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Just Energy Transition in Coal Regions

April 2026

CASE STUDY

Repurposing Tocopilla's Energy Infrastructure

Decarbonization, Repurposing, and Just Transition Challenges in a Former Coal-Based Territory

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Context of Decarbonization in Chile

When the first Decarbonization Working Group was established by Chile's Ministry of Energy in 2018, the National Electric System (SEN) had a predominantly hydrothermal generation mix, based on hydroelectric, gas, and coal-fired generation. As a direct outcome of this process, coal plant operators voluntarily assumed several commitments:

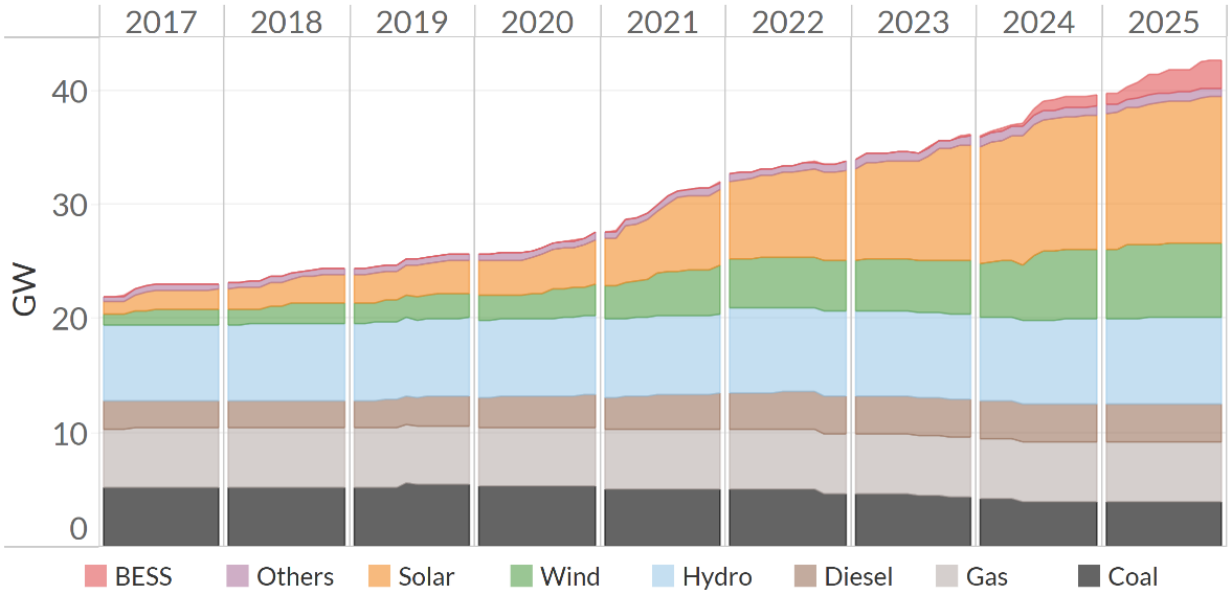
1. to not develop coal-fired generation projects without carbon capture;
2. to work toward retiring all coal-fired power plants by 2040;
3. to participate every five years in working groups to assess additional retirements; and
4. to retire eight out of the 28 existing coal units by 2024 (1,047 MW, equivalent to 19% of total installed capacity).

Subsequently and voluntarily, some companies expanded their commitments in line with their international decarbonization targets [1].

Since then, significant solar and wind capacity has been integrated into the Chilean Electricity System, more recently complemented by Battery Energy Storage Systems (BESS) (Figure 1).

Figure 1. Installed capacity in Chile.

Source: Authors' own elaboration.



By 2025, solar accounted for 24% of the SEN generation mix, wind for 14%, and hydroelectric generation for 25%. Coal-fired generation accounted for 18%, down from 39% in 2017. Nevertheless, thermal generation remains critical during periods of low hydro availability (such as autumn) or low solar output, as well as for meeting critical system security constraints.

