COMPLEX ENERGY SYSTEMS WORKSHOP

NOV 22, 2018 | SANTIAGO, CHILE

COORDINADOR ELÉCTRICO NACIONAL

Planning Resilient Transmission Networks in Chile

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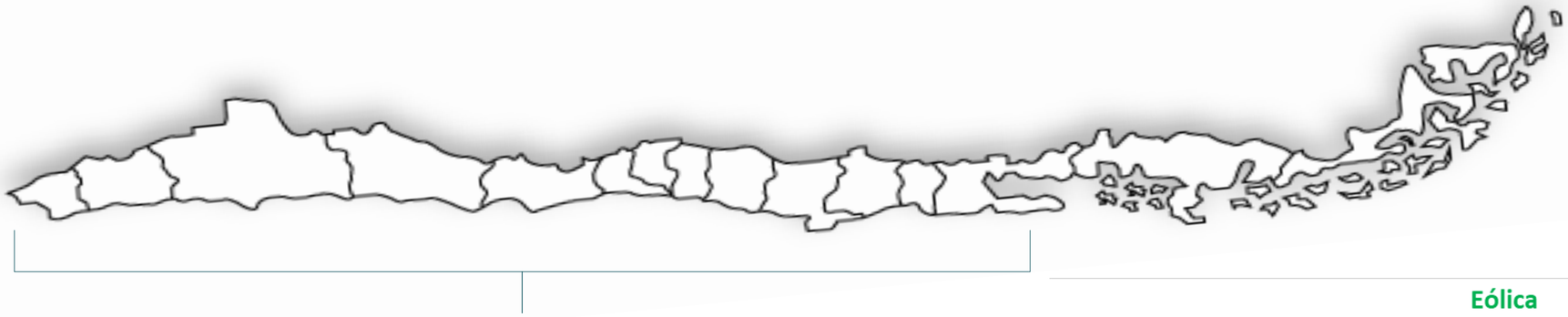
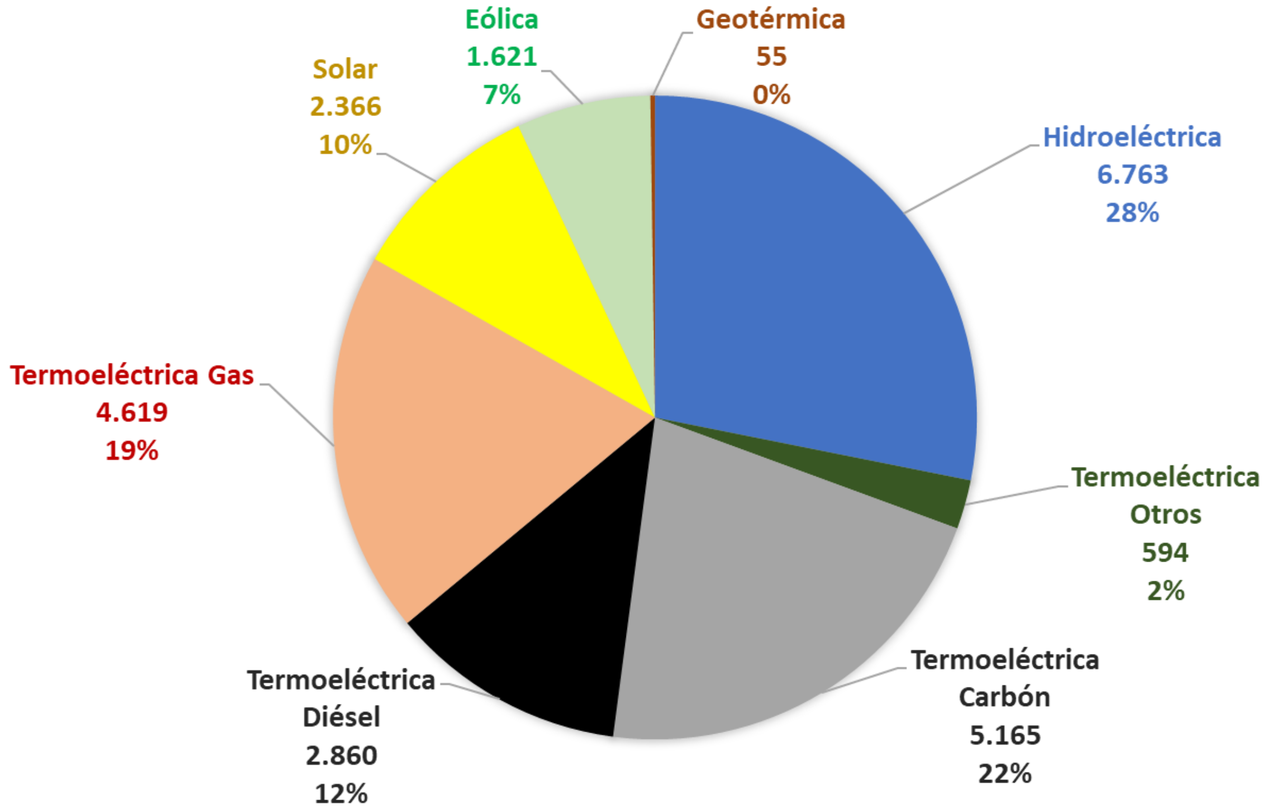
CHILEAN NATIONAL POWER SYSTEM 2018



