chile
Complex viability of network connection

- **Uncertainty in connection, even under open access regulation**
  - To date this matter has been the subject of disagreement with the Panel of Experts and the safety criterion has prevailed in relation to NCRE connections:
    - N° 20-2013: Discrepancy by Pattern Chile Development Holding SpA against the system operator (CDEC-SIC) in relation to open access of the additional line Paposo-Diego de Almagro 2x220 kV (not accepted).
    - N° 02-2014: Discrepancy by Helio Atacama Nueve SpA with Transelec S.A. for open access to that line (withdrawn).
- **Rearrangements in the transmission system (restriction to NCRE injection)**
  - NCRE plants connecting studies should consider adapting the equipment of the substation connection, as well as neighboring substations. There may be limitations on the equipment of these substations that may limit the NCRE generation (Valle de los Vientos case: 90 MW vs. 70 MW limit).
- **Equipment and investment requirements, such as EDAG systems, to ensure system operation and ease restrictions of injections by NCRE or other generation resources**
  - Although there is a feasible solution, there is the discussion of who and how the investment of these equipment is assumed. Limitations injections follow a principle of equality and do not distinguish between who performs or not the investments.

Difficulties for NCRE insertion in Chile

Challenges in the short & mid term in the Norte Chico



Potential capacities for barriers linked to transmission up to 2018

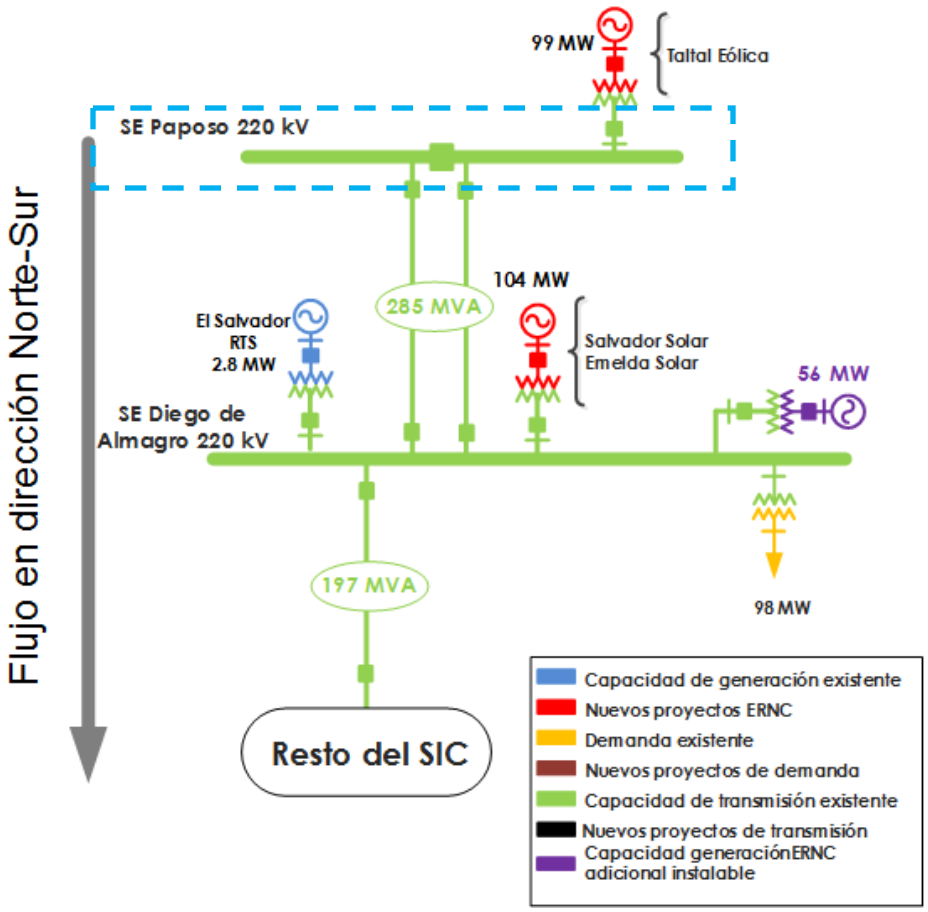
Considering the constraints of the transmission system in 2014, there would be additional capacity available in the Norte Chico close to 364 MW for new generation sources.

This capacity is expected to increase to approximately 538 MW by 2017, taking into account the extensions to the transmission system.

Given the lack of economic energy supply, some mining projects in the pipeline have been postponed or suspended its implementation, which has slowed the growth expectations of demand in the north of SIC.