Coal-fired generation units have been retired under national decarbonization policies. Chile once had ten coal-fired plants distributed across six municipalities, consisting of 28 units and 5.5 GW of installed capacity. Currently, only half of these units remain in operation, hence the retirement of 42% of the national coal-installed capacity. Of the remaining units, two are scheduled to be retired before the end of 2027. Decarbonization progress has been enabled by regulatory changes, favorable conditions for renewable generation, declining renewable technology costs, long-term power purchase agreements, and voluntary agreements between companies and the Ministry of Energy.

Tocopilla: An Energy Services District

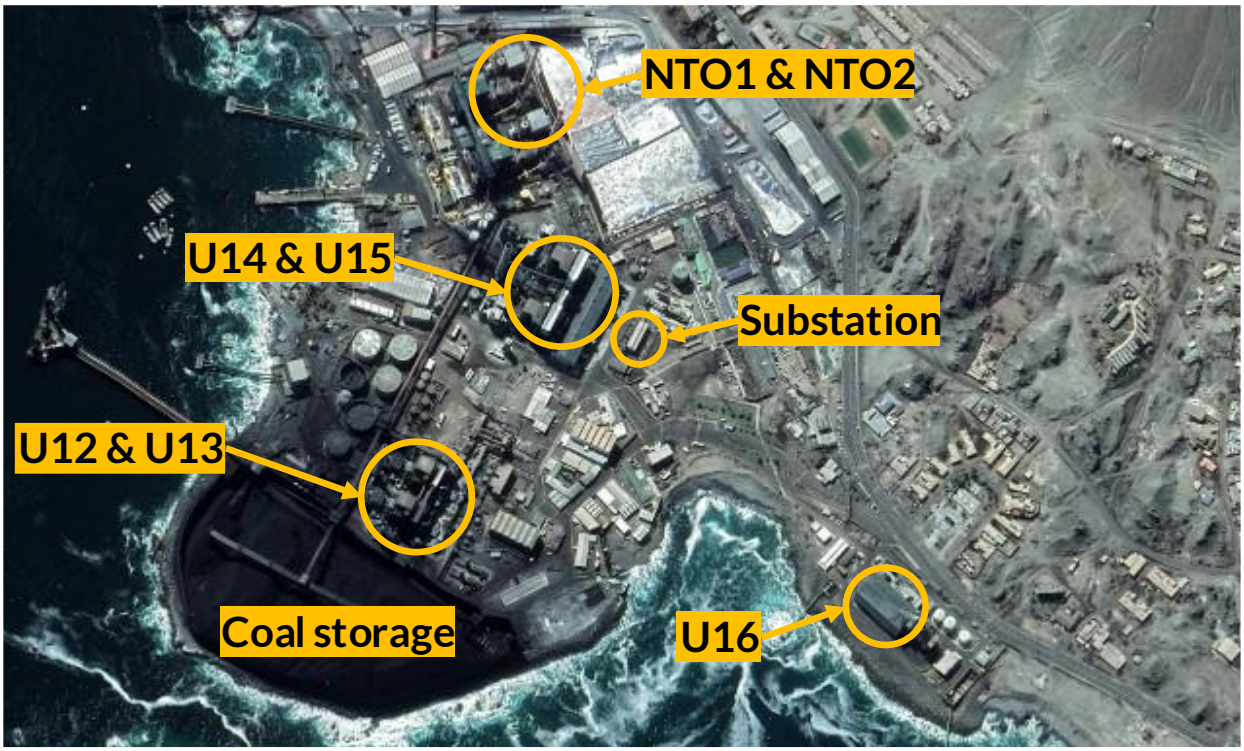
Tocopilla consolidated its role as an industrial city in the 19th century due to the saltpeter boom, which spurred port development and railway construction. After the decline of the saltpeter industry, the city maintained its industrial profile with the installation in 1915 of a large coal-

fired power plant to supply electricity to the Chuquicamata copper mine [2]. Over subsequent decades, the plant expanded with new boilers and turbines, incorporating oil- and coal-fired units, consolidating the Tocopilla–Nueva Tocopilla Thermal Complex (Figure 2). Located in the industrial zone south of the city, it eventually operated six coal-fired units (over 700 MW): four owned by Engie (U12–U15) and two by AES Andes (NTO1 and NTO2), commissioned between 1983 and 1997 and now all out of operation.

