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The Role of Distributed Energy Resources in the Long-Term Energy Planning in Chile: Models, Projections and Policy Implications

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IRES Special Seminar
University of British Columbia
09/06/22

OUTLINE

1. ABOUT CENTRA UAI

2. THE POTENTIAL OF DISTRIBUTED ENERGY RESOURCES IN CHILE

3. BARRIERS TO THE EFFICIENT DEVELOPMENT OF DER

4. QUESTIONS

UAI Center for Energy Transition (CEnTra)

Mandate for all UAI Centers

Develop research and development relevant for, and in partnership with, the public and public sectors.

Maximize impact on society.

CENTRA Mission

The Center for Energy Transition conducts and transfers interdisciplinary research that allows society to advance an energy transition towards economical, environmentally friendly, socially acceptable and reliable energy demand and supply.

CENTRA Vision

To be a national and international benchmark in applied research for the generation and transfer of solutions to global energy challenges and public policies that favor the development of a sustainable energy sector.

Multidisciplinary Challenges

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We promote the development of the clean fuels value chain to reduce the environmental and climate impact of the industrial, transportation, electricity generation, and thermal sectors. The Center for Energy Transition addresses the challenges associated with the production and use of green hydrogen and its derivatives, and alternative uses of biomass, including technical, economic and regulatory barriers.

The center seeks to contribute to the development of systems for diagnosing and monitoring sustainability and resilience in energy supply systems, tools for their planning and operation, and the design of markets and regulation, which allow the necessary investments to be made and ensure their sustainability. The role of storage is key in the massive integration of variable renewable energies.

The development of a sustainable Industry 4.0 in Chile is promoted through the evaluation, development and implementation of new technologies that allow a better use of available resources. It addresses energy efficiency, clean fuels, the integration of renewable energy, the electrification of demands, the capture and sequestration of CO2 and industrial clustering, with a focus on the mining and construction industries.

Solutions are proposed to face the gaps associated with the integration of local energy resources, and the efficient use of energy and water in cities and communities. This includes the design of hardware for the integration of local resources, the development of models for the efficient design and operation of local energy systems, and the design of markets and regulations that favor their efficient development.

CENTRA Researchers

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Dr. C. Agostini


Dr. E. Bitrán


Dr. L. Gutiérrez


Dr. T. Homem-de-Mello


Dr. E. Moreno


Dra. F. Jalil


Dr. F. Larraín


Dr. S. Nasirov


Dr. D. Olivares


Dr. J.L. Opazo


Dr. F. Ramirez


Dr. D. Jara


Dr. R. O'Ryan


Dr. P. Reszka


Dr. C. Silva


Dra. M. Thomsen


Dr. R. Carrasco

Regulation and Markets

Energy Systems

Technological Prototypes

Our Strategy

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- **CENTRA Industrial Research Chairs Program:** Applied research program to address industry-specific research questions
- **Project "UAI Intelligent and Carbon Neutral Campus 2030" and Living Labs:** This emblematic project of CENTRA UAI will allow, among other objectives, to generate an offer of laboratory services and applied research on sustainable and resilient energy systems.
- **Applied Research Projects with the Industry:** Applied research projects and CENTRA's specialized technical assistance for the local energy industry, including the public sector.
- **CENTRA Energy Dialogues Series:** Visions on the future development of the sector and its implications for public policy are presented. Space for discussion of our members, and representatives of public and private sectors.
- **CENTRA Working Papers Series:** Open access discussion papers reflecting the analysis of a group of CENTRA members on issues relevant to the national and global energy sector.
- **Distinguished Lecturers Program:** Seminar program for world leaders in research on different topics related to sustainable energy systems.
- **CENTRA Industrial Fellowships Program.**

Advantages of Decentralized Energy Solutions

What Constitutes Value in Electricity Suppy?

- **Past:** kWh, System security

  ==> Decision model: Generate kWh at a minimum cost, complying with security standards.

  ==> Consistent with a centralized management/decision making.

- **Today:** kWh, System security, Low GHG emissions, Low intervention of ecosystems.

  ==> Decision model: Generate kWh at a minimum cost, complying with security and environmental standards.

  ==> Largely consisten with a centralized management/decision making.