SEN
3,100 km

Installed Capacity: 24,000 MW
Peak Demand: 11,000 MW



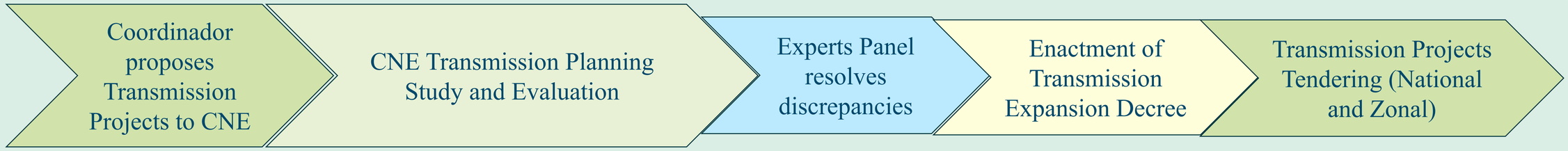
Source: Coordinador Eléctrico Nacional

Transmission Planning and Delivery (Electricity Law 20.936/2016)

Long-Term Energy Planning Process
(Developed every 5 years by Ministry of Energy)

Scenarios

ANNUAL TRANSMISSION PLANNING PROCESS



Market agents propose transmission projects to CNE

Upgrade and Expansion projects tendered by Coordinador (National and Zonal transmission)

TRANSMISSION PLANNING PROCESS 2017

Projects included in the Definitive Technical Report CNE (4 September 2018)

Transmission System	Upgrades		Expansions	
	N°	VI (MM USD)	N°	VI (MM USD)
National Transmission	4	19	7	657
Zonal Transmission	38	101	9	75
Sub Total	42	120	16	732
Total				**852**

New Transmission Planning Criteria (Electricity Law 20.936/2016)

- Minimize supply **risks**, considering events, such as:
  - cost increase or **unavailability** of fuels
  - delays or **unavailability** of energy infrastructure
  - **Natural disasters** or **extreme hydrology conditions**

- **Promote the offer and facilitate competition** in order to supply consumers at **minimum price**

- **Economically efficient** and **necessary** projects in the different energy scenarios

- **Modification of existing** transmission facilities in an efficient way

Transmission planning must include **roominess** and **redundancies** in order to incorporate all previous criteria

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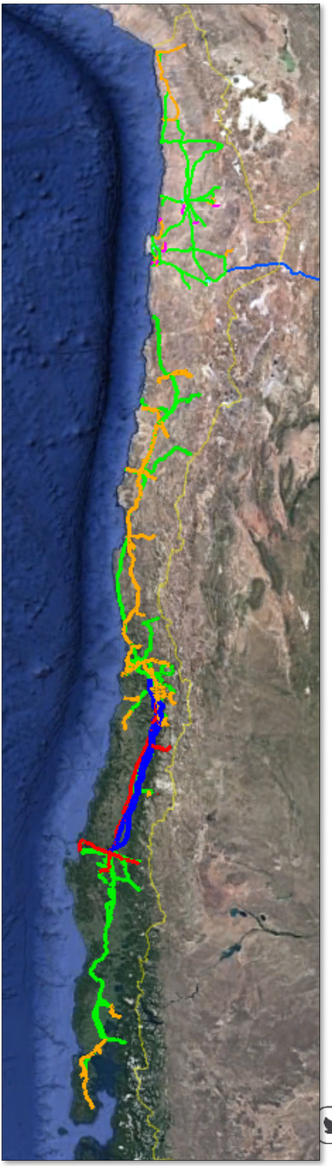
1. **Adequacy:**
   - CAPEX < NPV[Δ(OPEX+CENS)]
2. **Security of Service:** N-k criteria
   - Resilience: resist LPHI events
3. **Competition:** Open Access to the Grid
4. **Sustainability:** Efficient use of Territory
5. **Robustness:** Long Term Vision and Flexibility

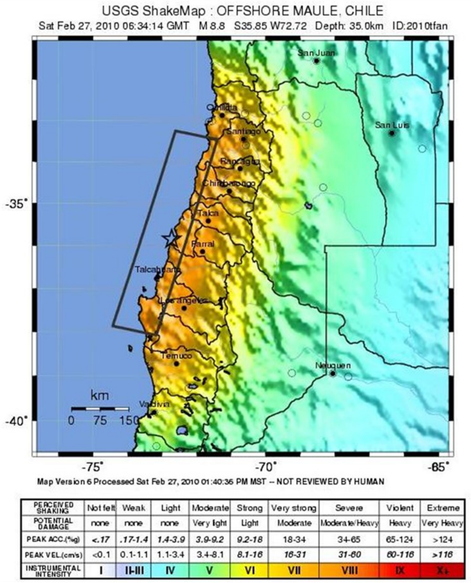
Robust Transmission Planning



- Anticipatory planning: making decisions under uncertainties
- Stripes for new transmission lines with Strategic Environmental Evaluation
- Roominess in the design of new transmission infrastructure
- Upgrade and uprate of existing lines and substations
- Zonal transmission:
  - Access to cities and towns
  - DER
- Design of resilient transmission infrastructure