In 2001, Engie added a 350-MW combined-cycle gas turbine unit (U16). It remains operational, making the reuse of existing infrastructure –or the site itself– attractive for new projects, as on-site activities (staff, administrative and logistics management) are already in place, facilitating project implementation.

Figure 2. Structure of the Tocopilla Complex in 2019.

Source: Authors' own elaboration.



The closure of Tocopilla power plant was expected to have a disruptive effect on Tocopilla, a region with limited economic diversification and a strong historical dependence on thermal power generation and industrial activity. Key economic activities include mineral extraction and processing and the export of saltpeter derivatives. The closure generated significant impacts on employment and the local economy: around 600 people worked at the Tocopilla power plant in 2018, including direct employees and contractors [3], most of whom resided in the district. These jobs offered above-average wages, amplifying the socio-economic impact by reducing both

direct employment and household purchasing power [4]. An additional 1,200 people are estimated to have depended on jobs linked to the Tocopilla power plant's value chain [3].

This situation posed the challenge of repurposing the local productive base and generating new economic development opportunities. Given the economic impact of plant closures, in December 2023 the Ministry of Energy published the *"Plan de Transición Socioecológica Justa de Tocopilla"* [5]. The Plan included 115 actions requiring the participation of more than 58 stakeholders, reflecting the process' complexity and the need for effective coordination among public, private, and social entities. Thirty-one organizations were responsible for leading these actions, including the Ministries of Energy, Environment, Economy, Education, Health, their regional Secretariats (Seremías), the Municipality of Tocopilla, Engie, among others. As of March 2026, there is no publicly available information documenting progress in the implementation of the measures outlined in the Plan.

Engie's role in National and Local Decarbonization

In 2019, Engie's generation portfolio in Chile was predominantly thermal and represented 8% of SEN generation, with 6.1 TWh generated that year: 63% from coal and 32% from gas. Back then, Engie operated nine coal-fired units in two locations, Mejillones and Tocopilla. Following the first Decarbonization Working Group, the company expanded its original retirement commitments from 440 MW by 2024 (four units at Tocopilla) to 1,500 MW by 2027, covering its entire coal-fired fleet. This decision aligned with its international climate targets: achieving carbon neutrality in direct and indirect emissions by 2045, eliminating coal in Europe by 2025 and worldwide by 2027, and expanding its renewable and BESS capacity to 95 GW by 2030 [6].

Engie has made rapid progress in fulfilling these commitments. Between 2019 and 2022, it closed the four coal-fired units at the Tocopilla Complex (440 MW). By the end of 2025, operations at the Mejillones Thermal Complex concluded for CTM1 (166 MW), CTM2 (172 MW), and IEM (377 MW), with the IEM unit slated for conversion to natural gas. The final two units of the complex, CTA (177 MW) and CTH (178 MW), are expected to end operations in 2027, coinciding with the commissioning of synchronous condensers, currently under development in the SEN. Additionally, the company increased its renewable capacity by more than 1,200 MW between 2019 and 2025, including nearly 500 MW of wind, 280 MW of solar, and 350 MW of BESS.

The site that originally hosted the Tocopilla coal power units is being reused to form an energy hub that includes both a BESS and synchronous condensers, in addition to the existing natural gas generation. This transition process has been enabled by various regulatory instruments and system conditions within the SEN:

1. Green Financing

Engie implemented innovative green financing structures with the support of international funds to advance its decarbonization process. Two credit facilities stand out, combining environmental and social objectives with investments in renewable energy and the early retirement of coal-fired units, marking significant milestones in Chile's energy transition.

In 2021, Engie and IDB Invest agreed on USD 125 million in financing, comprising an USD 110 million commercial loan and a USD 15 million concessional loan from the Climate Investment Fund (CIF). This financing supported the construction, operation, and maintenance of the Parque Eólico Calama wind farm (151 MW) [7] [8], which entered operation in mid-2021 to replace part of the energy generated by units U14 and U15 (268 MW).

The CIF concessional loan was structured as a bullet loan with a two-tier interest rate[1] and included a carbon pricing mechanism under which USD 3 per ton of CO_2 avoided is applied as a discount to interest payments,[2] contingent on emissions reductions resulting from early unit retirement. This discount is applied at the loan's maturity, providing a financial incentive for effective decarbonization [7]. Avoided emissions from the early retirement of U14 and U15 are estimated at 500–700 thousand tons of CO_2, implying an interest reduction of USD 1.5–2 million [7].