- **Future:** kWh, Low GHG emissions, Low intervention of ecosystems, System security?, Local production?, Self generation? Resilience against catastrofes?, Other?

  ==> Decision model: ¿?

  ==> Hardly consistent with a centralized management/decision making.

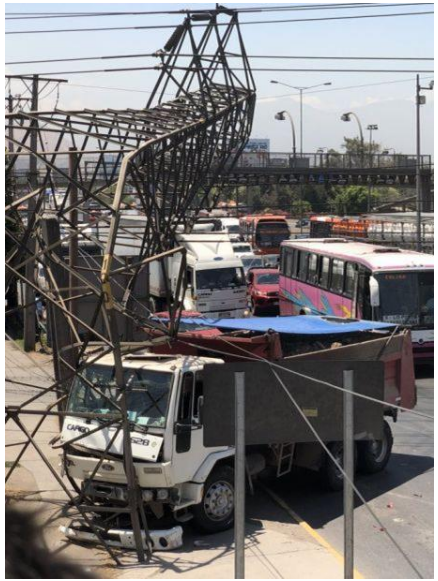
Advantages of decentralized energy supply solutions: Modularity and Adaptability

A market with a competitive offer from developers and a guaranteed supplies would be able to face potential energy shortage scenarios in the short to medium term more quickly and at lower costs.

Advantages of decentralized energy supply solutions: Local industry and new business models

The democratization of energy brings the possibility for users to choose their energy supplier, the generation sources used, self-supply from DG, and even offer their surpluses to the system.

Advantages of decentralized energy supply solutions: Resilience

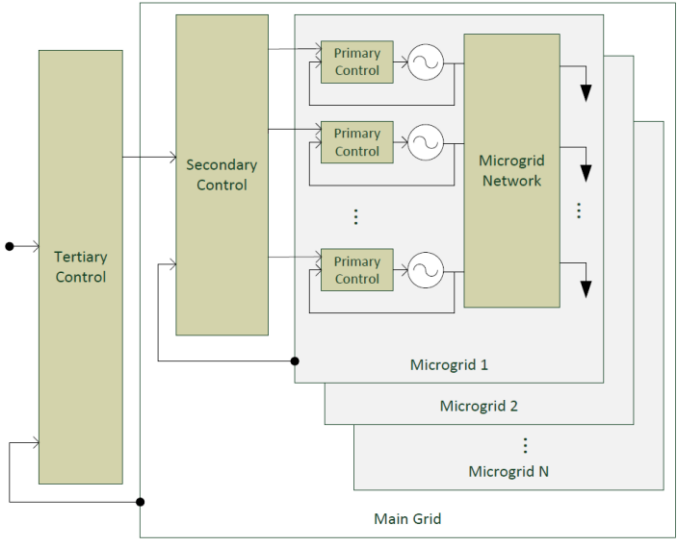


A massive penetration of DG will entail the development and implementation of control and coordination schemes in isolated microgrids within distribution networks.

(Some) Global Trends in Decentralized Solutions

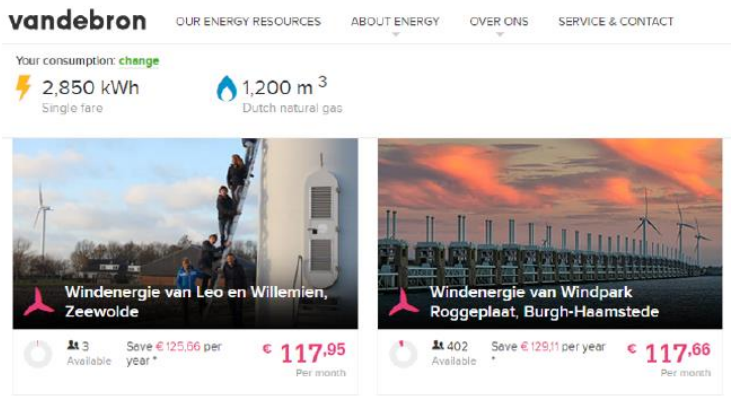
Global Trends: Microgrids and Local Markets

