

Modeling Net-Zero Emissions in the Global South: A Case Study of Pakistan



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Motivation & Context: The Global South

- **Balancing Act:** Meet rapid development and energy needs while achieving Net-Zero.
- **Major Hurdles:** Navigating import reliance, high fuel price volatility, and financial stress for green investment.

Pakistan: A Crucial Case Study

Challenge Area	Key Data Point	Implication for Modeling
Extreme Vulnerability	Among the Top 10 globally (e.g., 2022 floods cost >\$30B).	Requires resilient infrastructure pathway.
System Insecurity	power system reliance on imported fuels.	Mandates energy security diversification.
Infrastructure Stress	T&D losses; 6-8% annual demand growth.	VRE integration must account for weak grid.
Ambitious Targets	Pledged 30% GHG reduction by 2030 (Conditional NDC).	Requires aggressive, least-cost decarbonization.

Policy Ambition & Climate Goals

National Commitments (NDC 2021)

- **Goal:** Reduce projected emissions by **50% by 2030**
- **Long-Term Vision:** Transition towards **Net-Zero by 2050**

Policy Framework

Renewable Energy (ARE Policy 2019)

Electric Vehicles (NEV Policy 2019)

Energy Efficiency (NEECA)

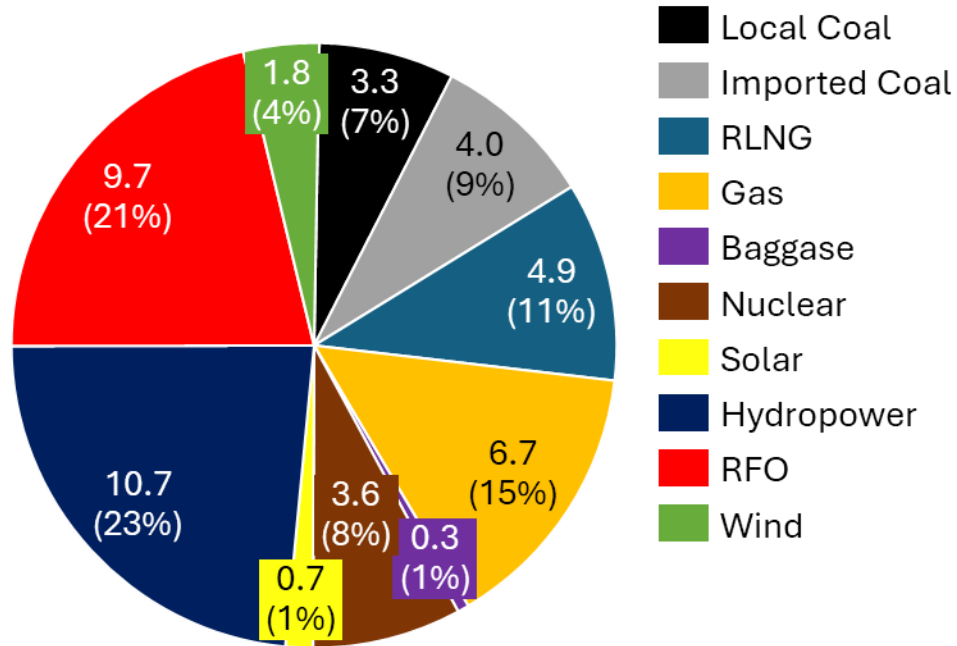
Key Targets Modeled

Achieve **60% Clean Energy** in generation mix by 2030 (30% RE + 30% Hydro).