Complementarily, in 2022 Engie secured USD 400 million in green financing led by the International Finance Corporation, conditional upon meeting three KPIs: closure or conversion of coal plants by 2026, incorporation of 500 MW of renewable capacity, and increasing female representation in management positions from 24% in 2022 to 31% by 2026. The loan supported the refinancing of two solar parks (268 MW) and the addition of BESS at these facilities [9].

2. System Security and Repurposing Opportunities

Decarbonization progress introduces an additional challenge: replacing synchronous generation (such as thermal power plants) with inverter-based generation (such as renewables) entails the loss of essential system security attributes beyond energy supply. The provision of inertia and short-circuit power (SCP), historically byproducts of thermal generation, is compromised as these units are retired or less frequently dispatched due to higher renewable integration. This creates a critical deficit, often forcing thermal units to be dispatched to maintain minimum requirements to allow a reliable operation of the SEN under conditions with high integration of inverter-based generation.

[1] First, a minimum fixed annual interest rate of 1%, payable semiannually. Second, the difference between that rate and the variable rate of the commercial loan granted by BID Invest, which is deferred and capitalized to be paid at loan maturity [7], on December 15, 2032 [8].
[2] Deferred and capitalized.

Synchronous condensers (SCs) emerge as a solution to provide SCP and stabilize voltage without generating active power [10]. These machines are like synchronous generators but do not produce electricity. When coupled with a flywheel, they can also provide inertia [11]. SCs can reduce reliance on forced thermal dispatch and enhance system stability in high-renewable scenarios more efficiently and with lower emissions, contributing to a reliable and sustainable energy transition.

To meet future voltage control and inertia requirements, in 2023 the Coordinator of the National Electricity System (CEN) launched a tender for 1,023 MVAr of SCs and 5 GVAs of inertia (flywheel required), with expected commissioning in November 2027.[3] Remuneration will be based on the annual infrastructure value, incorporated into a monthly ancillary services charge.

This tender opened the possibility of repurposing decommissioned thermal plants, as such conversions can be faster and up to 60% cheaper than greenfield SC projects (USD 3–20 million per unit, depending on its condition) [10] [12]. Among awarded projects is the conversion of Engie's U15 unit in Tocopilla into a SC [13]. The original project contemplated converting both U14 and U15 at a declared cost of USD 50 million [14], but only U15 was awarded, leaving the conversion of U14 on hold. The project is expected to employ an average of 25 workers during the construction phase. During operations, staffing is limited to one on-site operator and one control operation [14].

The project was declared under construction in April 2025 [15]; as of March 2026 it shows 37% progress, with operation expected by the CEN by the end of the first half of 2026 [16].

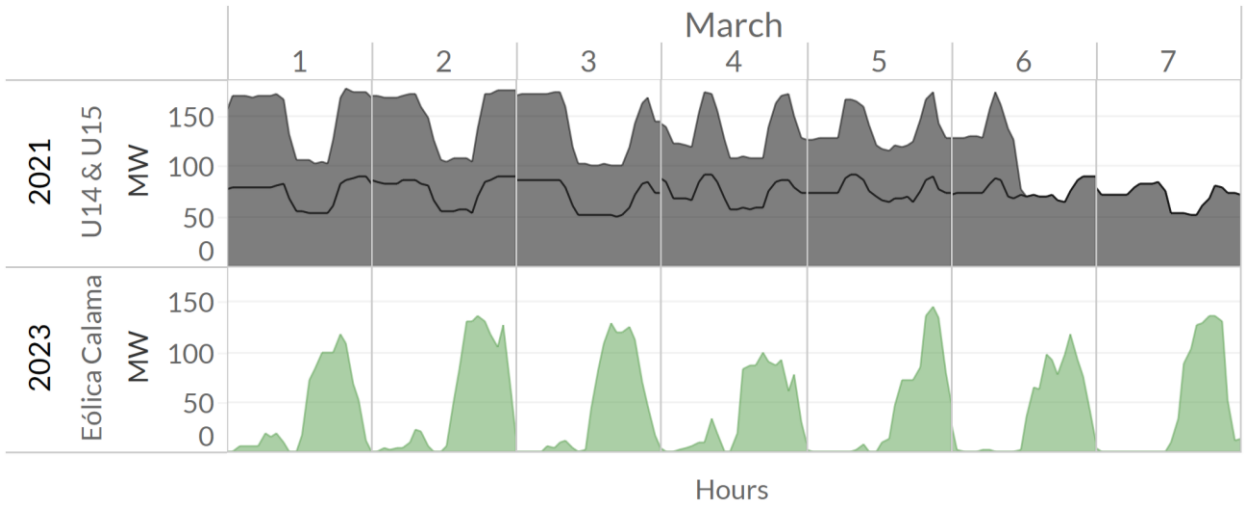
3. BESS in Tocopilla: Opportunities in the Decarbonization Context