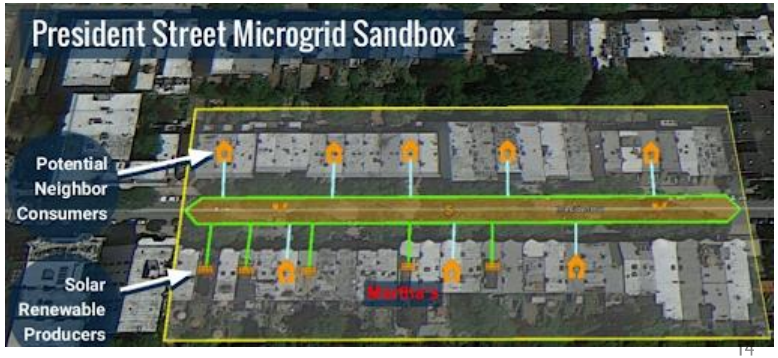
- Local **coordination of demand** and generation in distribution networks.
- Ability to improve the **resilience and reliability of networks**: islanding and supply of critical loads
- Ability to offer **services to distribution networks**: peak shaving, reactive support.
- Facilitates **decentralized integration** of distributed energy resources
- Facilitates the implementation of local market schemes:
  - Purchase and sale of electricity produced with local resources.
  - Co-financing of investments in generation and storage.



Global Trends: Microgrids and Local Markets

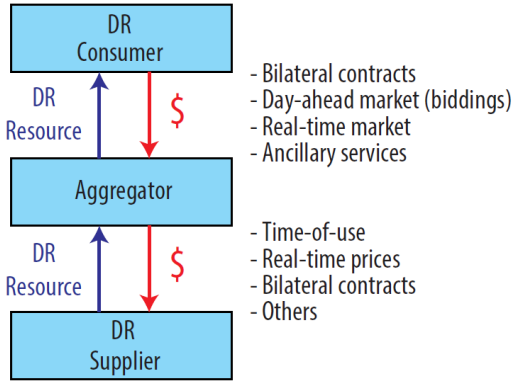
- Examples of local market arrangements:
  - Share Storage: Excess storage capacity is shared.
  - Share Distributed Generation (PVs): Unused energy is traded directly with interested parties
  - Share Flexibility Demand: Flexible load aggregation in equivalent stochastic batteries.
- Practical examples in the world: Vandebron (Holland), Brooklyn Microgrid (USA), Community Solar Hub (USA)

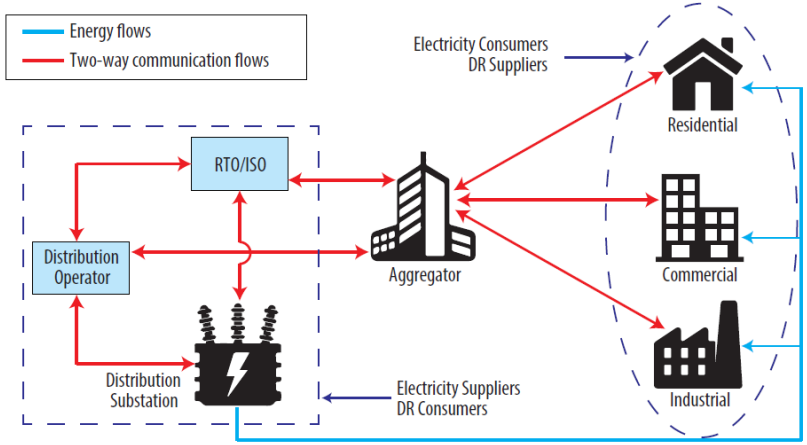




Global Trends: Demand Response and Aggregation

- **Demand Response:** Changes in the normal electricity consumption of end users in response to signals or commands, such as real-time prices or direct load control.
- The aggregator is an entity that coordinates the joint action of a **large number of small consumers** participating in demand response programs.
- The aggregator acts as an **interface between the final consumer and the system operators**, contracting DR programs with consumers and offering services to the operators. Examples: Flexitricity (UK), Voltalis (France), EnerNoc (global)





