The South American Way:

Methodologies, Analytical Tools and Challenges for Decarbonizing the Latin American Countries

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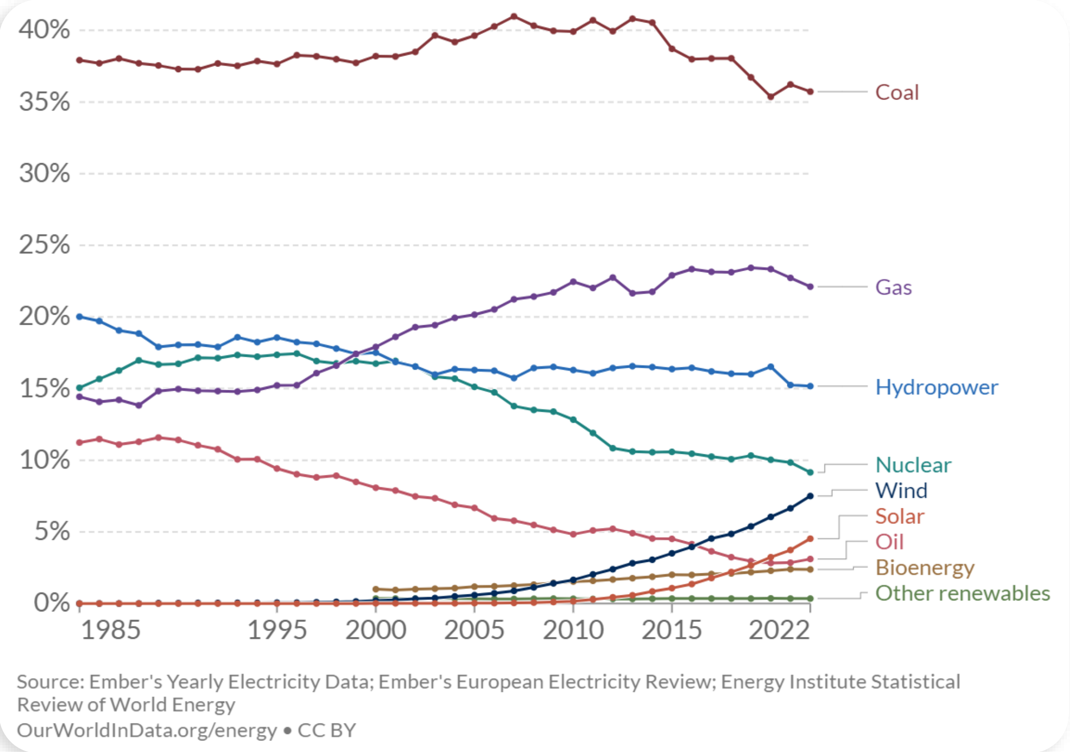
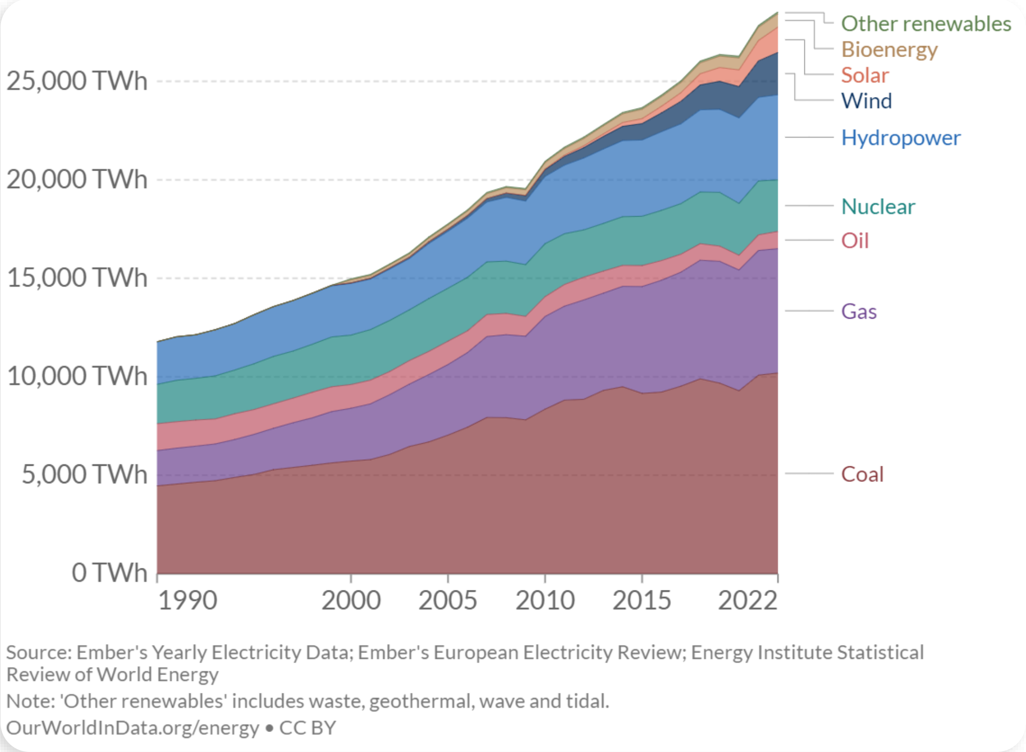
Introduction