Resilient Transmission

- Coordinador’s contribution on the planning of resilient transmission infrastructure:
  - Impact of tsunamis on power plants located on the coast and risk on voltage support (Transmission Expansion Proposal 2017)
  - Sponsorship of research project on Resilience with University of Chile, Catholic University of Chile, University of Manchester (UK) and University of Melbourne (Australia)
- Contribution of CIGRE Chilean Committee:
  - Lessons and Recommendations for the Electric Sector after the 8.8 Richter Chilean Earthquake - 27 February 2010
  - Proposal to CNE for a Norm “Seismic Requirements for High Voltage Electrical Installations” (September 2018)



PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<.17	.17-1.4	1.4-3.9	3.9-9.2	9.2-18	18-34	34-65	65-124	>124
PEAK VEL(cm/s)	<0.1	0.1-1.1	1.1-3.4	3.4-8.1	8.1-16	16-31	31-60	60-116	>116
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

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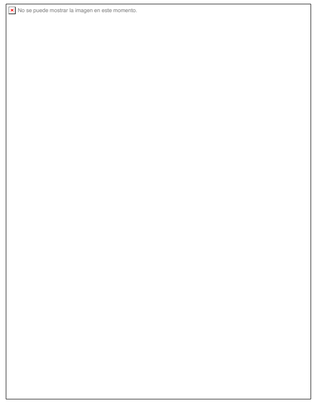
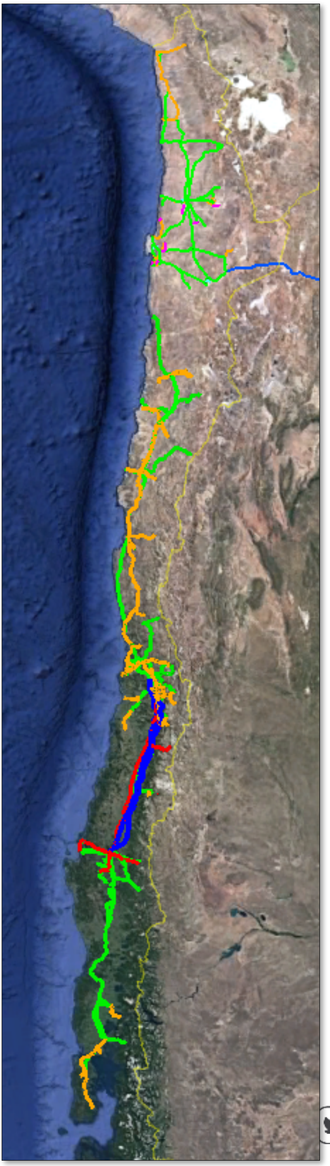
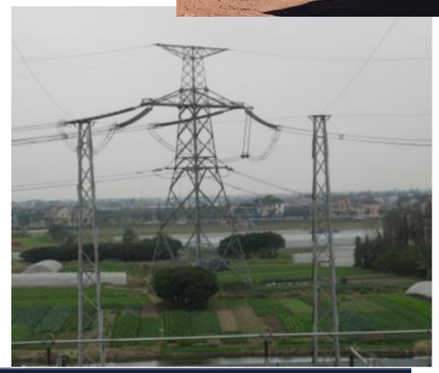
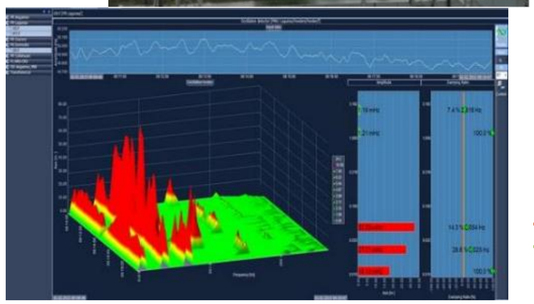


Flexible Transmission Market Oriented



- Transmission support associated to Variable Renewable Energy (VRE):
  - Size and location of reserves
  - Inertia constraints
  - Battery Energy Storage Systems – BESS:
    - Expansion deferral
    - Congestion relief
- Flexible AC Transmission Systems: FACTS
- HVDC Transmission Systems:
  - Long distance of Renewable potential
  - Back-to-Back converters (interconnections)
- Smart grid: SIPS, WAMPAC, DLR





TRANSMISSION PLANNING PROCESS 2018
CO-OPTIMIZATION GENERATION – TRANSMISSION

Stage 1
- Generation-transmission optimization multi-node simplified

- ✓ *Gx optimal location*
- ✓ *Gx investment to minimize Gx+Tx costs.*

Stage 2
- One node optimization with long-term operational constraints

- ✓ *Optimal integration of RVE with operational feasibility*
- ✓ *Flexibility options*

Stage 3
- Operational simulation and evaluation of the transmission system

- ✓ *Optimal Tx expansion proposal per scenario*
- ✓ *Proposal of resources to provide flexibility*