High renewable energy integration cannot fully replace coal-fired generation due to its variability and weather dependence. Replacing the U14 and U15 units with the Calama wind farm was feasible in 2022 thanks to high reserve margins and grid strength in the SEN, alongside renewable investments that enabled unit retirements without compromising system security or supply costs (Figure 3).

[3] The tender defined SCP requirements at four northern nodes (Ana María, Nueva Chuquicamata, Likantai, and Illapa). However, projects located at nearby nodes were accepted by applying an effectiveness factor (SCP contribution of the node relative to the target busbar). Nearly 99% of the tendered capacity was awarded to five projects, at a total cost of USD 54.07 million per year. With an estimated electricity consumption of 84–87 TWh in 2027, the initial service cost is estimated at USD 0.62–0.64/MWh, providing 5.8 GVAs of inertia to the Norte Grande.

Figure 3. U14 and U15 (top) and Calama wind farm (bottom) operations during the first week of March 2021 and 2023.

Source: Authors' own elaboration.



To mitigate renewable variability, BESS provide the opportunity to shift energy from surplus periods to deficit periods. BESS deployment has been favored by declining technology costs, driven mainly by Chinese manufacturers.

In addition to cost reductions, in 2024 Decree DS70 was published, regulating capacity market payments for BESS under highly favorable conditions. The capacity market remunerates availability to ensure sufficient system capacity. DS70 establishes a ten-year transitional recognition framework for BESS capacity, under which systems with a duration of five hours or more are granted full (100%) recognition of their maximum capacity, while systems with shorter durations receive proportional recognition[4] [17].

This favorable capacity payment scheme, combined with day–night energy price differentials, has accelerated BESS deployment in the SEN: by February 2026, 3.1 GW were operational [18], and by the end of 2025, more than 6.7 GW had been declared under construction by the CEN.

In this context, beyond the conversion of U15 to an SC, Engie developed a stand-alone BESS project at the Tocopilla plant site, known as BESS Tocopilla, reinforcing infrastructure that supports the transition to clean and flexible generation technologies. The project was declared under construction in August 2024 [19] and started operation in early February 2026 [20].