Source: Systep, 2014

Difficulties for NCRE insertion in Chile
Challenges in the short & mid term in the Norte Chico



Barriers linked to transmission in critical area (S/E Diego de Almagro)

Any project that wants to connect to S/E Paposo must apply for a permits connection to the owner of the line.

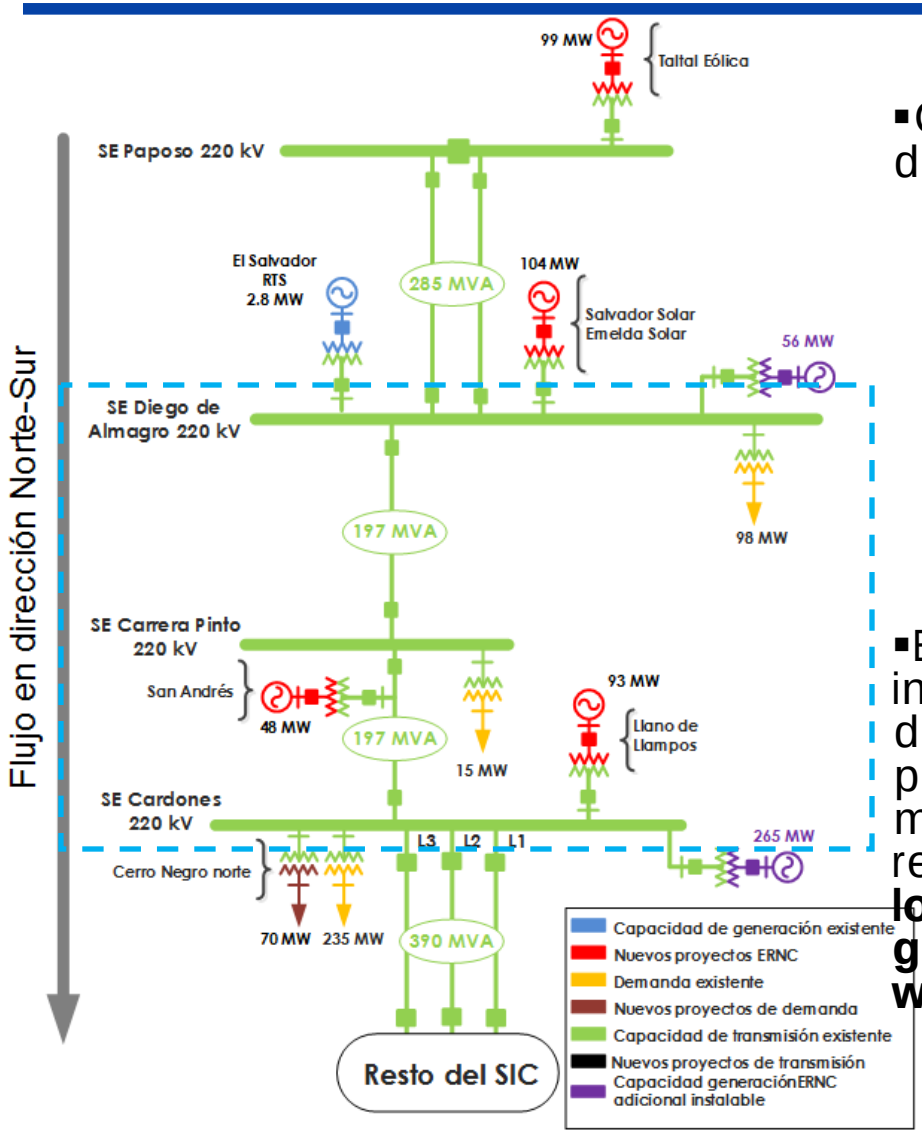
Much interest to connect in that area.

By request of the Panel of Experts, any project who wants to connect in the area must have an EDAG.

Source: CDEC-SIC, Systep

Difficulties for NCRE insertion in Chile

Challenges in the short & mid term in the Norte Chico



- Currently trunk system reinforcements are developing in the north:
  - New double circuit line "Cardones - Diego de Almagro 220 kV" (entre 2016 y 2017): it will ease local restrictions of transmission north of Cardones.
  - New 500 kV system between Polpaico & Cardones (2018): will solve trunk transmission security restrictions between the center and north of the SIC.

- Before new trunk transmission works enter into service, if a number of NCRE projects develops in the area, while new mining projects are postponed, price decoupling may occur between the north and the rest of the SIC system. **This could lead to low spot prices in the hours that the NCRE generation is coincident and higher prices when it is unavailable**.