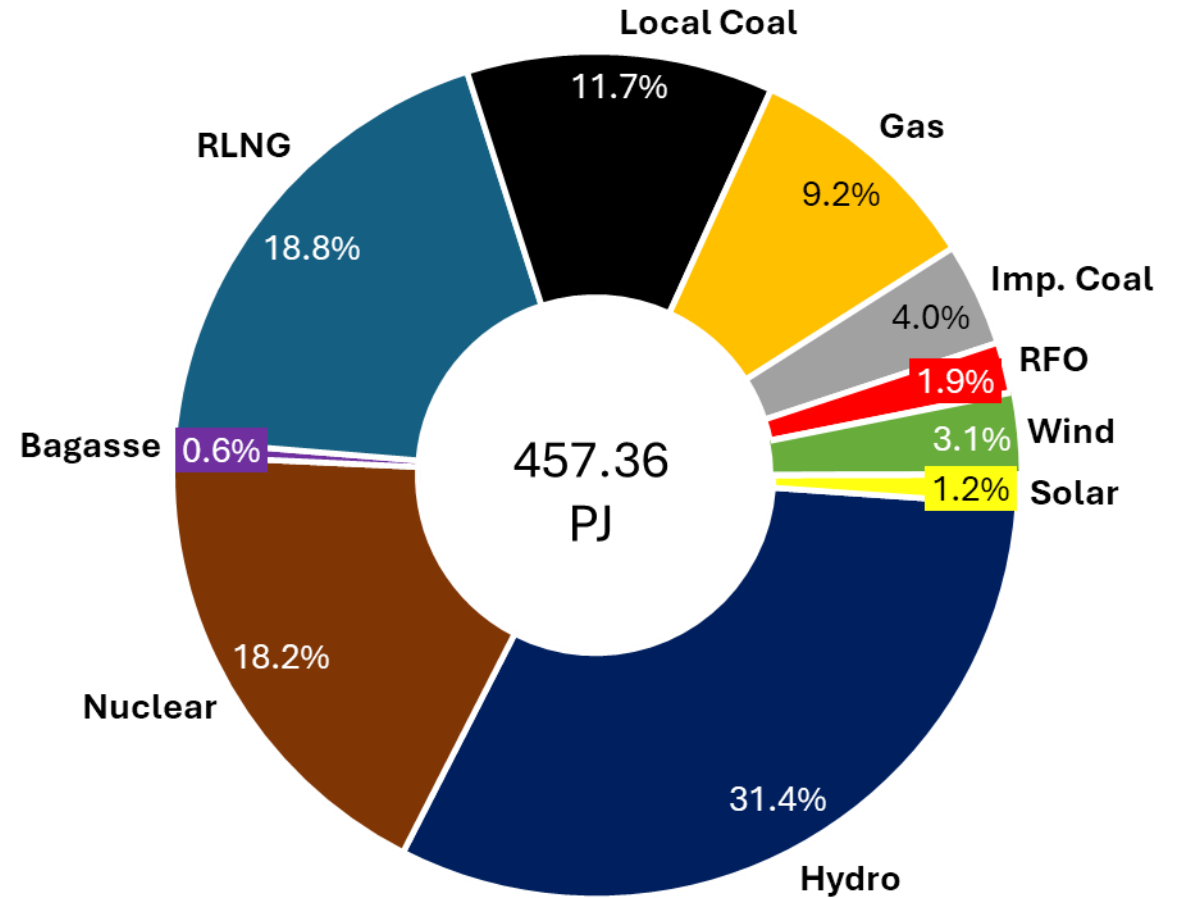
Target **30% EV share** in new car sales by 2030; **90% by 2040**.

Mandated **1.5% annual improvement** in energy intensity across industrial & residential sectors.