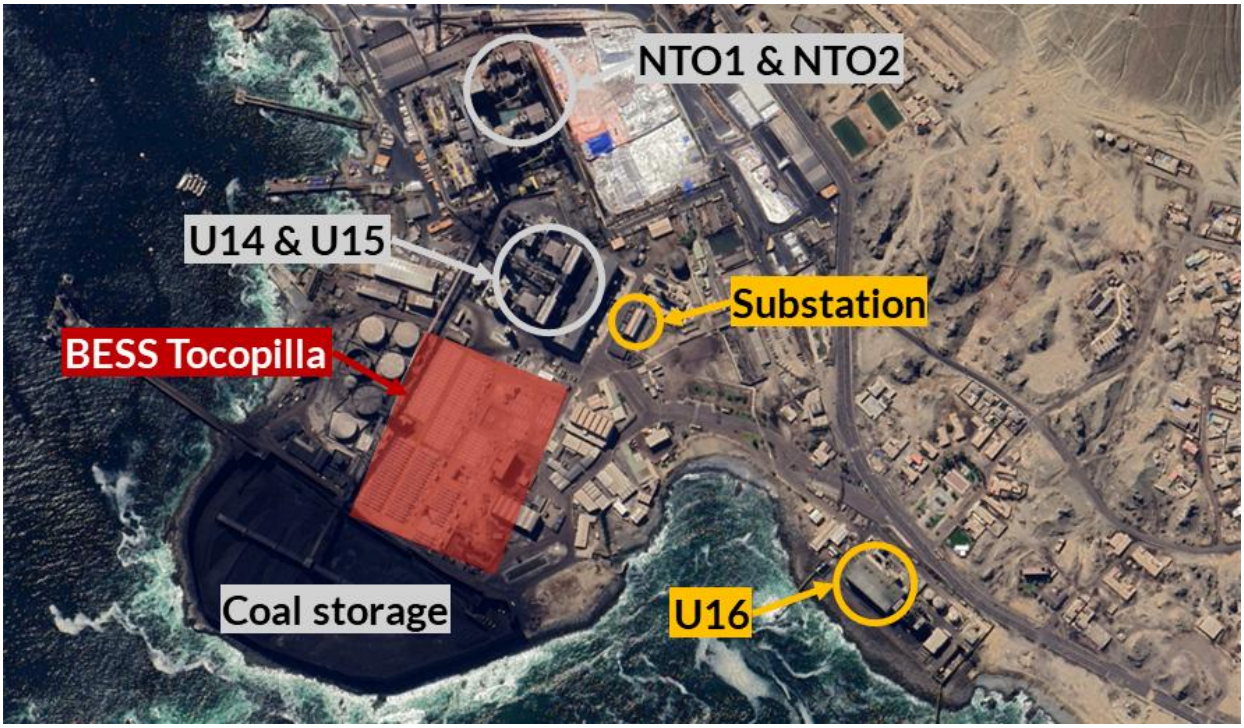
BESS Tocopilla covers an area of approximately 3.3 hectares, including the area formerly occupied by units U12 and U13. The BESS has a rated capacity of 116 MW with five hours of storage, representing an estimated investment of USD 180 million and an expected useful life of

[4] 0% (<1 h), 36% (1 h), 65% (2 h), 85% (3 h), and 98% (4 h).

30 years. Its configuration includes around 250 containers with inverters, transformers, and a connection to the Central Tocopilla busbar (Figure 4) [21].

Figure 4. BESS Tocopilla at the Complex today.

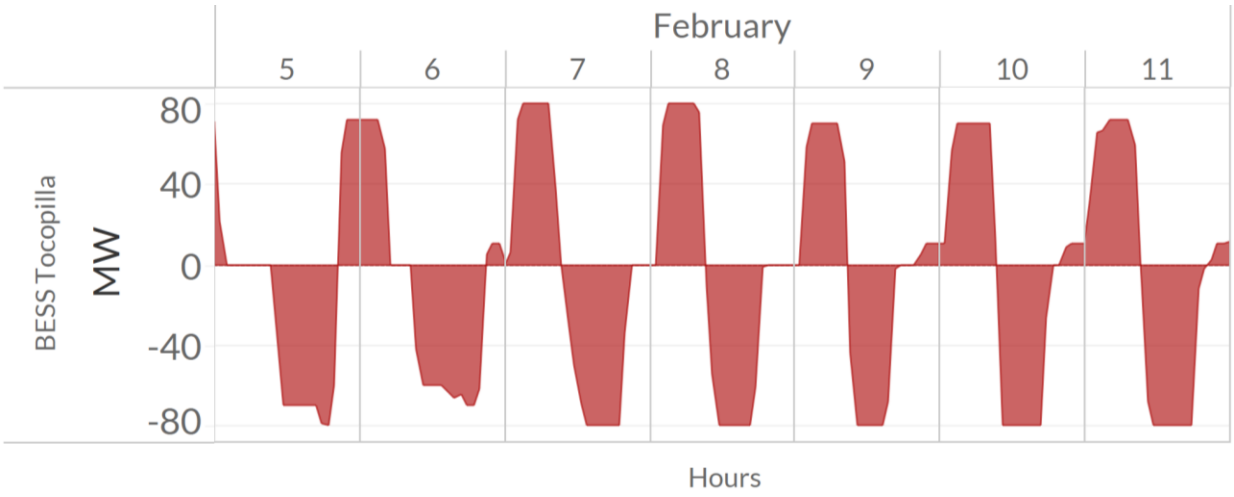
Source: Authors' own elaboration.