Stage 4
- Decision making with robust planning transmission tools

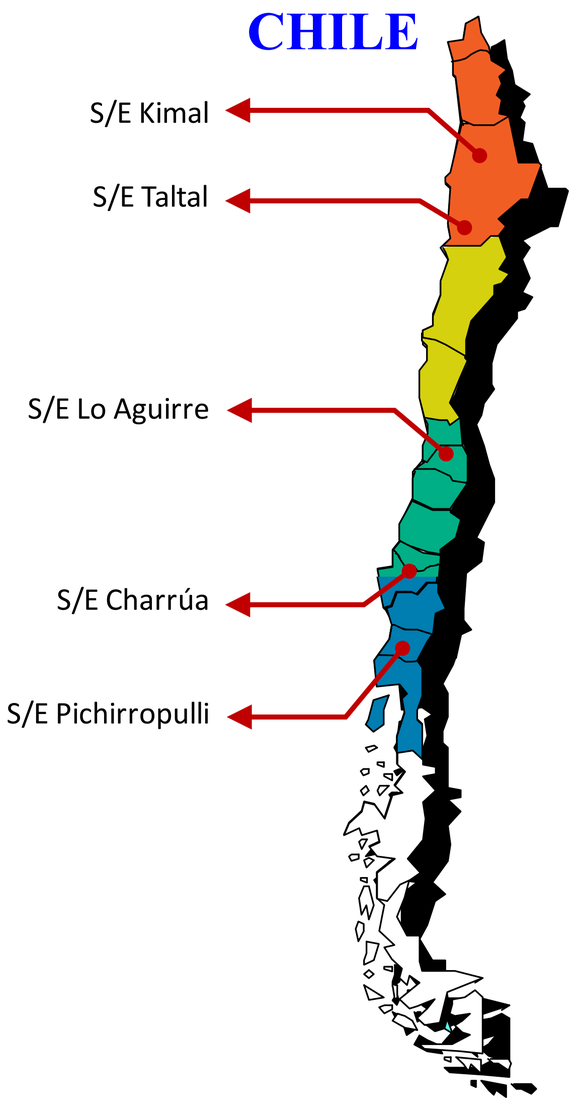
- ✓ *Optimal Tx expansion plan*
- ✓ *Requirements of resources that provide flexibility*

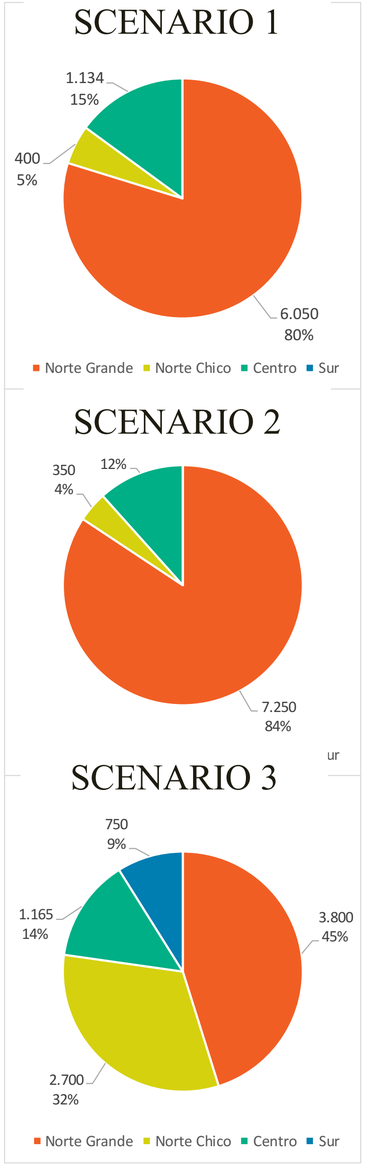
Why to CO-OPTIMIZE?

Transmission expansion must consider Generation options, location and costs, in order to optimize the total system investment and operational costs