Source: CDEC-SIC, Systep

Difficulties for NCRE insertion in Chile
Challenges in the short & mid term

Barriers associated to connection

- **Spinning reserve:**

  In the SIC, spinning reserve is around 400 MW. This implies challenges for renewable projects that expect to inject in one point more than that value.

  If this threshold is exceeded, the reserve will not react and load shedding will occur.

Actions to support insertion
Challenges in the long run

- **How to support the incorporation of NCRE?**
  - Support through funding
  - Supply contract auctions
  - Designing investment portfolios
  - Price stabilization funds

Actions to support insertion
Financing

- **Support through funding**
  - Though the Development Corporation (CORFO), the NCRE interested in undertaking projects in Chile can apply to both co-financing of pre-investment studies or direct financing of investment projects.
  - NCRE projects may apply to obtain financing through the Clean Development Mechanism of the Kyoto Protocol; born under the United Nations Convention on Climate Change.
  - The Energy Agenda has among its goals to reinvigorate pre investment support tools and access to financing for NCRE projects.

Actions to support insertion
Long term challenges

- **Supply auctions under the NCRE law**
  - The Ministry of Energy may carry up to two auctions a year
  - The aim is to cover part of the obligation that is not covered by NCRE projects in operation or construction
  - The term of the offered contracts is 10 years notice
  - All projects, not interconnected to the respective electric system at time of call, may participate in the tender process.
- **Supply auctions for distribution companies**
  - The only case to date of NCRE participating in tenders to supply regulated customers is the Monte Redondo wind farm, which in a 2009 auction was awarded a contract for 15 years to produce 275 GWh-year at 95 US$/MWh.

International auction experiences
Peru

▪**OSINERGMIN organizes NCRE energy auctions. The winners sign a power supply contract.**

- In February and July 2011 auctions were held to promote NCRE, the winners had access to 20-year contracts with distributors. The results of the auctions were:

Technology	Price [US/MWh]
Solar (90 MW)	220
Wind (140 MW)	80
Biomass (27 MW)	63
Minihydro (160 MW)	60

Source: Tesis Magister Ingeniería Sebastián Romero Moreau. PUC. Enero 2014

International auction experiences
Brazil

- **NCRE auctions for power contracts with distribution companies.**

Process	Technology offered	Average price by auction [US$/MWh]
2008 - (2400 MW)	Cogeneration with sugar cane	80
2009 - (1800 MW)	Wind	77
2010 - (2900 MW)	71% Wind	75
	24.5% Biomass	82
	4.5% Mini hydro	81

Source: Tesis Magister Ingeniería Sebastián Romero Moreau. PUC. Enero 2014

International trends
NCRE world generation and prospects

- **Worldwide, an important growth of solar technologies is expected**

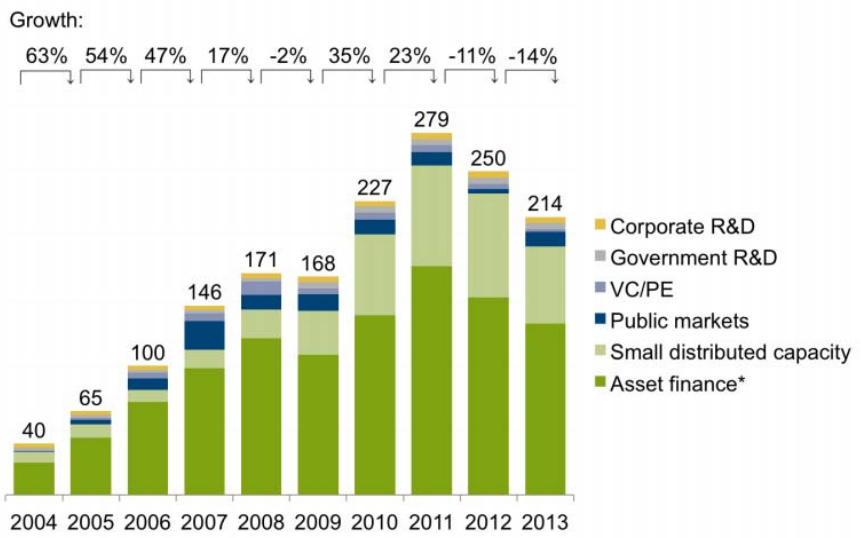
	Global generation per year [TWh]			
Technology	**2010**	**2020**	**2035**	**Rate 2010-2035**
Biomass	331	668	1,212	5.33%
Hydro	3,431	4,390	5,350	1.79%
Wind	342	1,148	2,151	7.63%
Geothermal	68	118	217	4.75%
Solar (PV)	32	282	524	11.83%
Solar (CSP)	2	39	141	18.56%
Wave	1	3	32	14.87%
Total NCRE	4,207	6,648	9,627	3.37%
Total No NCRE	16,828	22,256	30,486	2.41%
Total	21,035	28,904	40,113	2.62%