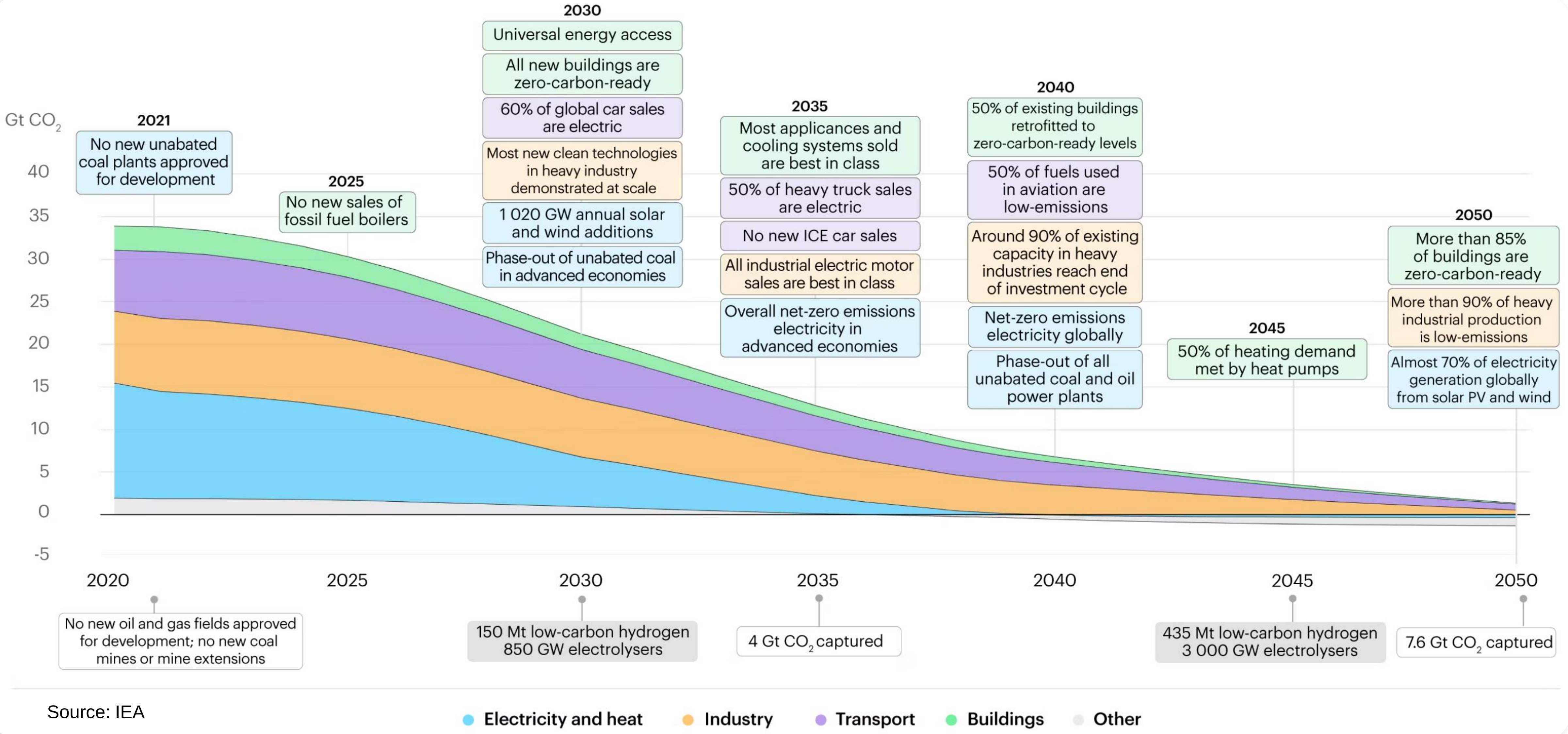
Electricity production by source





We are running out of time…

Roadmap for the reduction of CO_2 emissions

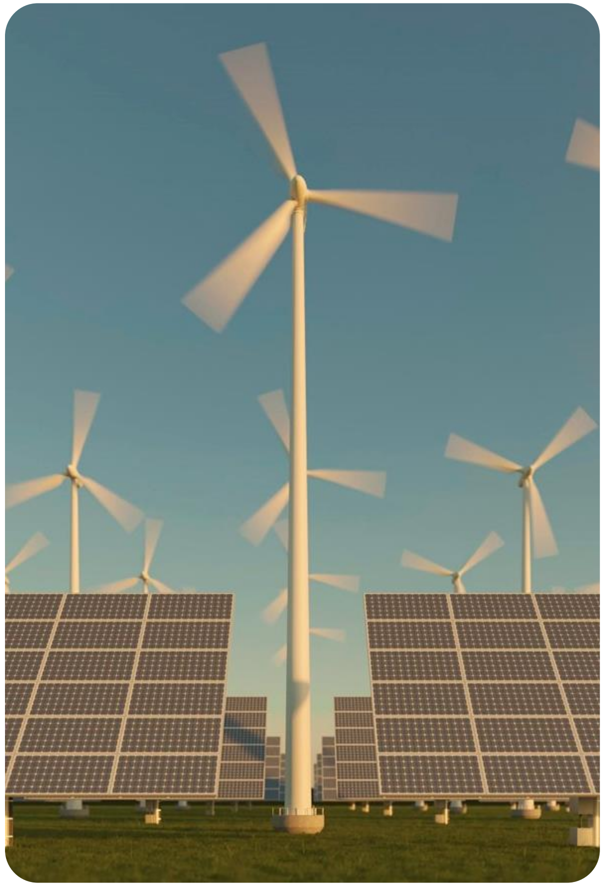


Source: IEA

Resource Modeling

Resource Modeling

Renewable Energy



General features

- Operation factor
- O&M and spilling costs
- Outage sampling and probability
- Concentrated Solar Panel (CSP) with storage representation

Physical characteristics

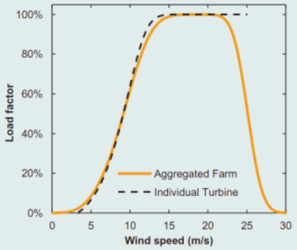
- Turbine characteristics
- Solar panel physical data

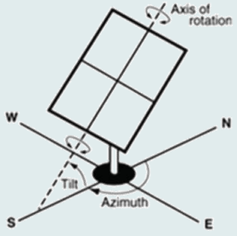
Georeferenced data

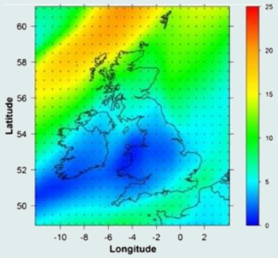
- Wind and solar irradiance data from geographic location

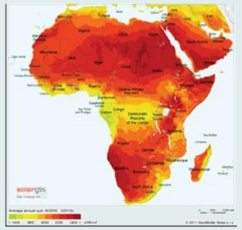
Generation data modelling

- Stochastic Variable Renewable Energy power production model, generating future synthetic scenarios with hourly resolution
- Scenarios are intertemporally and spatially correlated with hydro inflows



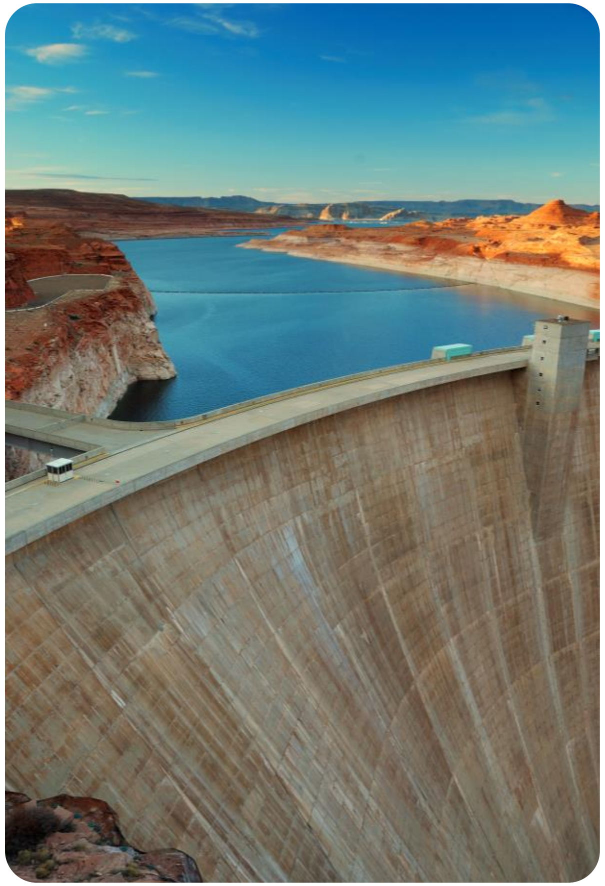






Resource Modeling

Hydro plants



H1 Data Preparation

- Extraction of drainage areas
- Inflow regionalization
- Project interferences
- Candidate site selection
- Head x Area x Storage curves

H2 Engineering Design & Budget

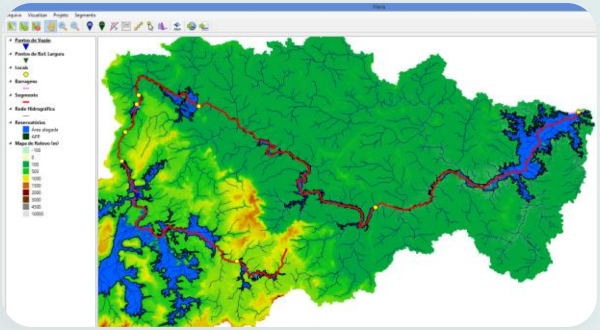
Layout Selection

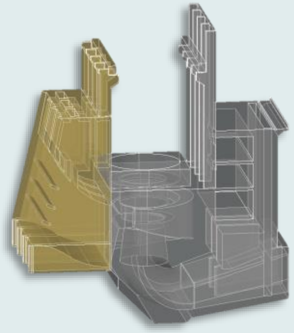
- Project design
- Budget estimate

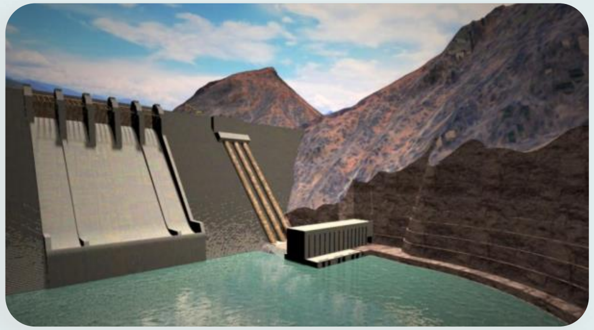
H3 Optimization

- Selection of projects that maximize the economic benefit of hydropower.
- Non-linear, integer, multistage, stochastic mathematical problem.