Power sector context

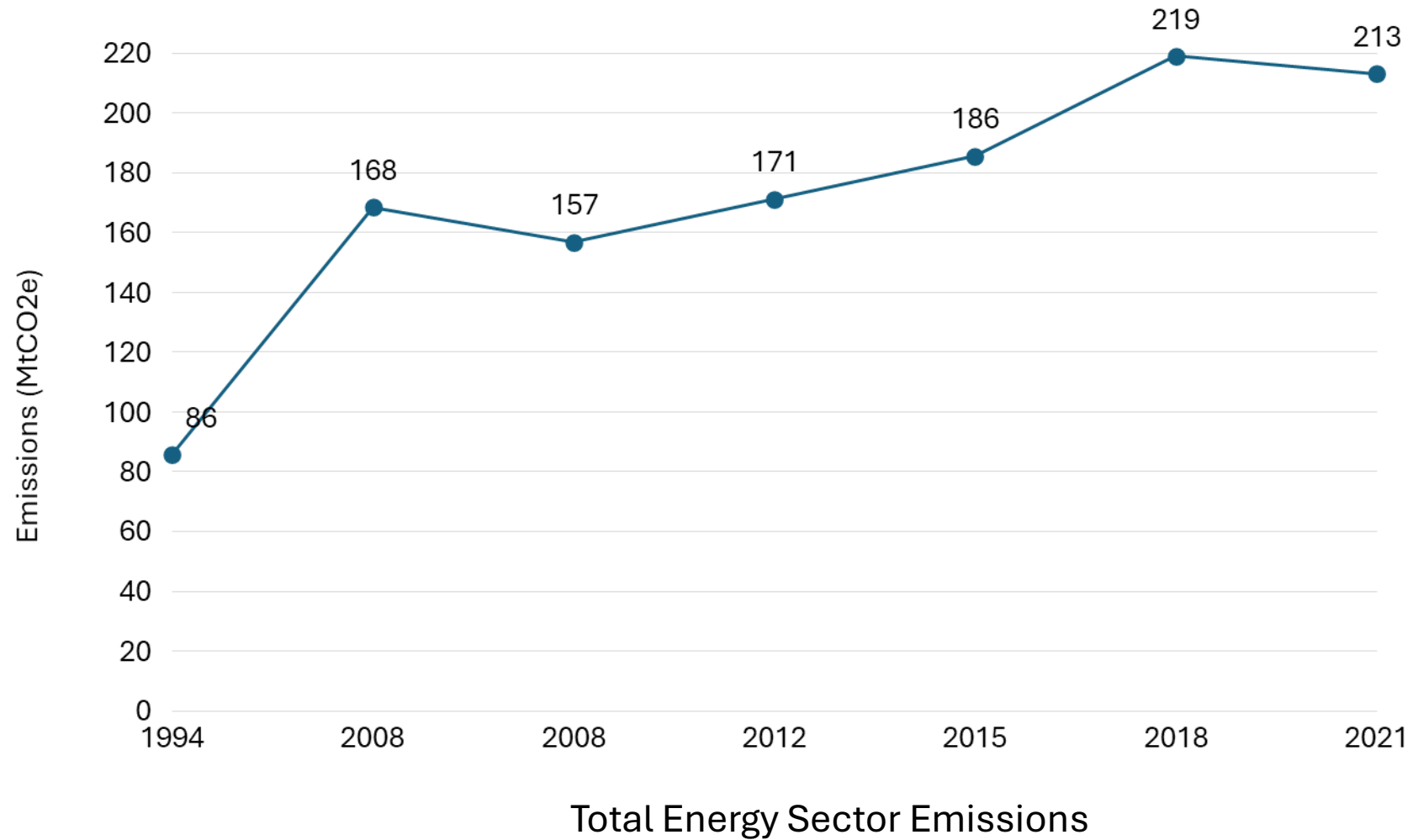


Installed Capacity GW



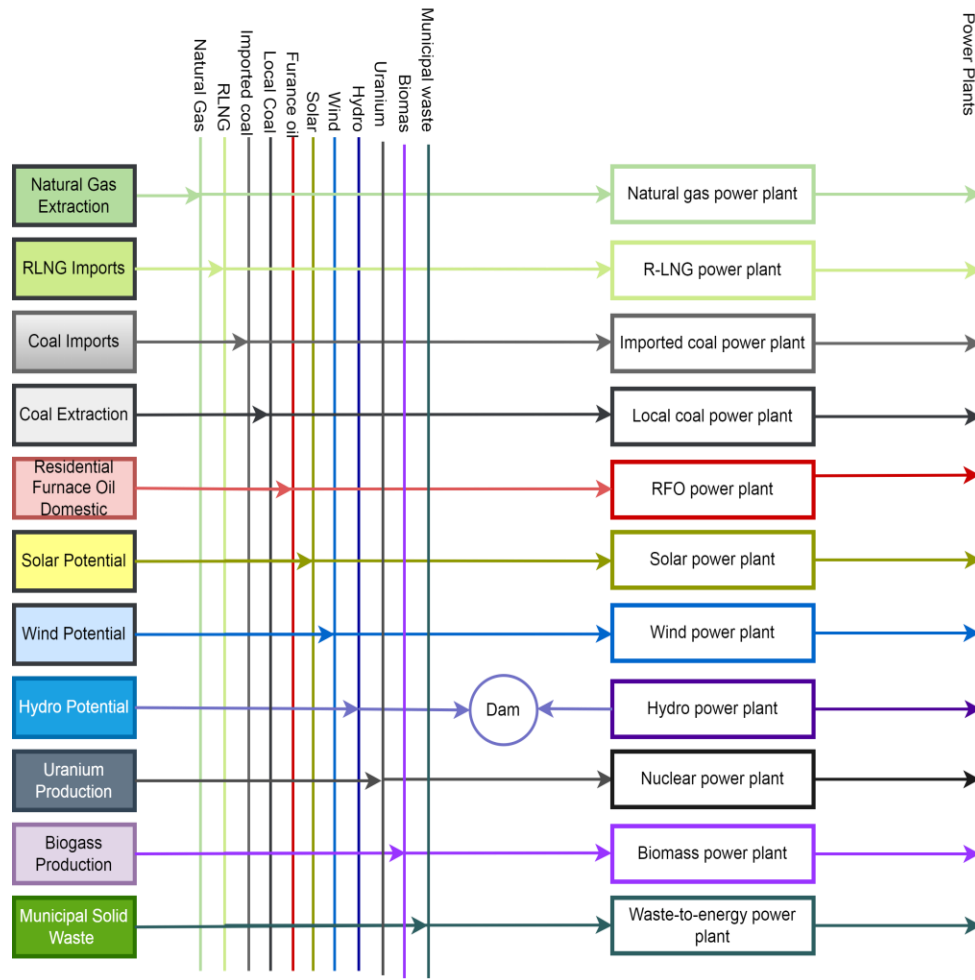