Source: IEA, 2012

International trends
Slowdown in investment in NCRE

- **However, in the past two years, investment in renewable energy (excluding large hydro) decreased, reaching $ 214 billion in the world, 14% less than in 2012 and 23% below the 2011 record.**

The only regions that increased investment are America (excluding USA and Brazil), with an increase of 26%, and Asia-Pacific (excluding China and India), with an increase of 47%, with Japan largely responsible for this increase due to the solar boom which increased by 80% investment in renewable energy.



Source: Global trends in renewable energy investment 2014. Frankfurt School of Finance & Management

International trends
Spain

- **The 2005-2010 plan to promote renewable energies set a target that by 2010, 12% of primary energy consumption would come from renewable sources cover. Two forms were established, through which renewable energy generators could trade their energy:**
  - Sell their energy to the system operator at a price defined by the authority.
  - Sell their energy in the electricity spot market price plus a premium, also defined by the authority.
- **Accumulation of a tariff deficit in the last decade over 24,000 million euros.**
- **January 27, 2012: the Spanish government approved Royal Decree Law 1/2012 to suspend the premiums to the power generated from renewables**

• Real decreto 661/2007

Source: Diario el País, 28 de Enero 2012

International trends
Spain

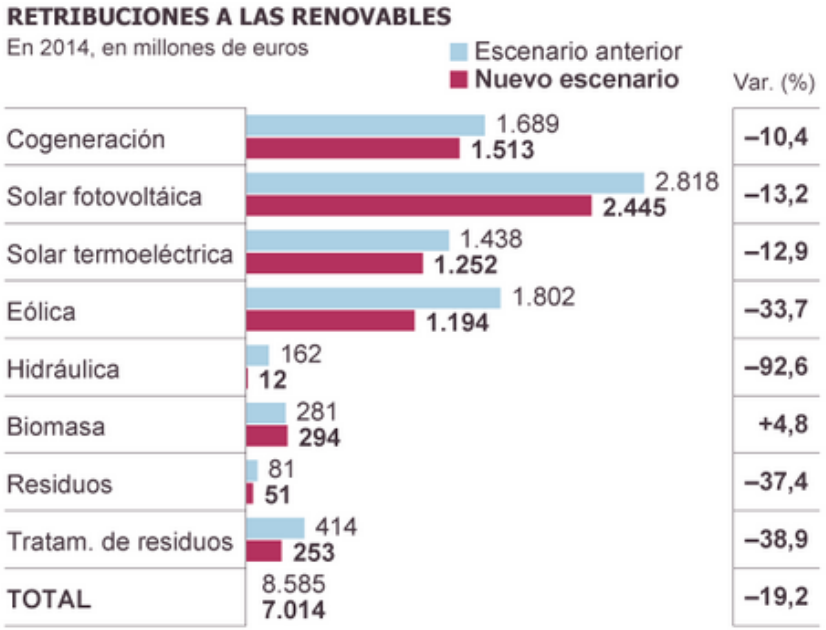
- **Impact**

- Spanish Wind Energy Association (AEE) and Association of Renewable Energy Producers (APPA) question new energy policy driven by the Spanish Government and the premium cuts to renewable energy.

- International claims against Spain for premium cuts. Such is the case of Masdar, from Abu Dhabi emirate, which in February 2014 began an arbitration at the World Bank, considering illegal the payment cuts of solar thermal installations.

- Brussels predicts that Spain will not meet the renewable share of 20% of the total energy consumption fixed for 2020.