Results



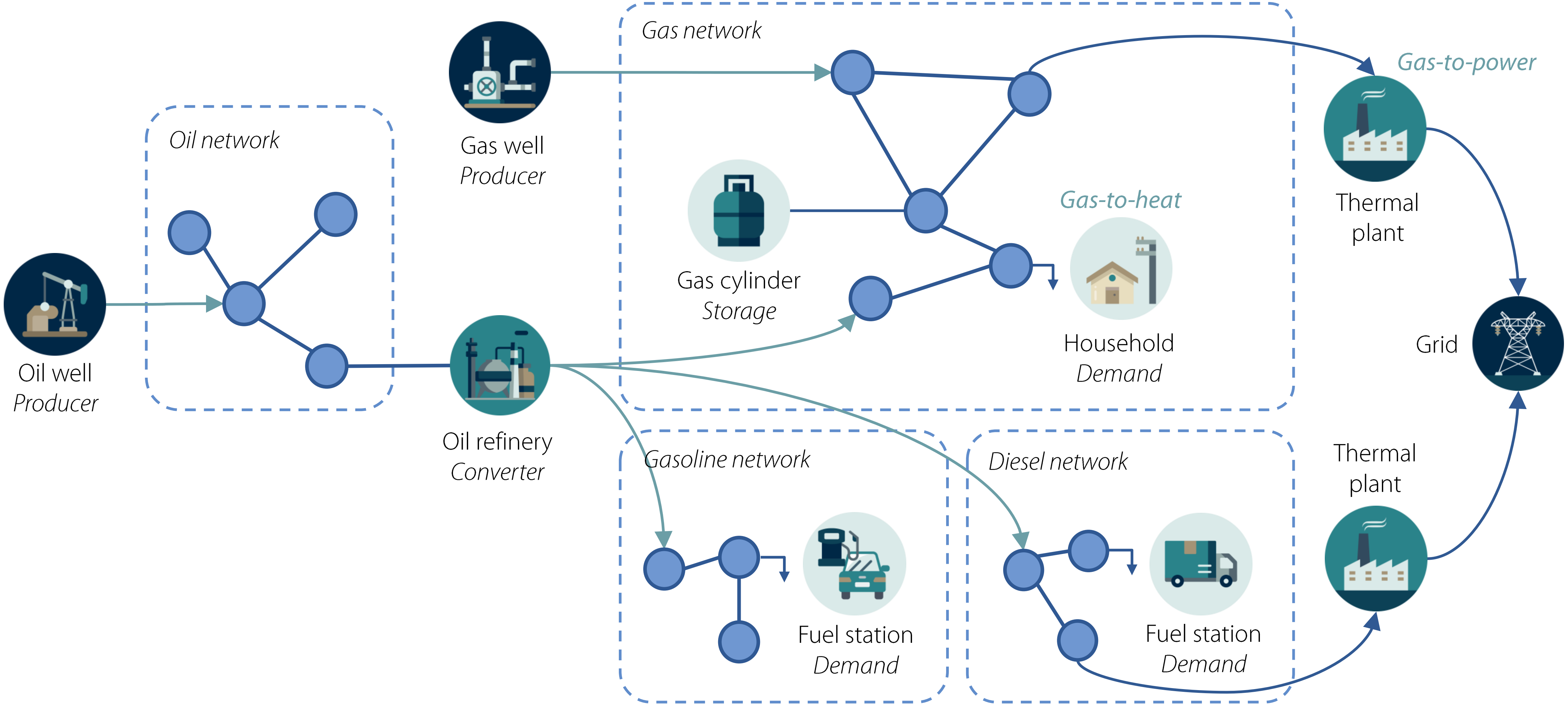




Sector Coupling

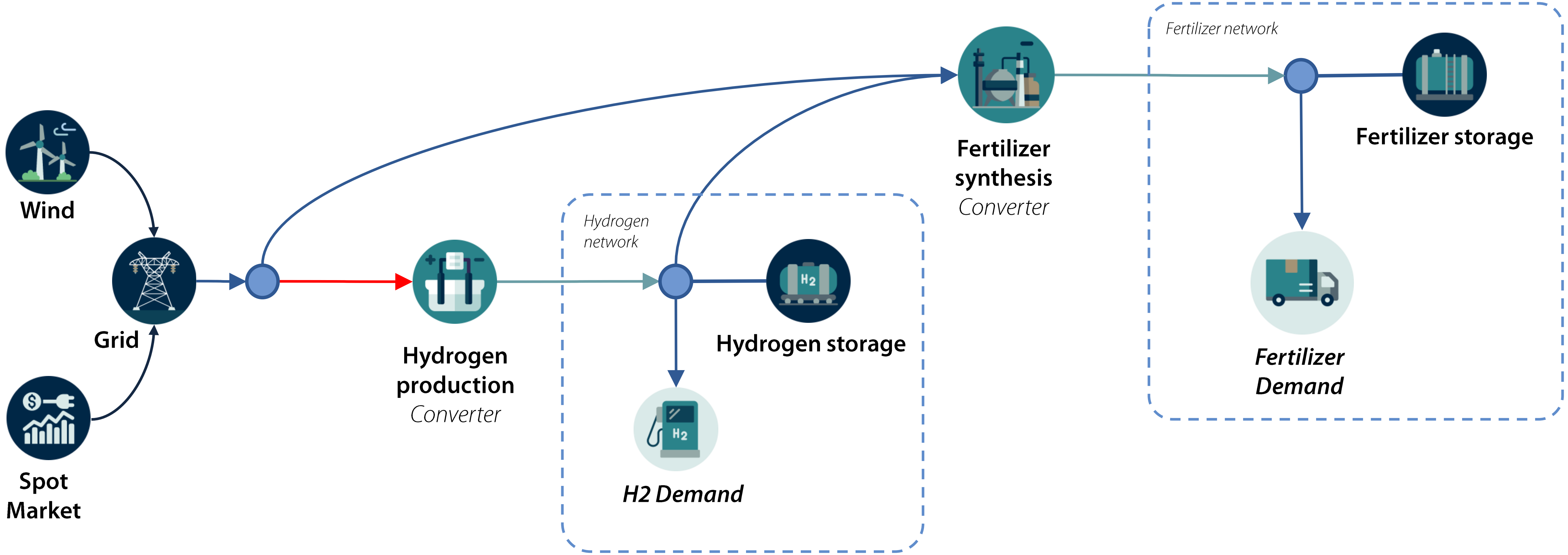
X-to-Power

Oil & Gas Supply Chain Example



Power-to-X

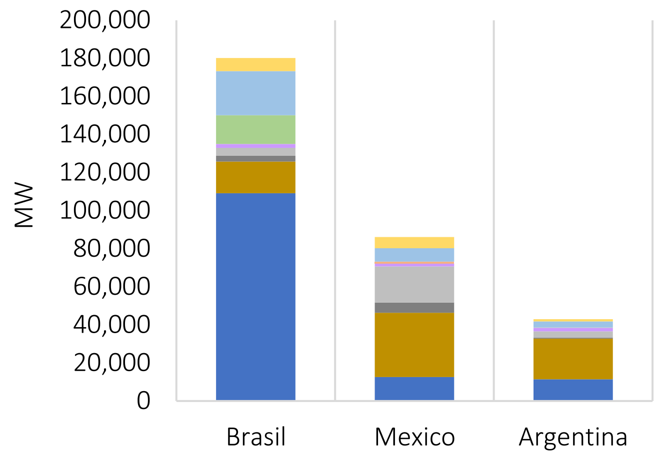
Hydrogen Supply Chain Example

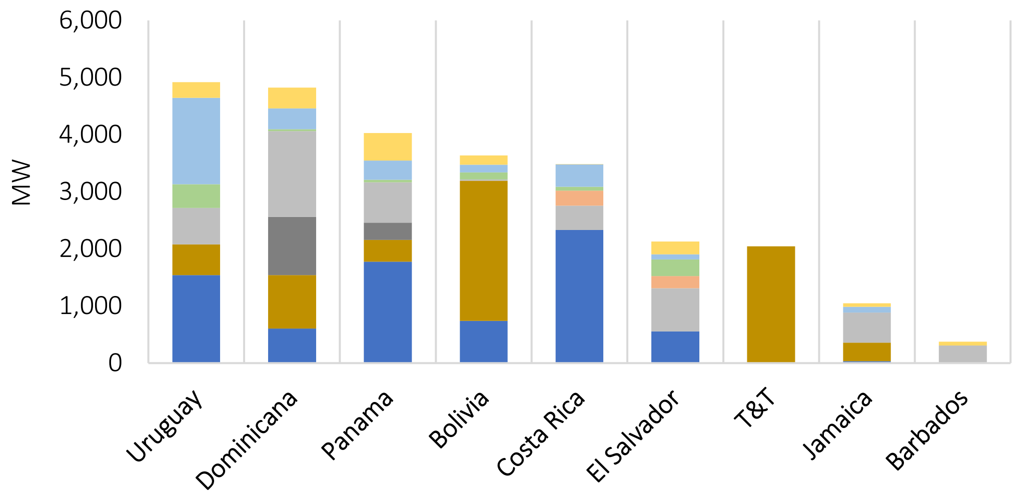


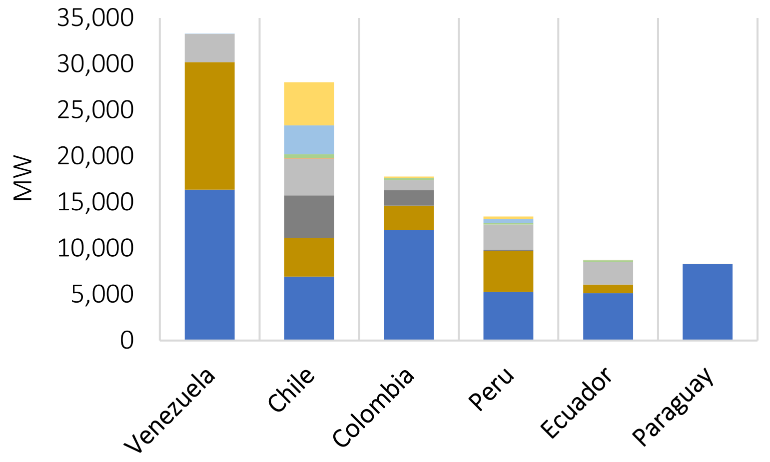
Energy Transition in LATAM

18 Countries Evaluated

- In this study, 18 Latin American countries were modeled, from large countries such as Mexico and Brazil to small countries and islands such as Barbados and Jamaica.
- 590 million people (30% > Europe)
- Total GDP of 5 trillion USD (20% > US GDP)