→ Long-term **LOCATION SIGNALS** via Optimal Transmission

SCENARIOS OF NEW GENERATION CAPACITY IN 2030

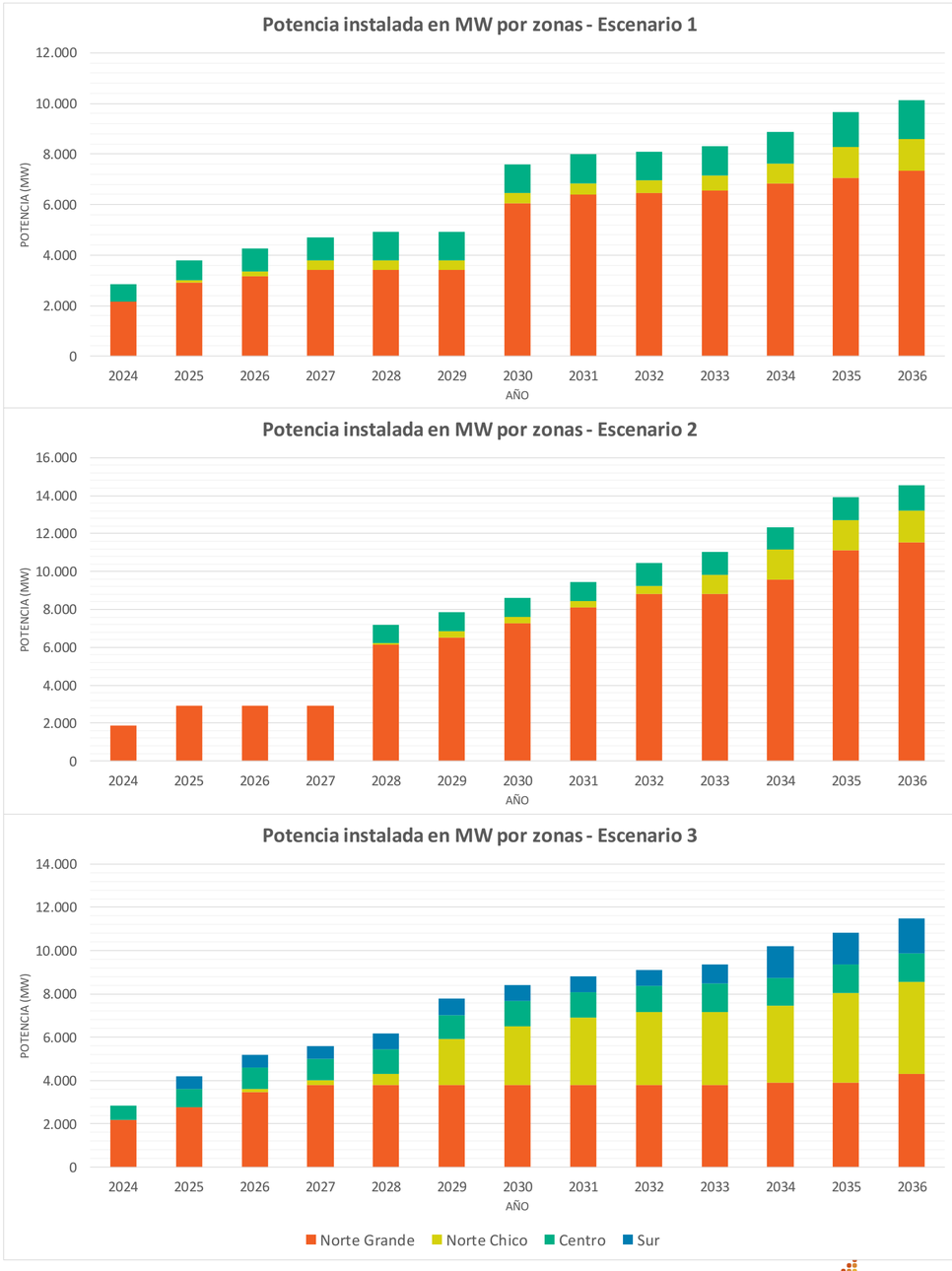




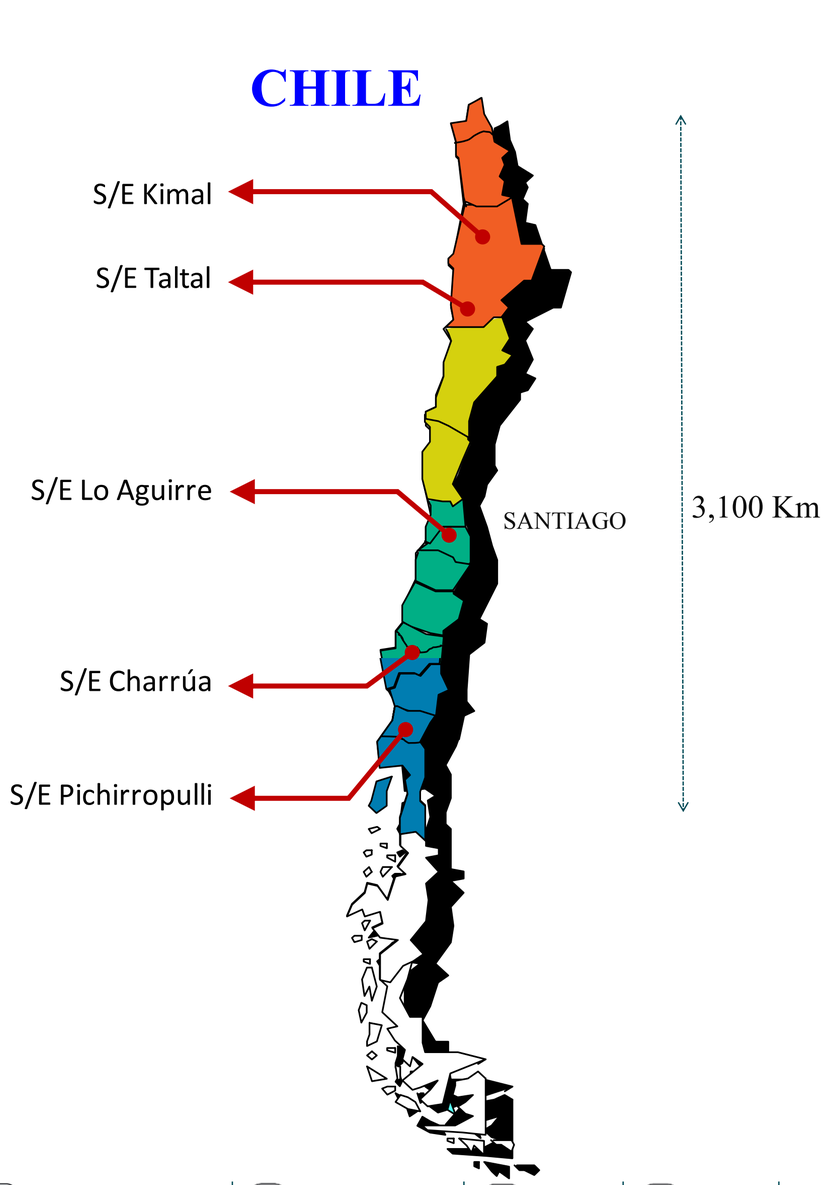
Solar: **97%**
Wind: **0%**
Other: **3%**