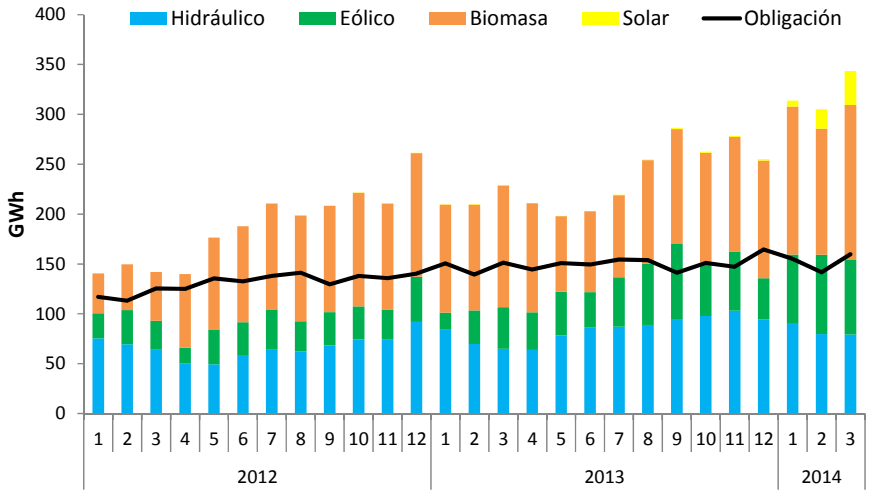
- Expansion of renewables freezes.

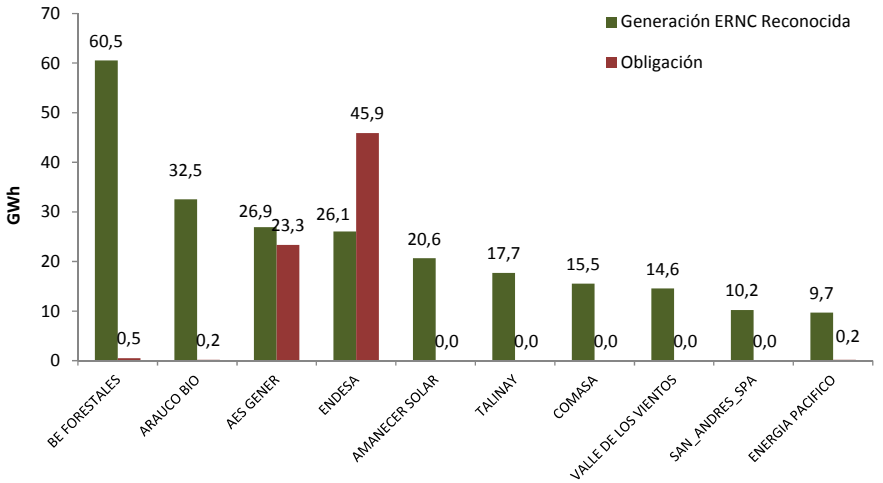


It is estimated that during 2014, 1,671 million euros in revenue of NCRE production facilities will be cut.

How are we in Chile?
State of NCRE

- **Renewable generation is nowadays over the required volume (additional 115% energy).**
- **Involvement of different technologies is currently:**
  - **Biomass (45%)**
  - **Hidro (23%)**
  - **Wind (22%)**
  - **Solar (9.9%)**
- **Endesa was the only with deficit in March 2014**





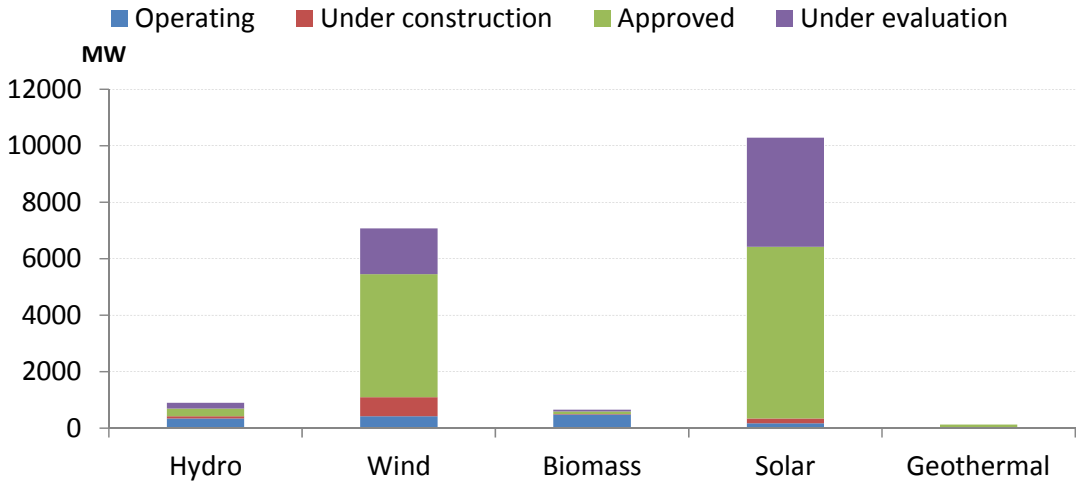
Generation recognized by company for March 2014

Source: Reporte Systep, Mayo 2014

How are we in Chile?
State of NCRE

Nearly 11,862 MW of renewable capacity, split between projects being built and projects environmentally approved.