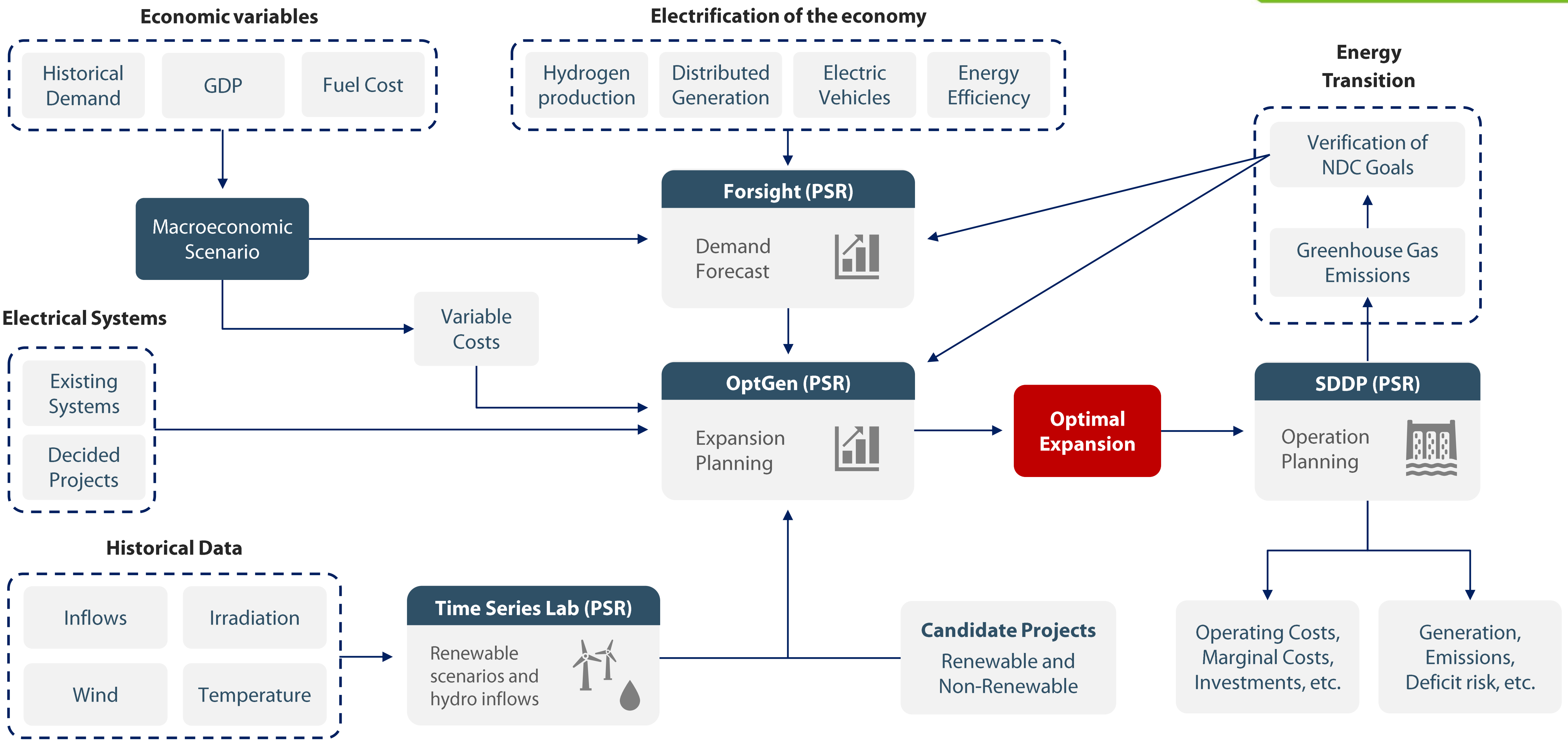






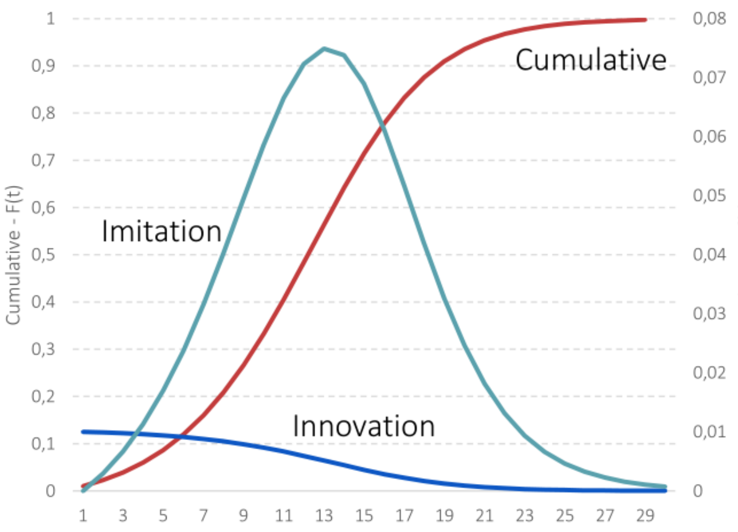
Hydro | Natural gas | Carbon | Liquid fuels | Nuclear | Geothermal | Biogas/biomass | Wind | Solar

Methodology



H2 + DG + EV + EE Modeling

- A model frequently used to carry out forecasting is the **Bass Diffusion Model**, which is focused on estimating the innovation adoption curve
- The Theory of Diffusion of Innovations indicates that the insertion of a technology can be represented by an “S curve”, divided into the phases of early adopters (innovators), majority adoption (imitators) and final adopters (late adopters)
- The model consists of four stages: (i) definition of the potential market; (ii) estimation of the final potential market; (iii) determination of market diffusion; and (iv) calibration of the model according to historical data



Definition of the potential market

$$Final\ Potential\ Market = fmm \times initial\ potential\ market$$

$$fmm = e^{-SPB \times TPM}$$

Where:

fmm: maximum market fraction

SPB: *payback* sensitivity

TPM: *payback* time in years

Definition of market diffusion

$$F(t) = \frac{1 - e^{-(p+q)\times t}}{1 + \frac{q}{p} \times e^{-(p+q)\times t}}$$

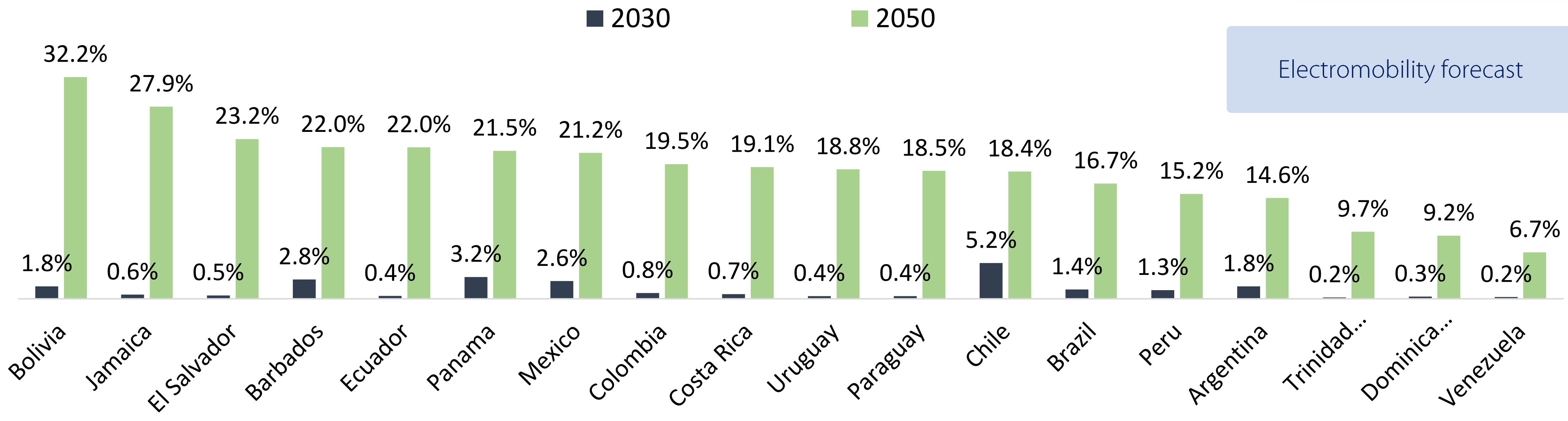
Where:

$F(t)$: accumulated distribution function

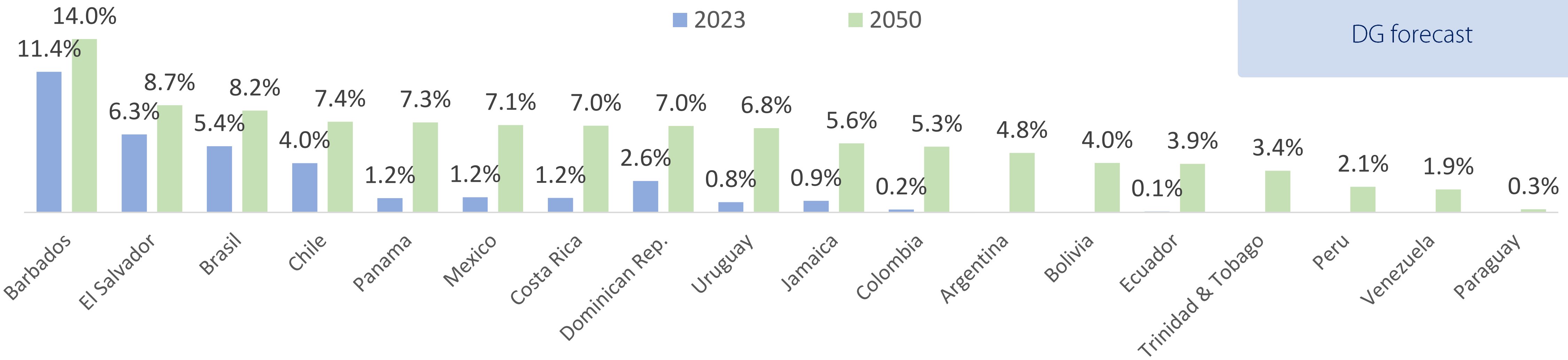
p: innovation coefficient

q: imitation coefficient

DG & Electromobility

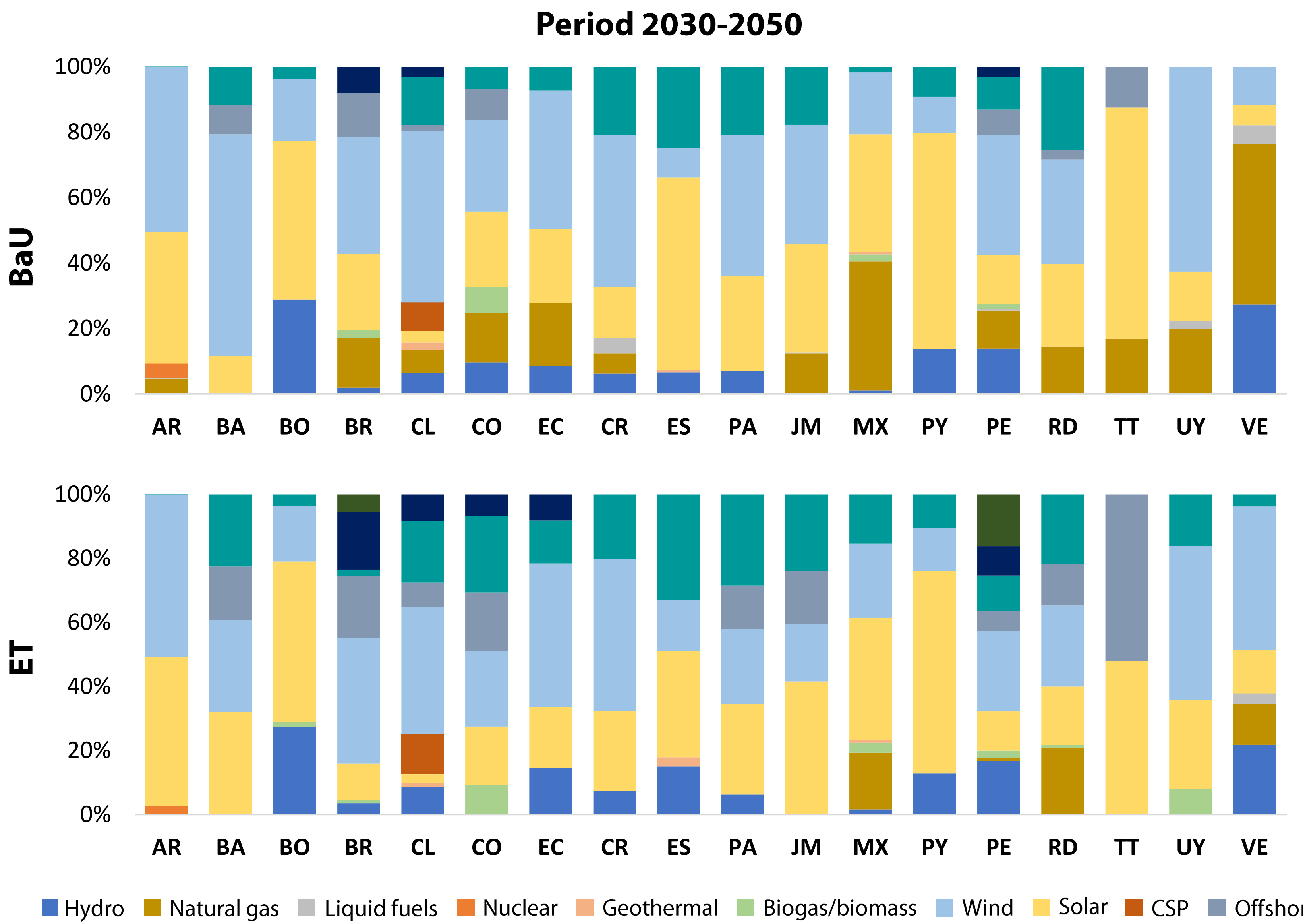


Electromobility forecast



DG forecast

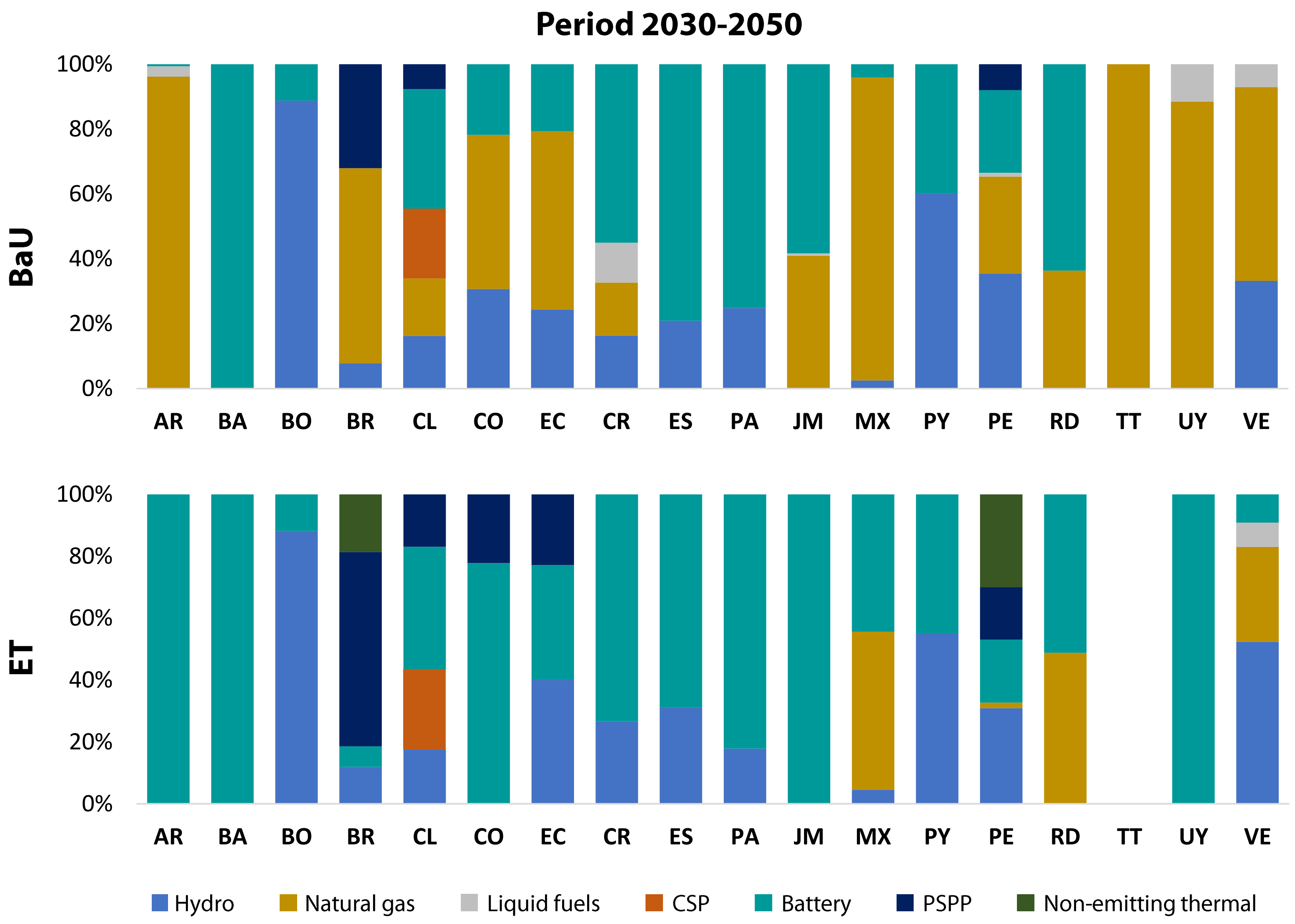
Investment Summary (BaU vs. ET)