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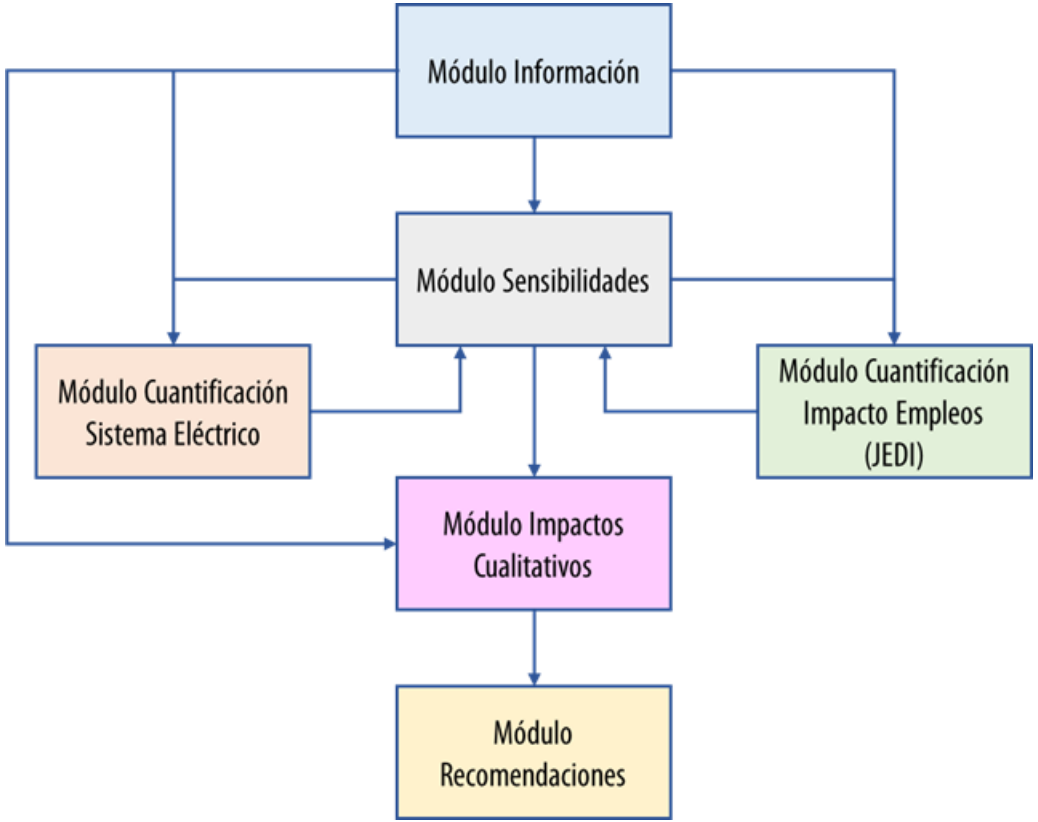
The Potential of Distributed Energy Resources in Chile

Collaborators: Nicolás Lobos (Vinken-UC), Cristián Villalobos (Vinken-UC), Matías Negrete (PUC-Chile), Alejandro Navarro (CE-UChile), Rodrigo Moreno (UChile)

General Methodology



The NewEn Planning Model

- Power systems planning and operation model developed from The SWITCH model (UC Berkeley and LBNL).
- The model determines the optimal investment decision from a central planner perspective in a long term horizon (typically 20 to 30 years)
- It is capable of capturing some short term dynamics with high level of detail (e.g., unit commitment constraints, ramping constraints).
- Each planning stage is represented by a number of representative days with hourly resolution, which allows to represent reserves, hydro network, and short term storage technologies.

The NewEn Planning Model

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Investment Decisions

When, what and where to build generation units and transmission lines.