5,758 in the environmental evaluation process



			SEA	
Technology	**Operating [MW]**	**Under construction [MW]**	**Approved [MW]**	**Under evaluation [MW]**
Hydro	338	85	270	202
Wind	421	671	4,359	1,624
Biomass	482	22	85	67
Solar	173	170	6,080	3,865
Geothermal	0	0	120	0
Total	**1,414**	**948**	**10,914**	**5,758**

Source: SEA, CDEC, CER, Abril 2014

How are we in Chile?
Opportunities for NCRE development

- **Wind potential**
  - According to a study conducted by the Ministry of Energy, the installable capacity by region with plant factor equal or greater than 30% is as follows:

	Cartera de proyectos		Potencial disponible		Potencial total	
Región o zona	**Capacidad (MW)**	**Factor de planta**	**Capacidad (MW)**	**Factor de planta**	**Capacidad (MW)**	**Factor de planta**
De Antofagasta (sin Taltal)	240	0,37	2.622	0,32	2.862	0,32
Taltal	99	0,41	11.479	0,36	11.578	0,36
De Atacama	533	0,34	86	0,34	619	0,34
De Coquimbo	777	0,35	389	0,36	1.166	0,36
De Valparaíso	21	0,40			21	0,40
Del L. B. O'Higgins			75	0,34	75	0,34
Del Biobío	419	0,32	4.581	0,33	5.000	0,33
De La Araucanía	407	0,38	1.933	0,33	2.341	0,34
De Los Ríos	51	0,39	2.863	0,35	2.914	0,35
De Los Lagos (sin Chiloé)			3.770	0,36	3.770	0,36
Isla Grande de Chiloé	428	0,39	9.678	0,34	10.106	0,34
Total	**2.975**	**0,36**	**37.477**	**0,34**	**40.452**	**0,35**

Source: Ministerio de Energía. El potencial eólico, solar e hidroeléctrico de Arica a Chiloé, 2014

How are we in Chile?
Opportunities for NCRE development

- **PV Solar potential**
  - According to a study conducted by the Ministry of Energy, the installable capacity by region with plant factors over 24% for fixed arrangements and 30% for sun following is as follows:

	Arreglo fijo		Arreglo con seguimiento	
Región	Superficie (ha)	Capacidad (MW)	Superficie (ha)	Capacidad (MW)
De Arica y Parinacota	104.015	20.803	205.024	41.005
De Tarapacá	309.163	61.833	1.055.670	211.134
De Antofagasta	4.995.313	999.063	6.003.064	1.200.613
De Atacama	769.467	153.893	920.363	184.073
De Coquimbo	11.442	2.288	16.201	3.240
De Valparaíso	117	23	319	64
Total	**6.189.517**	**1.237.903**	**8.200.641**	**1.640.128**

Source: Ministerio de Energía. El potencial eólico, solar e hidroeléctrico de Arica a Chiloé, 2014

How are we in Chile?
Opportunities for NCRE development

- **Solar CSP potential**
  - According to a study conducted by the Ministry of Energy, the installable capacity by region with plant factor greater than 50% and a minimum of 200 hectares of continuous extension is as follows:

Región	Superficie (ha)	Capacidad (MW)
De Arica y Parinacota	25.242	6.311
De Tarapacá	544.339	136.085
De Antofagasta	1.579.472	394.868
De Atacama	62.427	15.607
Total	**2.211.480**	**552.871**

Source: Ministerio de Energía. El potencial eólico, solar e hidroeléctrico de Arica a Chiloé, 2014