- In the BaU Case there is a substantial investment in **renewable** sources for economic reasons.
- These investments are complemented by the addition of **hydroelectric** and **natural gas** mainly, which provide flexibility to the system

- In the ET Case, there are also substantial investments in **renewable** sources for economic reasons.
- In this case, these investments are mainly complemented with **storage** devices, replacing the retirement of thermal power plants

Flexible Technology Additions (BaU vs. ET)



- In the BaU Case, **natural gas** is the most technically and economically attractive option to provide flexibility in most countries
- In countries with the capacity to invest in **hydroelectric plants**, this option has proven to be attractive.
- Some countries have also concentrated their investments in **batteries**

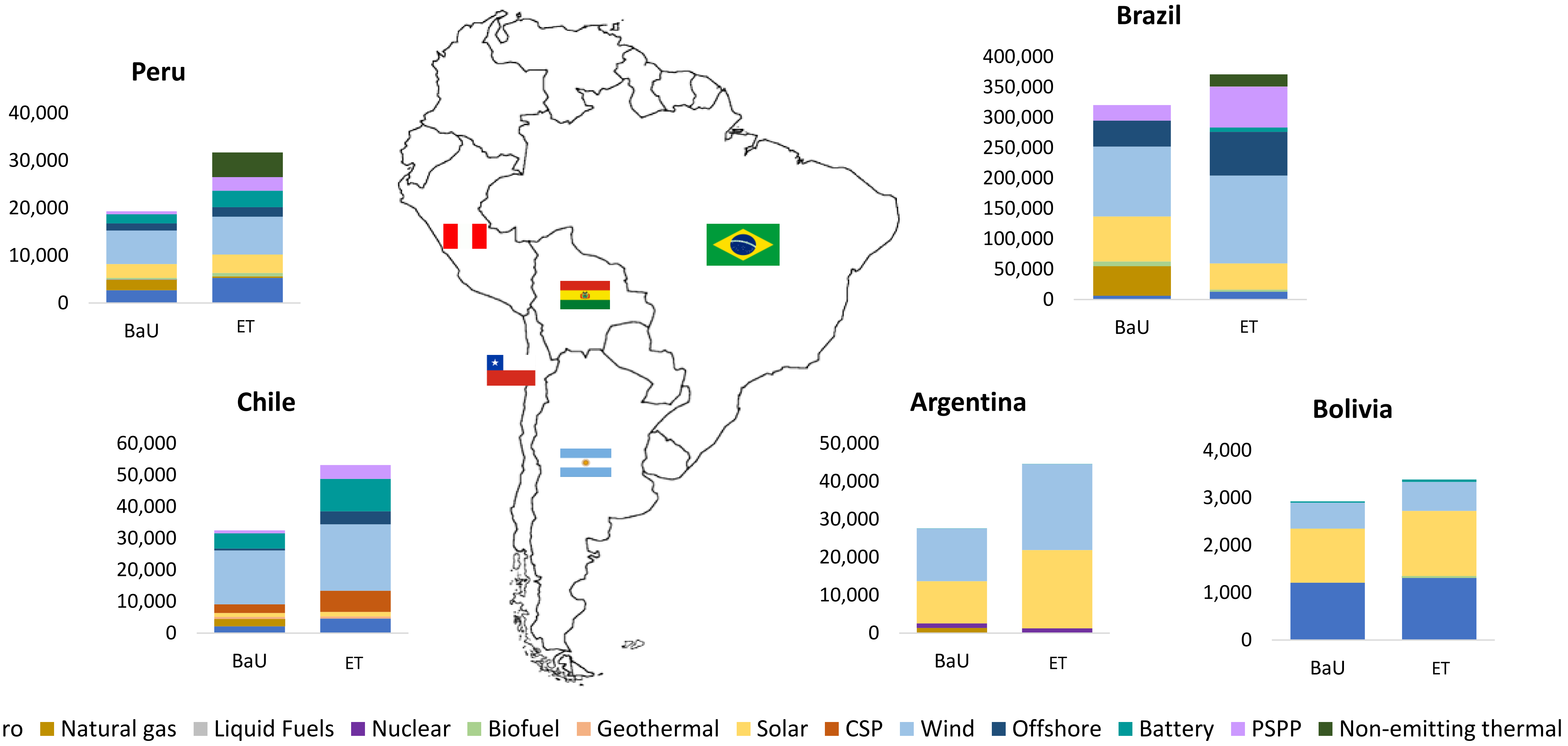
- In the ET case, the most prevalent option to incorporate flexibility has been the implementation of **batteries**
- In certain countries, the installation of **pumped-storage power plants** has also been chosen
- Thermal power plants with carbon capture were not as competitive in most countries.

Country Goals

Country	Goals until 2030	Goals until 2050
Argentina	Not exceed 359 MtCO2e (general economy) 20% renewable energy by 2025	75% clean generation by the year 2050
Bolivia	79% de renovables 19% de otras renovables	75% clean generation
Peru	Not exceed 208.8 MtCO2e (general economy) or 179 MtCO2e (conditioned goal)	Carbon neutrality
Brazil	50% reduction in CO2e emissions (vs. 2005)	Carbon neutrality
Chile	80% renewable energy	Carbon neutrality

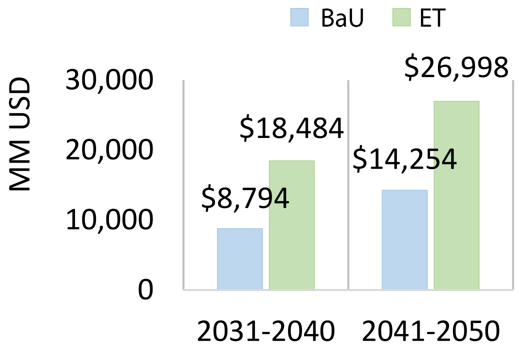
Investment Needs (BaU vs. ET)

Installed Capacity (MW)

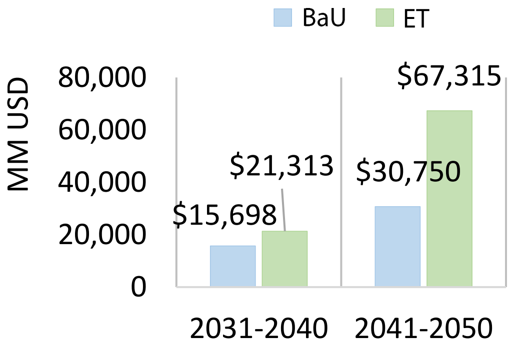


Investment Costs (BaU vs. ET)