Total Energy Generation

Energy GHG Emissions

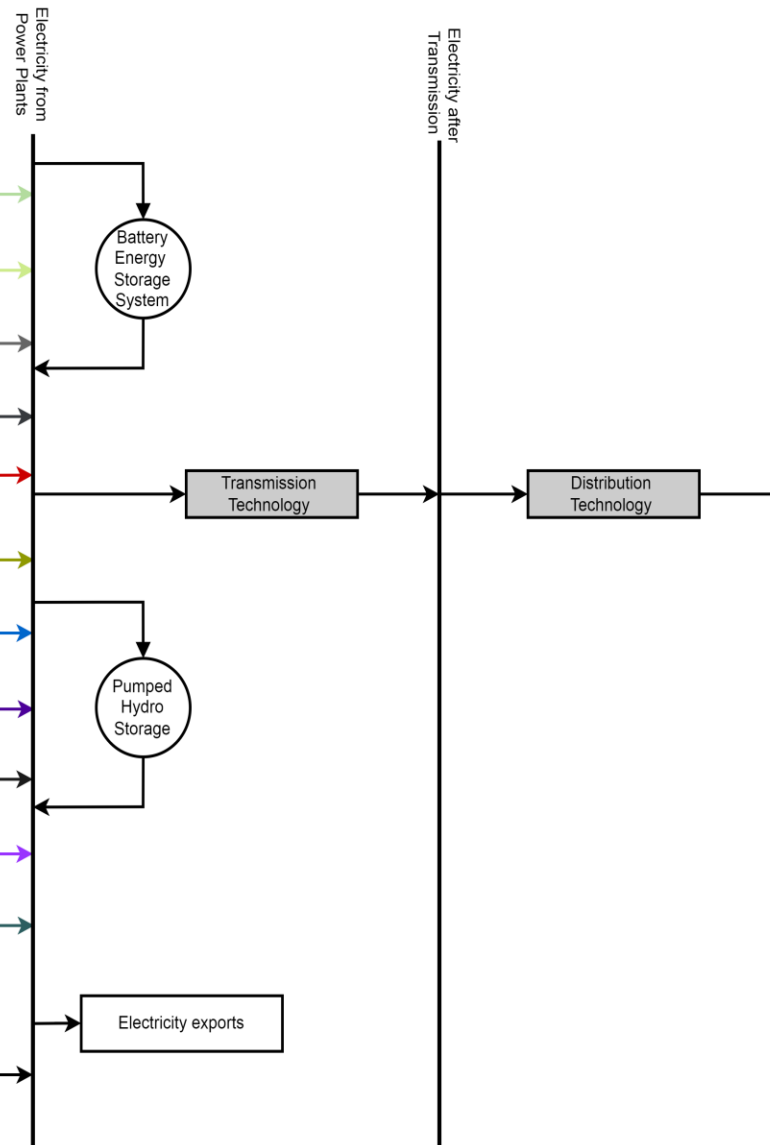


Reference energy system