How are we in Chile?
Opportunities for NCRE development

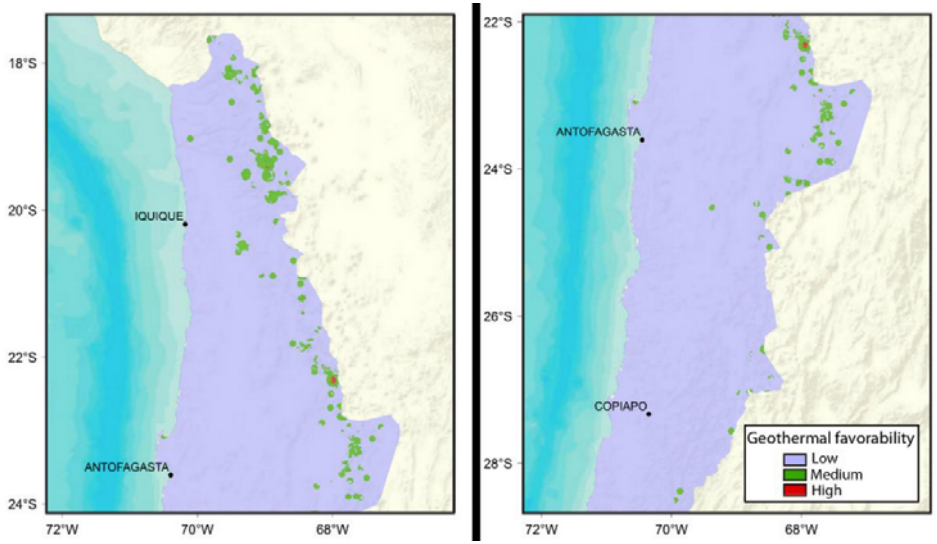
- **Geothermal potencial**

- The figures of geothermal potential range from 3,350 MW (ENAP) to 16,000 MW (Lahsen, 1988).

  The country has 75 exploration concessions in force (3 million acres and $ 380 million in investment commitments)

  There are eight concessions in force in 2013 (38,000 acres and $ 1.16 billion in investment commitments).

  It is projected that the first plant could be operational by 2017.
- Projects with more progress status are Caracautin (70MW) & Cerro Pavellon (50 MW).



Geothermal sites (Aravena et al, 2013)

How are we in Chile?
Opportunities for NCRE development

- **Marine potential**
  - According to a study conducted by Aquatera Ltd, for the British Embassy in Chile, the potential capacity by region is as follows:

Factor	*Units*	Norte Grande	Norte Chico	Centro	Centro Sur	Los Lagos	Aysén	Magallanes	Pacific Islands
Marine energy resources									
Pacific coastline	*km*	1,242	1,229	486	1,195	831	1,213	2,619	73
Wave power resource	*MW*	20,000	21,300	10,700	32,000	25,700	45,200	88,600	1,900
Tidal power resource[25]	*MW*	0	0	0	14	1,067	220	3,560	12

Source: Recommendations for Chile's Marine Energy Strategy. Aquatera Ltd. 2014

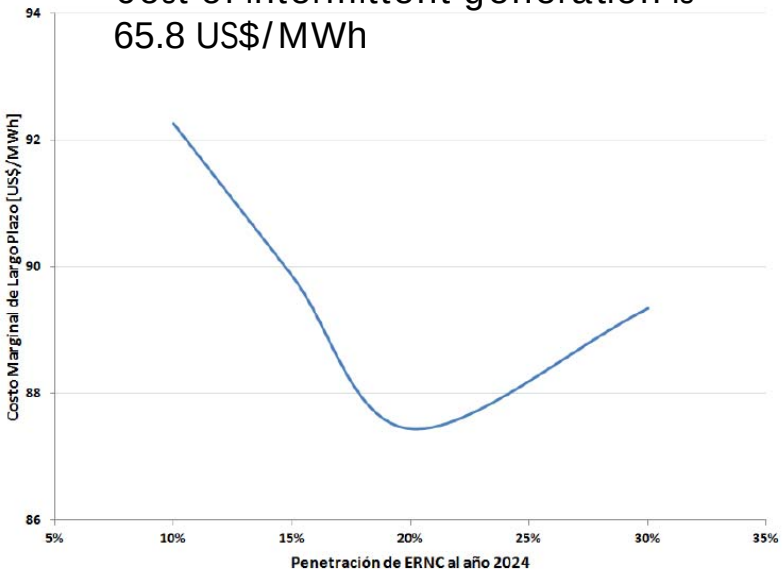
Impacts of larger insertion
PUC study

- **Incorporating intermittent NCRE in the SIC would imply a higher total system cost**

$$Total\ cost = Generation\ cost + Investment\ in\ power\ plants + Investment\ in\ transmission$$

- The marginal cost of energy decreases by increasing renewable generation up to 20% NCRE penetration, then the displacement of thermal generation by renewable generation is harmful.
- The marginal cost of energy decreases 0.48 US$ /MWh per 1% increase in NCRE penetration by 2024 up to 20%, then increases 0.19 US$ / MWh per 1% increase in NCRE penetration.
- In theory, NCRE generation should replace thermal generation, however, in the hours that NCRE generation is not present, marginal cost increases because of more expensive thermal units.