The construction phase involved an average workforce of 100 people, while the operational phase includes two operators and an eight-person maintenance team [21]. Figure 5 illustrates system operation during one week in February 2026.

Figure 5. BESS Tocopilla operation during the first week of February 2026.

Source: Authors' own elaboration.



Impact of Repurposing Tocopilla's Energy infrastructure

As a result of Engie's decarbonization process in Tocopilla, the Tocopilla plant has fully eliminated coal use, focusing instead on natural gas generation and the provision of ancillary services through a SC and a BESS. While this repurposing can be considered successful from a coal-free technology perspective, the broader transition process in Tocopilla must also be considered.

Technological transition does not automatically translate into an equivalent socioeconomic transition. The new energy infrastructure employs fewer workers than the former coal plants, making it essential for Tocopilla to attract new economic developments to achieve effective productive transformation. Achieving this will require building on its historical focus, competitive advantages, strong links to the mining sector, and existing infrastructure to attract large-scale, high-impact investments.

In recent years, the municipality has secured two strategic projects, signaling the start of a new productive phase. One is the Aguas Horizonte desalination plant, designed to meet growing water demand from mining and regional industry. Its location in Tocopilla positions it as a key provider of water resources, supporting the viability of future mining and productive projects in northern Chile. Additionally, mining remains a fundamental pillar of Tocopilla's economy. The Tovaku Project, promoted by Pucobre and recently submitted for environmental evaluation, represents an investment of USD 870 million for copper extraction in the north. The initiative includes a 28-month construction phase, followed by 21 years of operation and two years of closure, generating employment and stimulating the local economy.

However, the scale and diversity of measures proposed under the *"Plan de Transición Socioecológica Justa de Tocopilla"* create significant challenges in terms of management and prioritization for the organizations involved. Of the 115 actions initially identified, at least 54 pose a risk of limited impact relative to the magnitude of the challenges arising from plant closures. Moreover, two years after the Plan's publication, there is no publicly available monitoring of implementation progress or assessment of expected community impacts.

Given the complexity of the process and the challenges associated with securing sufficient resources, it is essential to focus efforts on strategic initiatives and, where appropriate, streamline the roadmap to prioritize high-impact measures. International experience underscores the need to strengthen socioeconomic impact monitoring and ensure long-term community participation through formal mechanisms to guarantee a truly inclusive and sustainable transition.

Conclusions

The repurposing of the Tocopilla plant represents an emblematic case of the challenges and opportunities associated with the energy transition in territories historically dependent on coal-fired generation. It demonstrates that thermal assets can be transformed in favor of decarbonization: the incorporation of BESS and SC, together with continued natural gas generation, positions the Tocopilla plant as a functional example within the SEN's new energy landscape.

However, technological transition has not been matched by an equivalent socioeconomic transition. The new infrastructure requires fewer workers than coal-fired units, highlighting that decarbonization alone does not guarantee productive transformation or adequate compensation for local labor impacts. It is therefore essential to align energy policies with industrial and territorial development strategies.

This case provides valuable lessons for future closure or repurposing processes of thermal power plants in Chile and internationally. The Chilean power system will require diversification of resources contributing to security and adequacy. Hybrid repurposing strategies may be necessary, enabling units to operate either as SC or as thermal plants, contributing non-emitting services that enhance system security (voltage control through SCP and inertia) while maintaining the ability to contribute to adequacy through their energy injection capacity during renewable scarcity, transmission system operations, or in emergency situations.

The strategic use of existing infrastructure, public–private coordination and focused just transition plans are key to advancing toward an energy transition that is environmentally sustainable and socially and economically just.

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This publication was produced with the financial support of the International Climate Initiative of the German Federal Ministry for the Environment, Climate Action, Nature Conservation and Nuclear Safety (BMUKN) and the European Union under a Grant Agreement with GIZ. Its contents are the sole responsibility of their authors and do not necessarily reflect the views of BMUKN, the EU or GIZ.