Operational Decisions

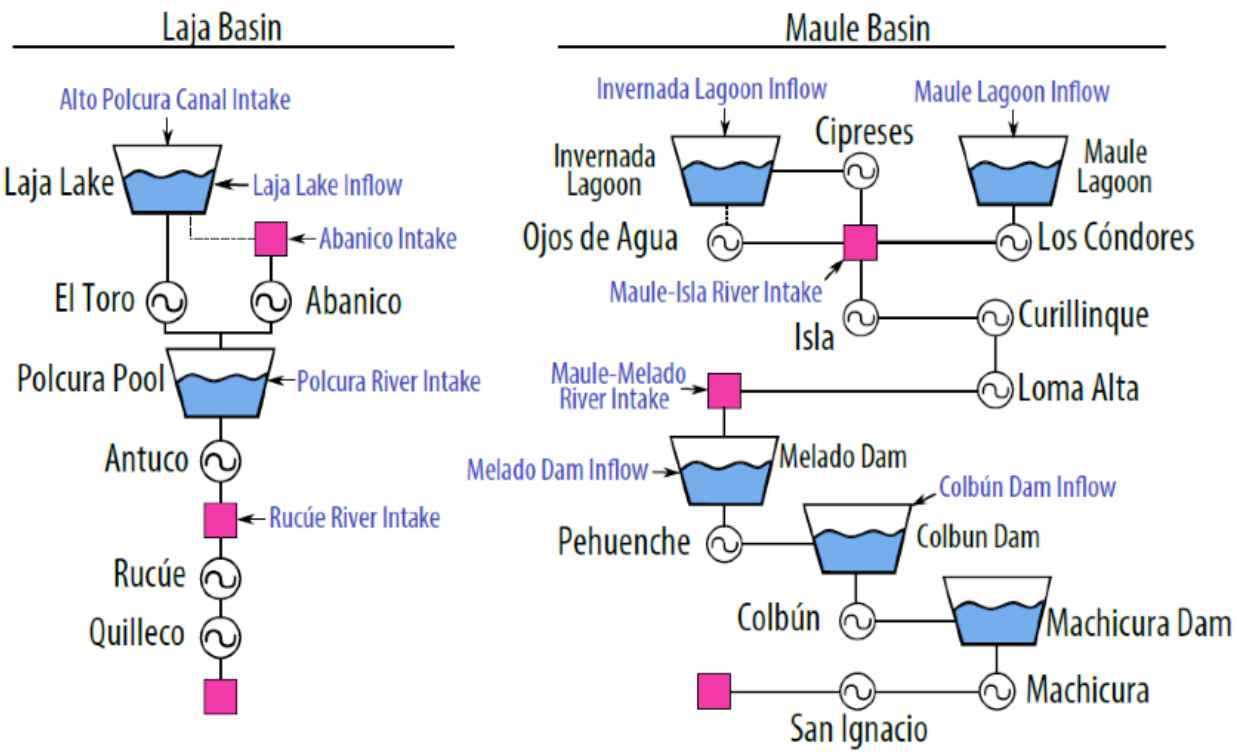
Generation, power flow through lines and other operational variables to meet expected demand, in order to estimate operational cost.

The NewEn Planning Model: The Chilean Network

- The Chilean National Electricity System is modelled using en 20 nodes or load zones.
- Generation Fleet: 137 existing and 209 candidate units.
- Transmission system: 23 transmission corridors with candidate expansions.

NewEn Planning: Hydro Network

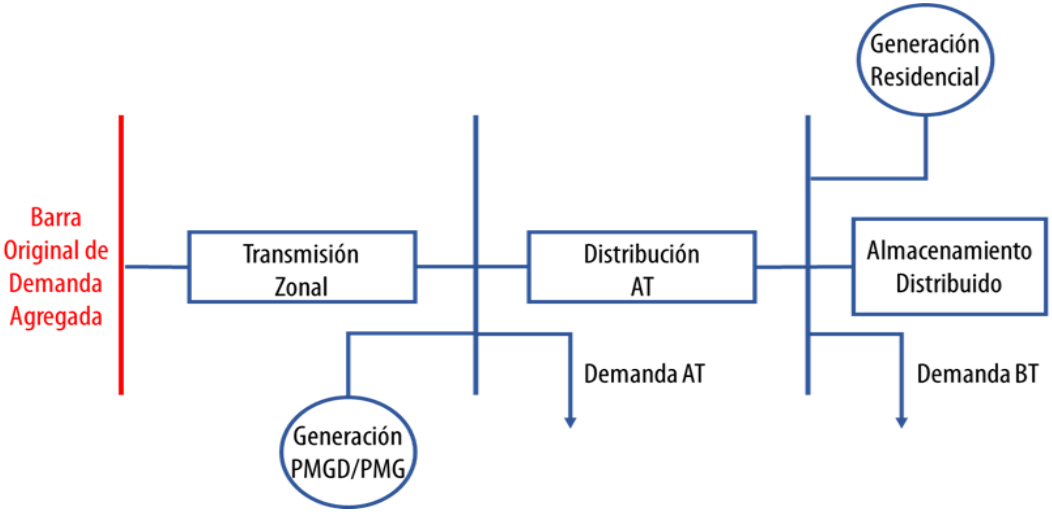
- The Chilean water network is represented by a graph of nodes and edges, based on Maluenda et al (2018).
- 23 nodes (12 of them reservoirs), 19 edges, and 21 hydro power units.