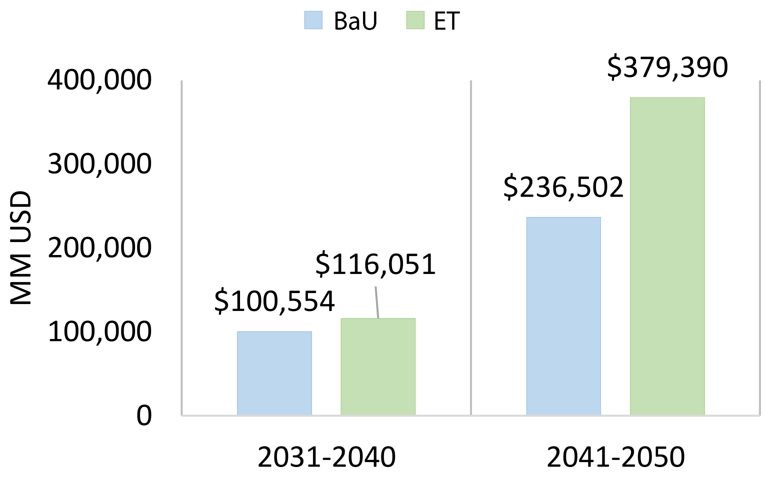
Peru



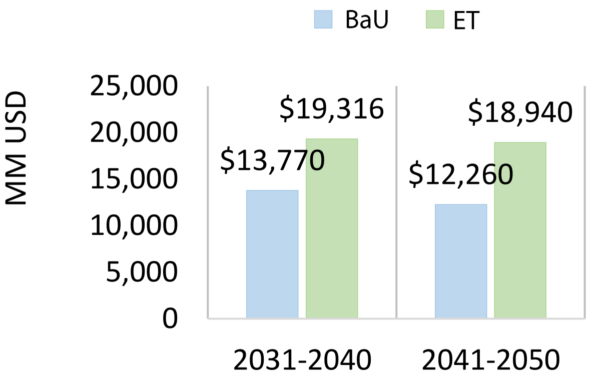
Chile



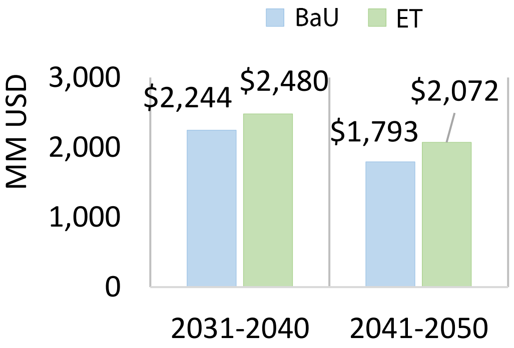
Brazil



Argentina

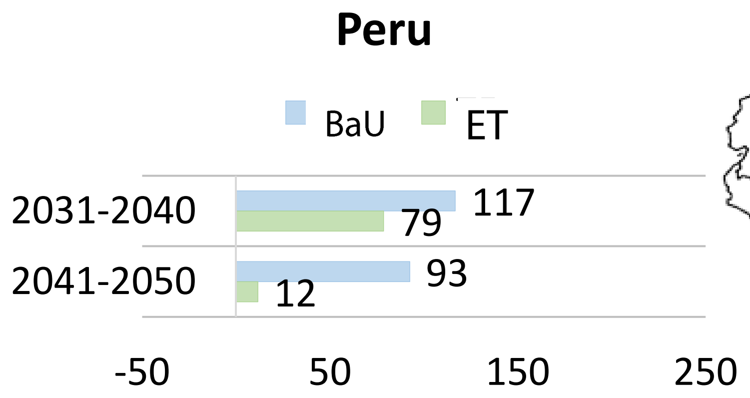


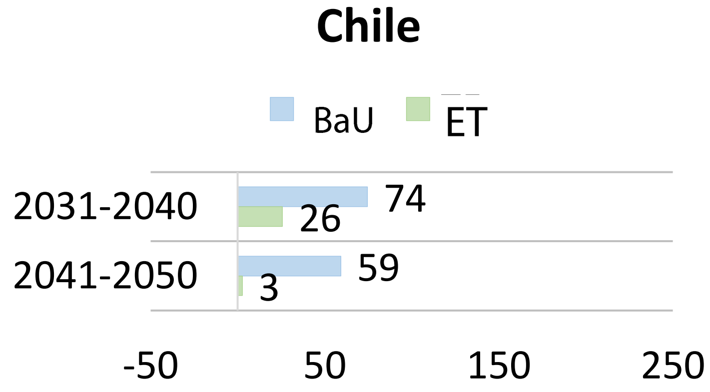
Bolivia

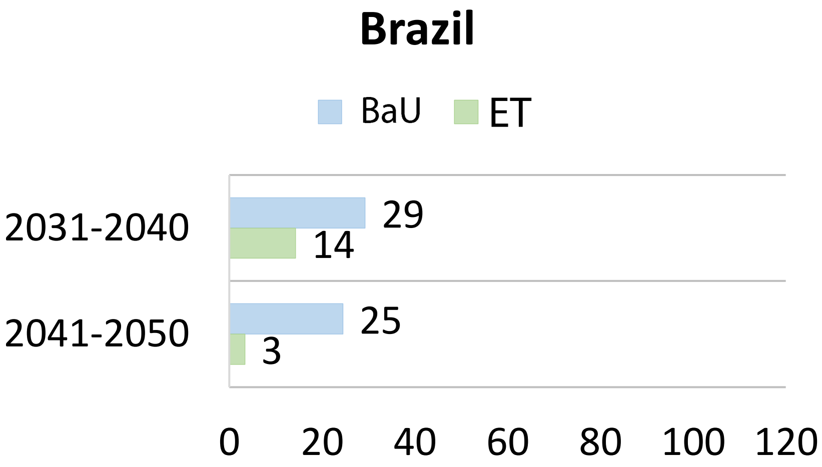


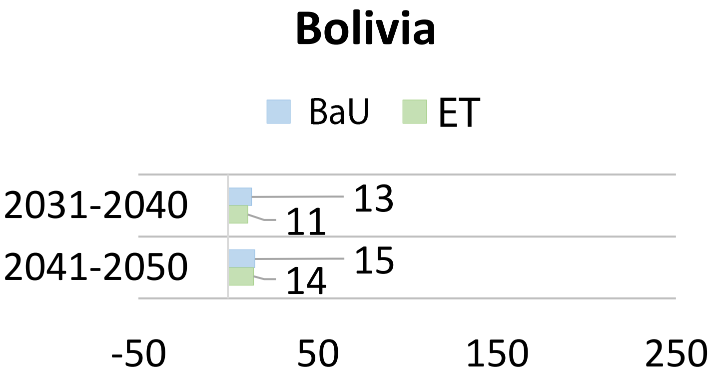
Note: Total value of each decade

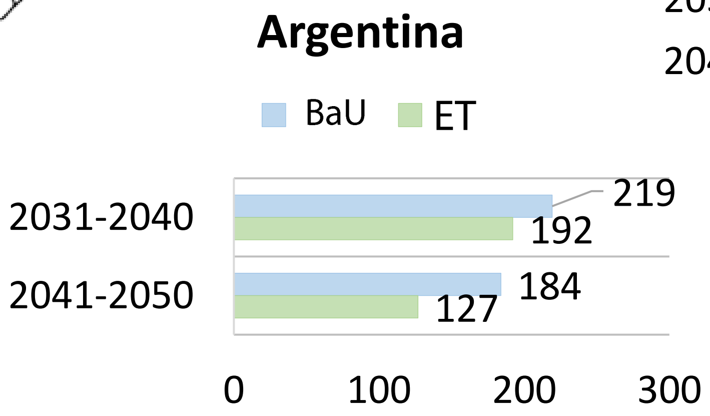
Emissions Intensity (tCO_2/GWh)











Note: Average value of the decade

Expansion Marginal Cost & *Green Premium*

Expansion Marginal Cost (EMC / LRMC)

Indicator that estimates the ratio between the variation in the **total annual cost** (investment + operation) and the variation in **electricity demand** in a country.

EMC or LRMC

$$EMC_t = \frac{Total\ Cost\ Variation\ (Investment + Operation)}{Demand\ Variation}$$

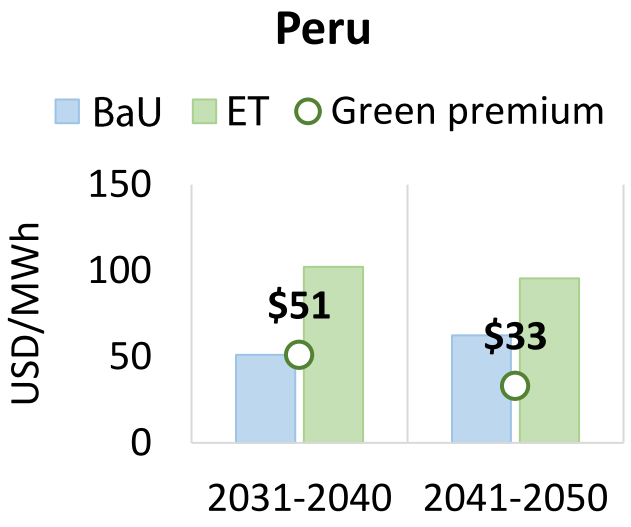
Green Premium Estimation

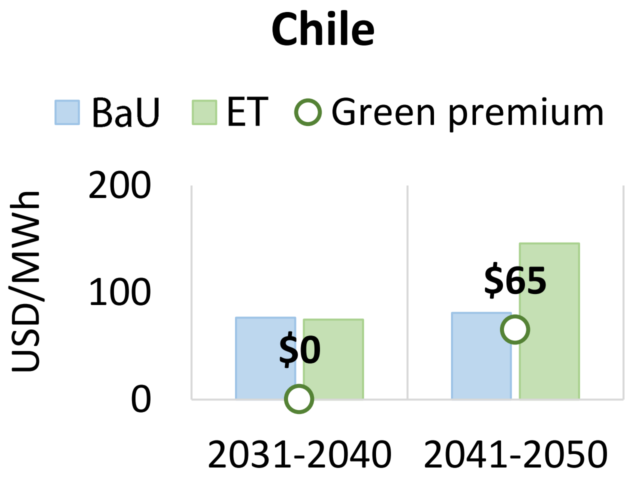
To estimate the green premium required in the transition scenario, it is proposed to consider the difference between the expansion marginal costs of both scenarios:

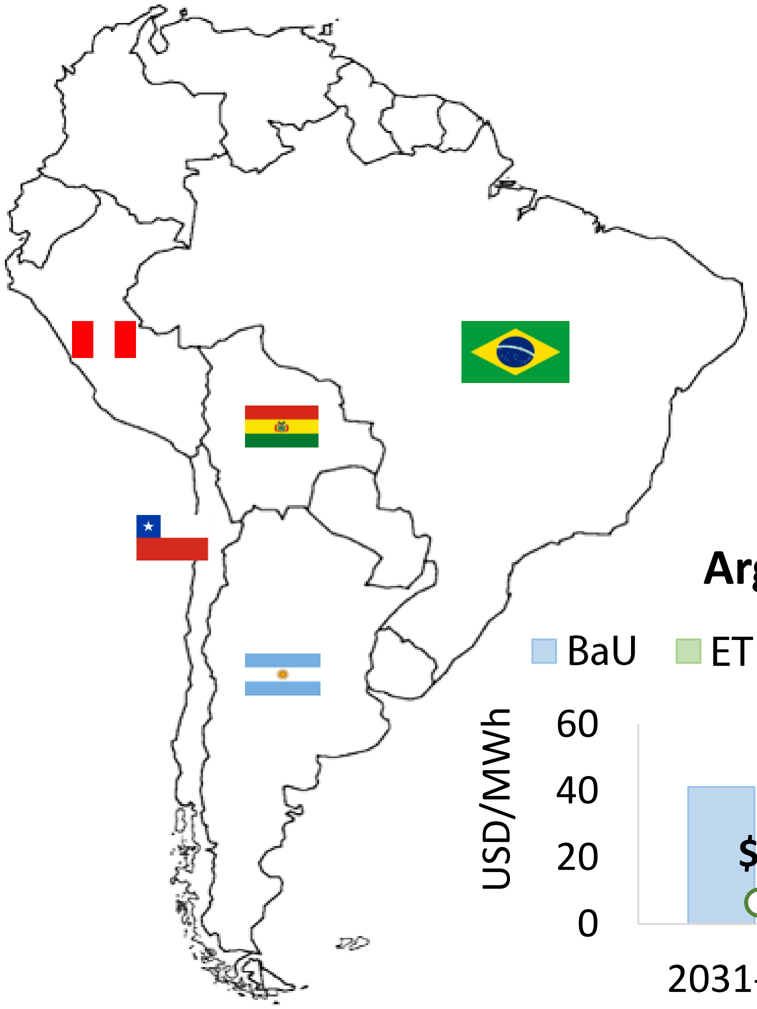
Green Premium

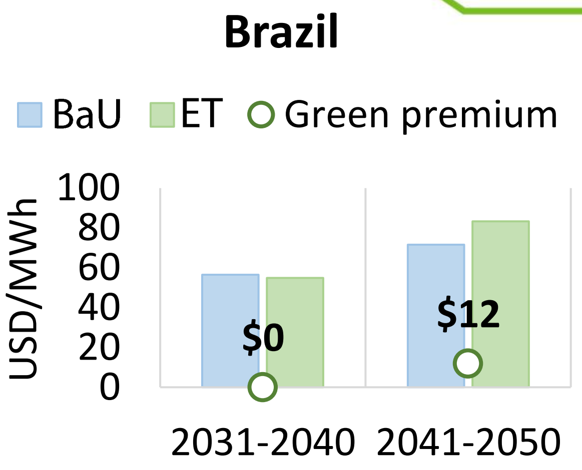
$$Green\ Premium = EMC_{ET} - EMC_{BaU}$$

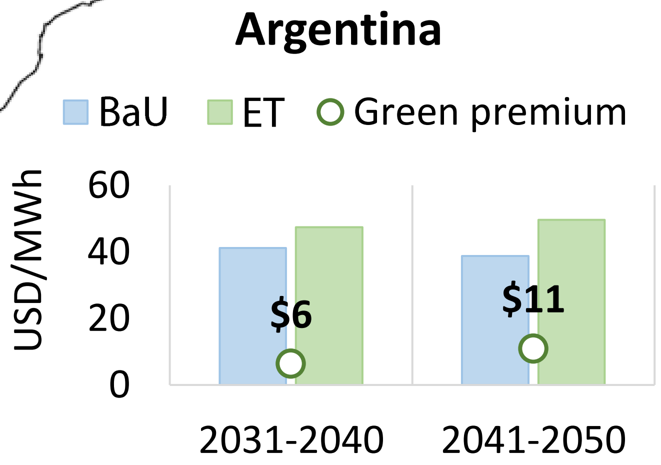
Expansion Marginal Cost (BaU vs. ET)

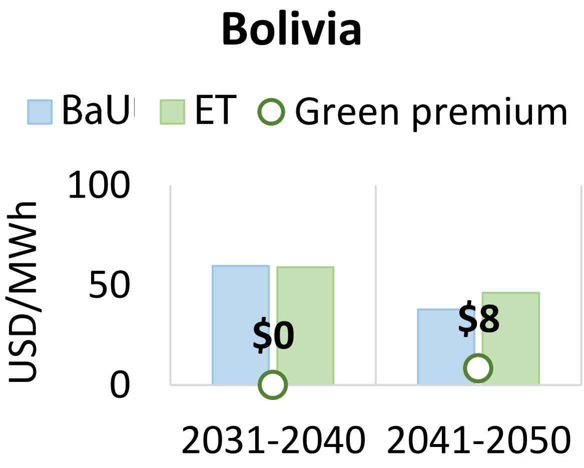












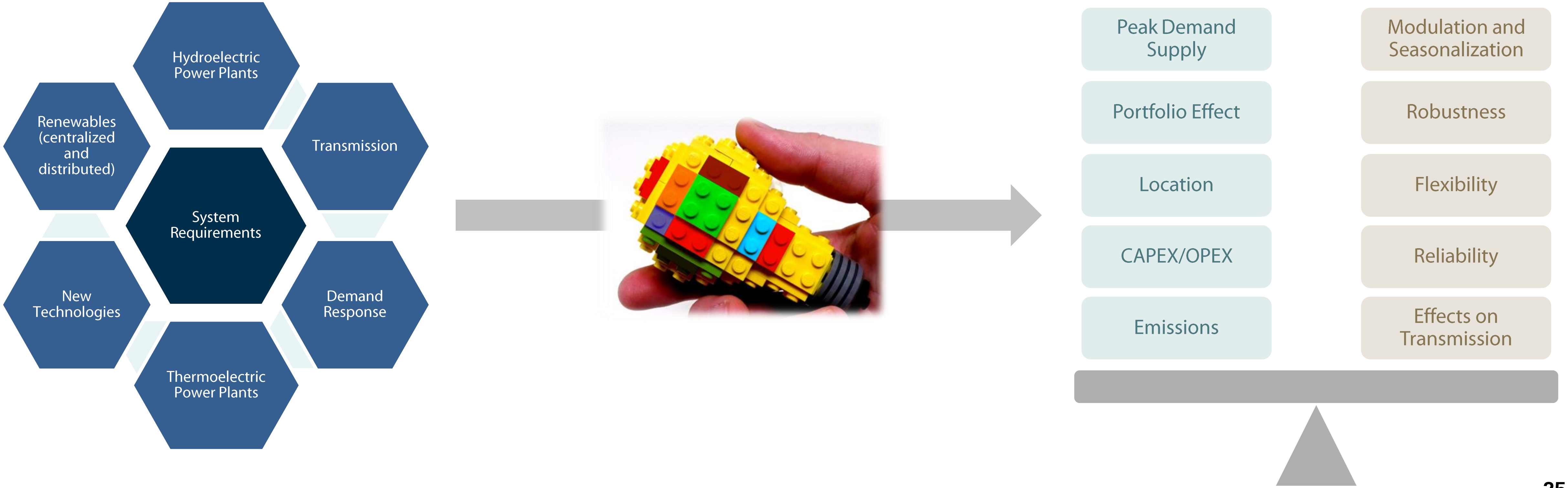
Hydro Natural gas Liquid fuels Nuclear Biogas/biomass

Note: Average value of the decade

Conclusions

Conclusions

- Each technology is a piece of the “puzzle” of the energy transition / decarbonization process
- The cost of the energy transition will be determined by the initial conditions of each country and the goals adopted by each one



THANK YOU!

Any questions?

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