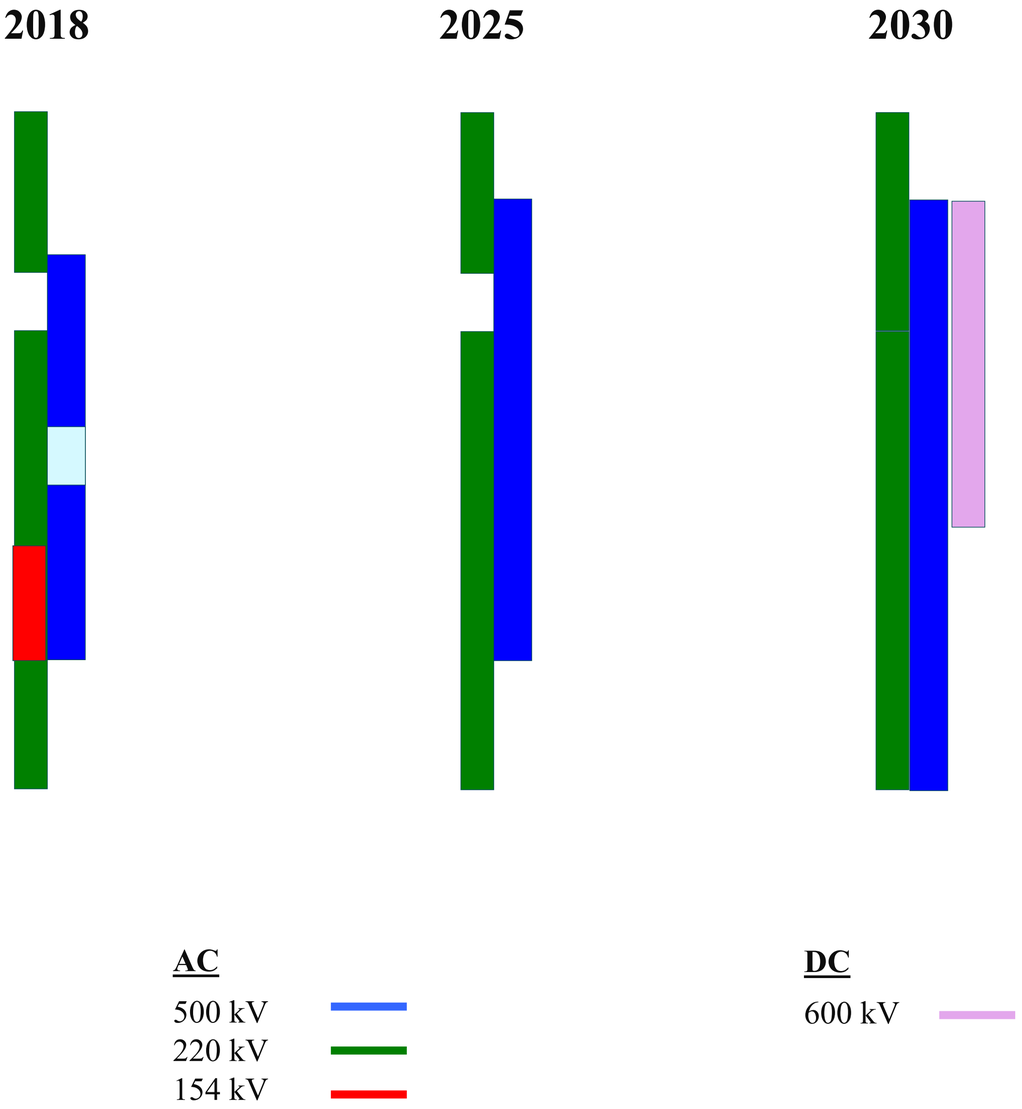
Solar: **99%**
Wind: **1%**
Other: **0%**