The NewEn Planning Model

- The NewEn model has been developed and used for more than 5 years, and its results have been reported in severa publications:
  - (Verástegui et al., 2020) Verástegui, F., Lorca, Á., Negrete-Pincetic, M., & Olivares, D. (2020). Firewood heat electrification impacts in the Chilean power system. Energy Policy, 144, 111702.
  - (Verástegui et al., 2019) Verástegui, F., Villalobos, C., Lobos, N., Lorca, A., Negrete-Pincetic, M., & Olivares, D. (2019). An optimization-based analysis of decarbonization pathways and flexibility requirements in the Chilean electric power system. ISES SWC, 2019, 1-12.
  - (Mena et al., 2019) Mena, R., Escobar, R., Lorca, Á., Negrete-Pincetic, M., & Olivares, D. (2019). The impact of concentrated solar power in electric power systems: A Chilean case study. Applied Energy, 235, 258-283.
  - (Maluenda et al., 2018) Maluenda, B., Negrete-Pincetic, M., Olivares, D. E., & Lorca, Á. (2018). Expansion planning under uncertainty for hydrothermal systems with variable resources. International Journal of Electrical Power & Energy Systems, 103, 644-651.

NewEn Planning Model Upgrades: DER Modelling



- Each load zone is **disagregated** into 3 nodes.
- The first node represents the original bus in NewEn at the HV transmission level.
- The second node represents a main distribution substation, where large distributed generation projects are typically connected, together with large industrial customers.
- The third node represents low voltage distribution networks, where commercial and residential consumers are connected, together with rooftop PV, and distributed storage.

Integrating DERs in Chile: Base Case

The **Base Case** of the study considers the following **assumptions**:

- The level of DER penetration is direct result of the optimal planning from a central planner's perspective, as a function of the cost.
- The DG hoting capacity in nodes representing LV distribution networks, without requiring investment in network upgrades, is a 30% of the peak hourly demand in each node.
- Considers a **descarbonization plan** with zero carbon-fired generation in 2040.
- Base (medium) trajectory of electricity demand and costs

Other Scenarios

Additionally, we considered the following **technological scenarios**:

DER integration scenarios:

- Forced integration of 50% and 100% of the hosting capacity in LV Dx networks.
- Forced 0% integration of distribution generation and storage in LV and HV Dx networks.

Scenarios of renewable rnergy integration:

- Scenarios of decarbonization of the electricity system by 2040 and 2030.
- Target of 100% renewable generation by 2040.

Sensitivities on key parameters:

- Sensitivities on capital costs (Low, Medium, High).
- Sensitivities on demand growth (Low, Medium, High).
- Other relevant sensitivities regarding transmission expansion candidates for Chile.