Average incremental integration cost of intermittent generation is 65.8 US$/MWh



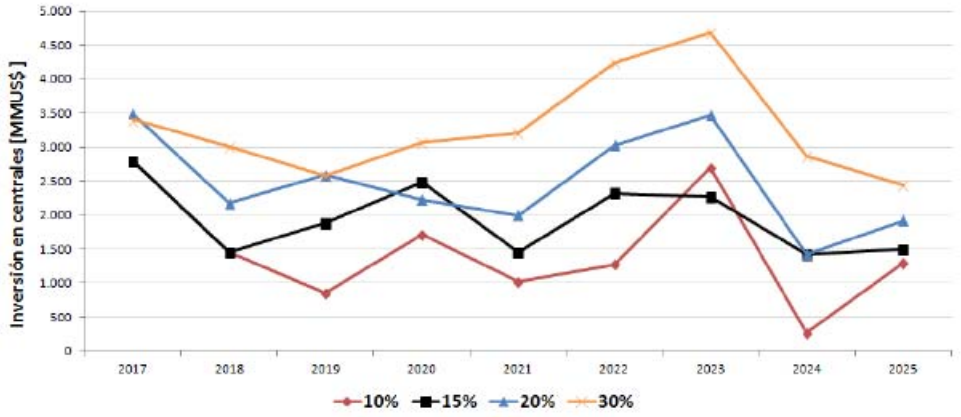
Source: Tesis Magíster en Ciencias de la Ingeniería. Ignacio Urzúa Manchego. PUC. Supervisión: Enzo Sauma y Juan Carlos Olmedo. 2014.

Impacts of larger insertion
PUC study

While generation costs decrease, the costs associated with investments increase, with a turning point of average costs a penetration of nearly 20%.

- **Investment in generation:**
  - The scenarios with the highest intermittent NCRE penetration have higher investment since these technologies are more expensive due to higher unit investment cost and lower capacity factor, compared to traditional technologies.
  - The lower cost of generation by incorporating NCRE does not compensate the costs of investment in power plants and transmission lines.
- **Investment in transmission:**
  - The capacity increase is mainly in the north, product of the increased solar generation in the region.
  - Only in the case of 30% penetration there is the need to invest in increased capacity in the southern SIC, because of increased wind generation in the region.

If the NCRE generation increases by 1%, the average annual emission decreases by 537,000 tonnes of C02.



Obra de transmisión	Voltaje [kV]	Fecha de Entrada	Distancia [km]	Aumento Capacidad [MVA]	Costo [MM US$]	Caso 10 %	15 %	20 %	30 %
Pan de Azucar 500 -> Maitencillo 500	500	sep-22	209,2	750	70,65				✓
Pichirropulli 220 -> Puerto Montt 220	220	ene-23	76,9	166	19,29				✓
Línea P. Azucar 500 - > Maitencillo 500	500	ene-24	209,2	750	70,65	✓	✓	✓	✓
Línea P. de Azucar 220 - > Maitencillo 220	220	ene-24	196,6	130	38,64	✓	✓	✓	✓
Pan de Azucar 500 -> Polpaico 500	500	ene-24	401,8	750	135,70		✓	✓	✓
Los Vilos 220 -> Nogales 220	220	jun-24	97,1	160	23,49		✓	✓	✓
Línea Pan de Azucar 500 - > Polpaico 500	500	ene-26	401,8	750	135,70	✓	✓	✓	✓
Pan de Azucar 500 -> Maitencillo 500	500	jun-26	209,2	750	70,65		✓	✓	✓
Cardones 220 -> Diego de Almagro 220	220	jun-26	72,2	210	22,91				✓
Carrera Pinto 220 -> Cardones 220	220	jun-26	75,3	280	31,88				✓

Balance

- **Relevant issues:**
  - The high wind potential and increased solar investment in the north of the SIC have been greater than that established by law from NCRE generation. However, the requirement of the 20/25 law is still challenging from the technical and economic points.
  - Meeting the target requires the realization of a significant number of NCRE projects.
  - This involves the development of strategies for energy sales, portfolio design, and a new auction mechanism to support NCRE development.
  - Required to solve connection and transmission problems.
  - To meet the target, a parallel development of conventional energy is needed. Challenges in the remaining 80% of the matrix and the effective capacity to support intermittency.

Integration of renewable energies to the power grids in Chile

Regulatory framework, state of affairs and mid term and long term challenges

Pacific Economic Cooperation Council

FROM PROTOTYPE TO MARKET: DEVELOPMENT OF MARINE RENEWABLE ENERGY POLICIES AND REGIONAL COOPERATION

24-25 June 2014