Solar: **88%**
Wind: **10%**
Other: **2%**

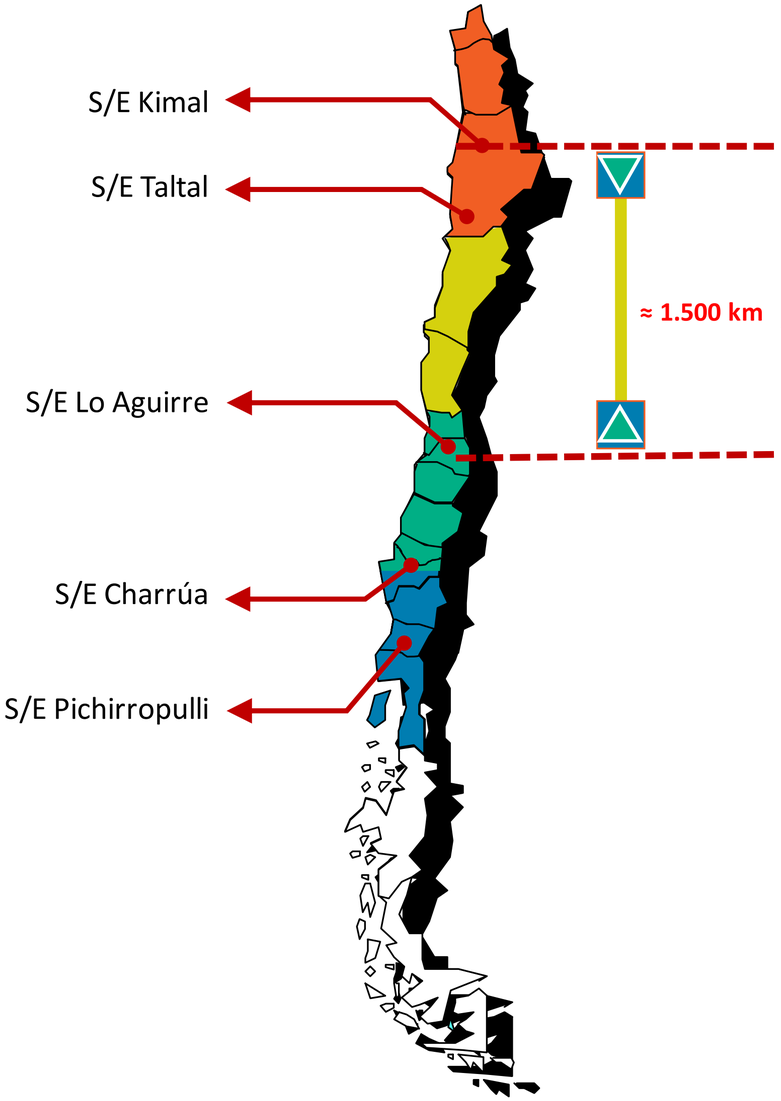


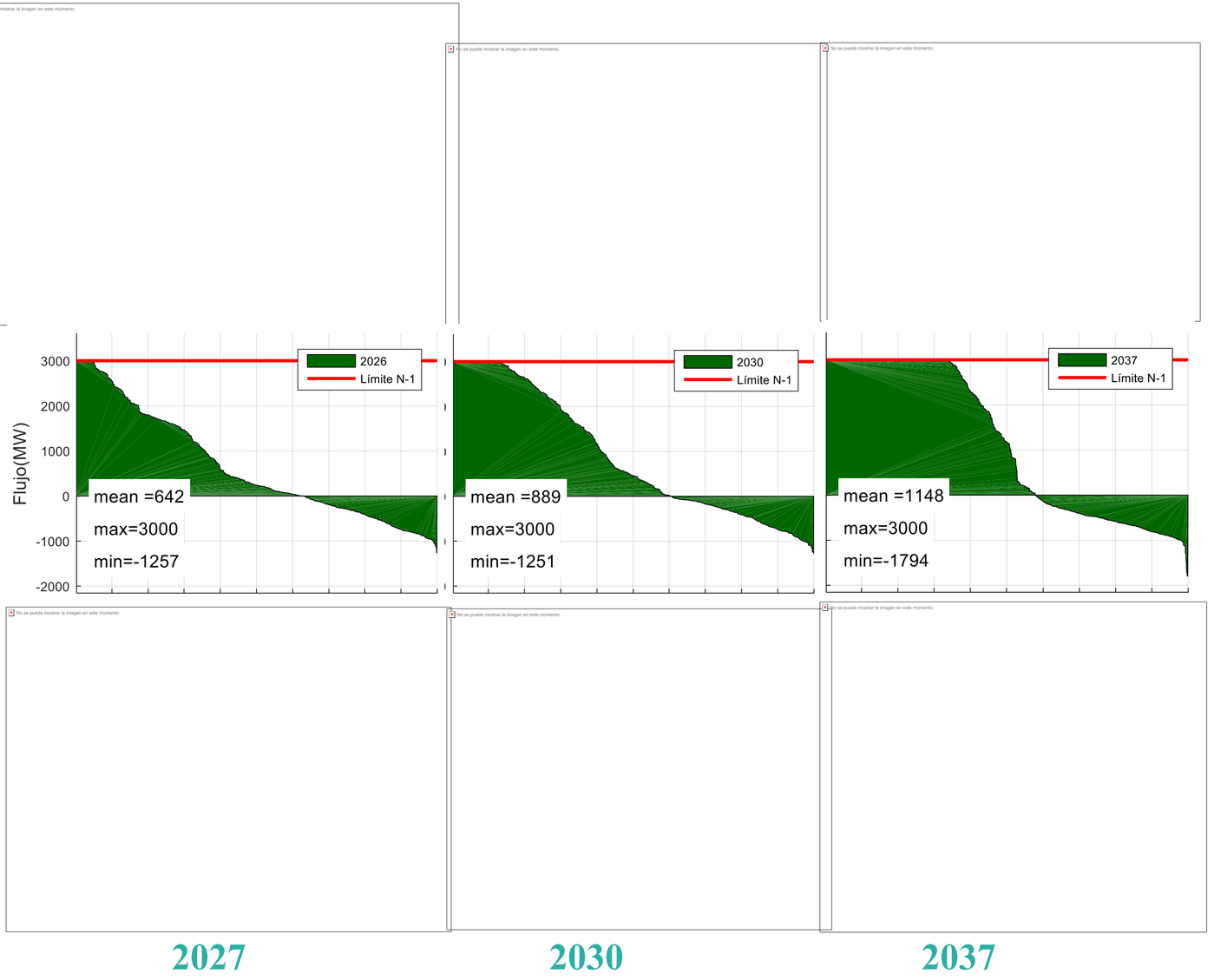
NATIONAL TRANSMISSION NETWORK DEVELOPMENT