Net Differential Benefit

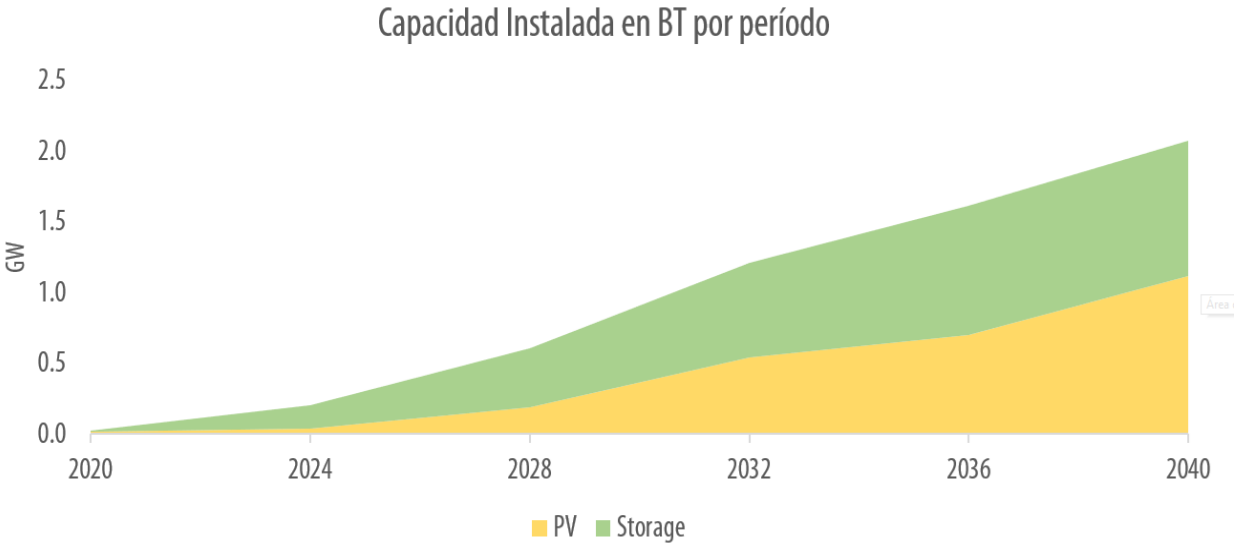
In order to faciitate the comparison of different scenarios, we defined the parameter **of Net Differential Benefit** for each scenario and sensitivity, as follows:

$$\Delta_{DG} = CCC - CDG$$

- *CCC* = NPV of the operation and plannning cost for the base case scenario.
- *CDG* = NPV of the operation and plannning cost for each corresponding scenario.

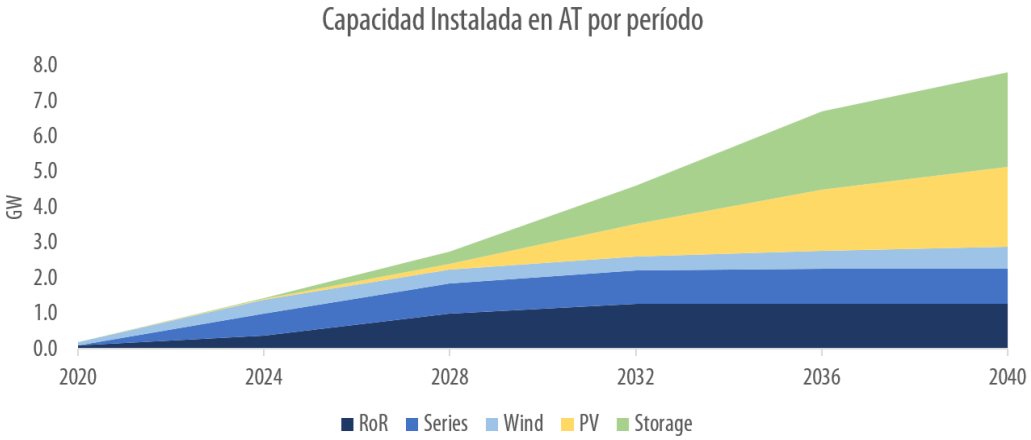
Main Results: Overall impacts on the Chilean Electricity System

- The base case results show that efficient DG integration at LV Dx nodes accounts for **62% of their total hosting capacity**, which is nearly **1,12 GW** of solar PV capacity.
- Also, the base case scenario shows an efficient integration of nearly **0,96 GW** of storage (4-hour) in LV Dx node.