POWER FLOWS HVDC KIMAL – LO AGUIRRE





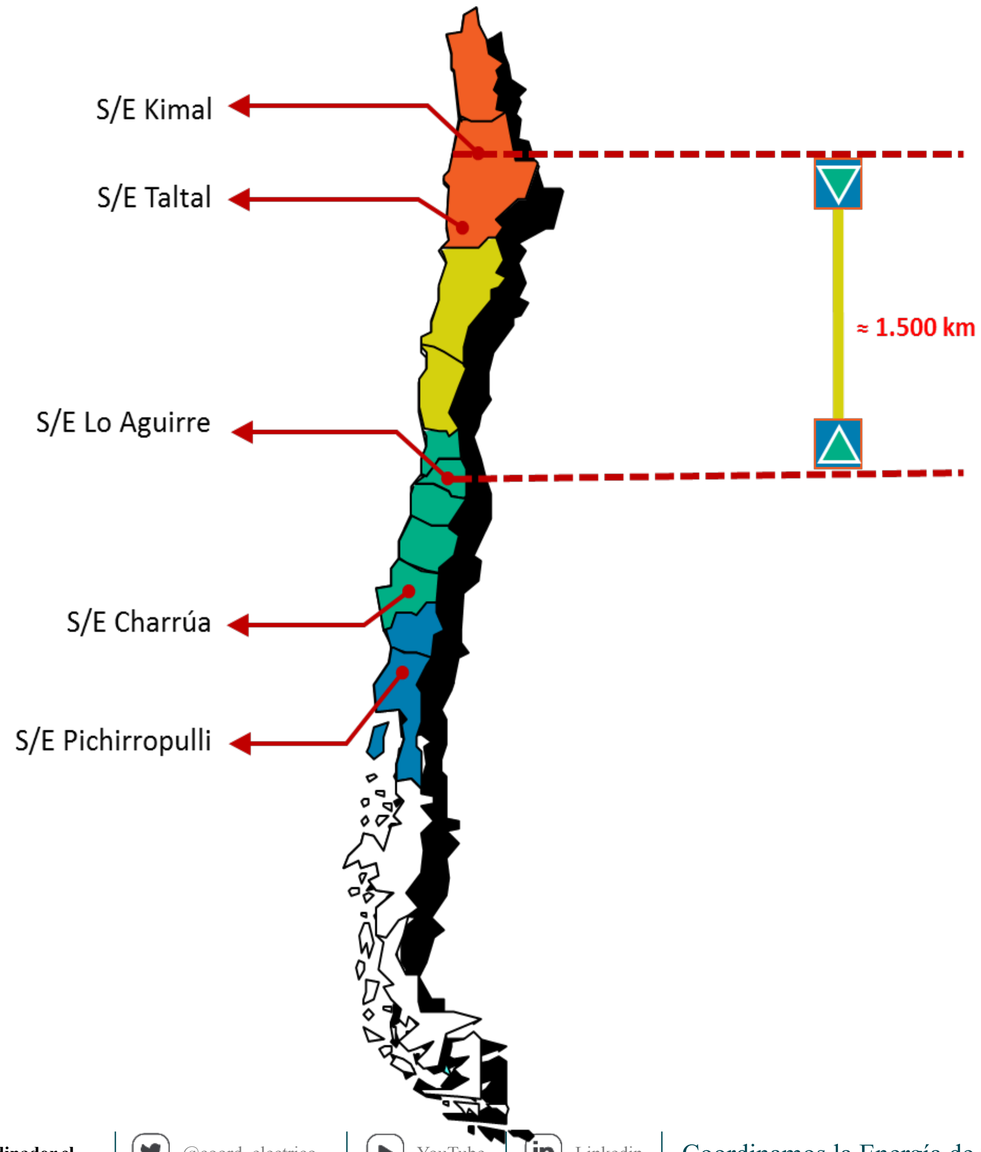
Scenario 1

Scenario 2

Scenario 3

2027 **2030** **2037**

HVDC KIMAL – LO AGUIRRE PROJECT



1	Current Type	DC
2	Technology	To be defined/Tendering
3	Voltage	±600 kV
4	Capacity	3,000 MW
5	Number of Poles	2
6	Number of Terminals	To be defined: 2 or 3
7	Length	≈1,500 km
8	Commissioning	2027

TRANSMISSION PLANNING PROCESS 2018

Projects included in Coordinador's Transmission Expansion Proposal (23 January 2018)

System	Upgrades		Expansions	
	N°	VI (MM USD)	N°	VI (MM USD)
National Transmission	4	55	6	109
Zonal Transmission	35	147	6	69
HVDC Kimal – Lo Aguirre Line (*)			1	1,305
Sub Total	39	202	13	1,483
Total				**1,685**

Note (*): Capacity 3,000 MW

TRANSMISSION PLANNING PROCESS 2018

Projects included in CNE Preliminary Technical Report (RE N° 747, 14 November 2018)

System	Upgrades		Expansions	
	N°	VI (MM USD)	N°	VI (MM USD)
National Transmission	9	57	3	20
Zonal Transmission	34	69	8	96
HVDC Kimal – Lo Aguirre Line (*)			1	1,176
Sub Total	43	126	12	1,292
Total				**1,418**

Note (*): Capacity at least 2,000 MW

In Summary

- Coordinador faces transmission expansion challenges associated to:
  - Future location and mix of renewable resources along the National Power System (3,100 km)
  - Implementing the new transmission planning and delivery processes
- Flexibility in transmission expansion must be reflected via robust planning (resilient grid) and market oriented solutions

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