Main Results: Overall impacts on the Chilean Electricity System

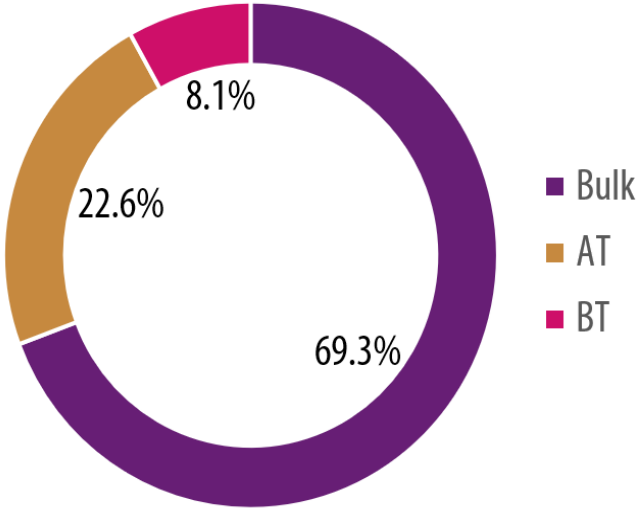
- In the case of DERs in HV Dx networks, the base case invests in nearly **5,1 GW** of DG by 2040, together with nearly **2,7 GW** of storage.



- The efficient integration of DG in LV and HV Dx networks reach **6,22 GW** by 2040 in the base case, which represents a **39,6% of the new generation capacity installed in the system** over the planning horizon (20 years).

Main Results: Overall impacts on the Chilean Electricity System

- The base case results show a significant integration of storage, which reaches **11,92 GW** of 4-hour energy storage capacity by 2040.
- **The high penetration of storage in LV Dx networks is likely to have a positive impact on the hosting capacity of such networks.** This might allow higher DG penetraton levels, beyonf 30% of the peak demand.



- The sensitivities on cost parameters associated with DG and their forced integration level **show no significant differences in terms of total CO2 emissions** due to fossil fuel-based generation.

Main Results: Case studies and Sensitivities

- The base case scenario has, in practice, identical costs to scenarios in which DG is forced to 50% and 100% of hosting capacity.

- The overall investment + operation cost can **increase in as much as $1.558 MM USD in extreme scenarios where DERs are now allowed in the system**, both in LV and HV Dx networks.

- This largely justifies efforts to lower barriers to entry and promote efficient deployment of DERs in Chile.

Scenario	Objective Function	%ΔDG
Base Case	48,687	-
Foced 50% DG case	48,688	0.0%
Forced 100% DG case	48,692	0.0%
0% DG in LV and HV Dx	49,663	2.0%
0% DG and storage in LV and HV Dx	50,244	3.2%
Base case + 100% renewables	48,718	0.1%
Decarbonization by 2030	50,349	3.4%
Descarbonization by 2030 + 100% Renewable	50,384	3.5%
Low investment costs projection	46,750	-4.0%
High investment costs projection	49,968	2.6%
Low demand growth projection	43,339	-11.0%
High demand growth projection	52,943	8.7%
Base Case + HVDC Line	49,166	1.0%

Specific Barriers and Challenges in Chile

Structural Barriers:

1. The zonal transmission expansion planning process only triggers new investments based on demand growth, not so for efficient DERs.
2. Distribution network expansion and ratemaking does not consider network upgrades needed to allocate efficient DERs.
3. DERs have limited Access to wholesale markets (e.g., spot market, ancillary services market).

Other challenges:

4. Information transparency: DER developers do not have public access to information about hosting capacities, and fase uncertainty regarding injection limits and/or network upgrade costs.
5. Education and financing: The general population is not aware of the costs and benefits of DERs, and many do not have access to financing properly tailored for this purpose.
6. Lack of a system-wide integration strategy and target: There is no strategy in place to maximize the benefits of DER integration in terms of resilience, efficiency and reliability in distribution networks. This is very much needed in light of the tremendous potential for DER development revealed by our study.

Summary of Results

- DG and distributed storage integration in the base case can reach nearly **40% of the new generation capacity** installed between 2020 and 2040.
- Forcing DG to installed a 100% of the available hosting capacity has virtually the same cost as the base case scenario, and **can represent nearly 60% of the new generation capacity** in the planning horizon
- The large penetration of distributed storage observed in the case studies **can unchain much higher hosting capacities of Dx networks, and also allow higher resilience and reliability** of electricity supply.
- The results suggest that the massive deployment of DERs in Chile can happen by privete innitiative, without significant state intervention, **provided that the markets allow adequate price signals to reach end users in Dx networks**.
- Nevertheless, certain speciific barriers need to be addressed by the state in order to allow the efficient deployment of DERs in Chile, including consumer education, and financing tools.

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Thank you!

Questions?

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