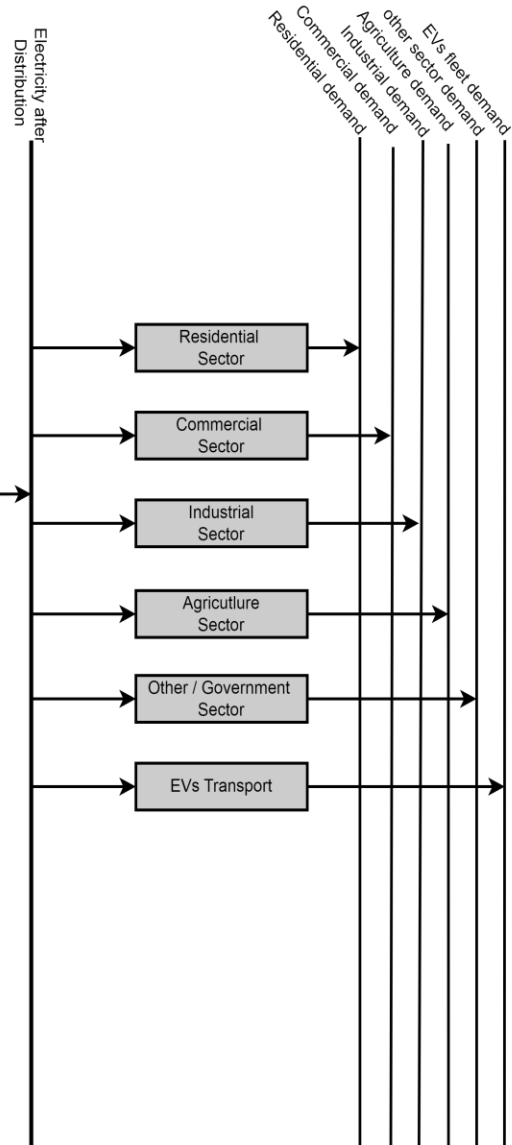
Primary Commodities



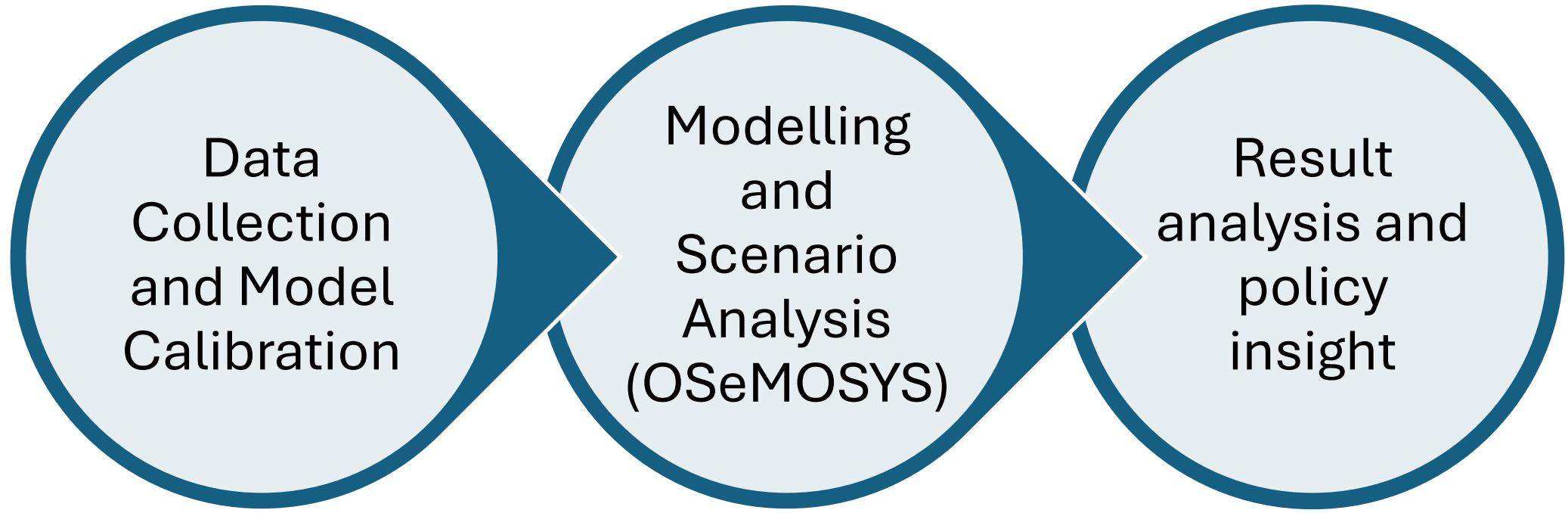
Secondary Commodities



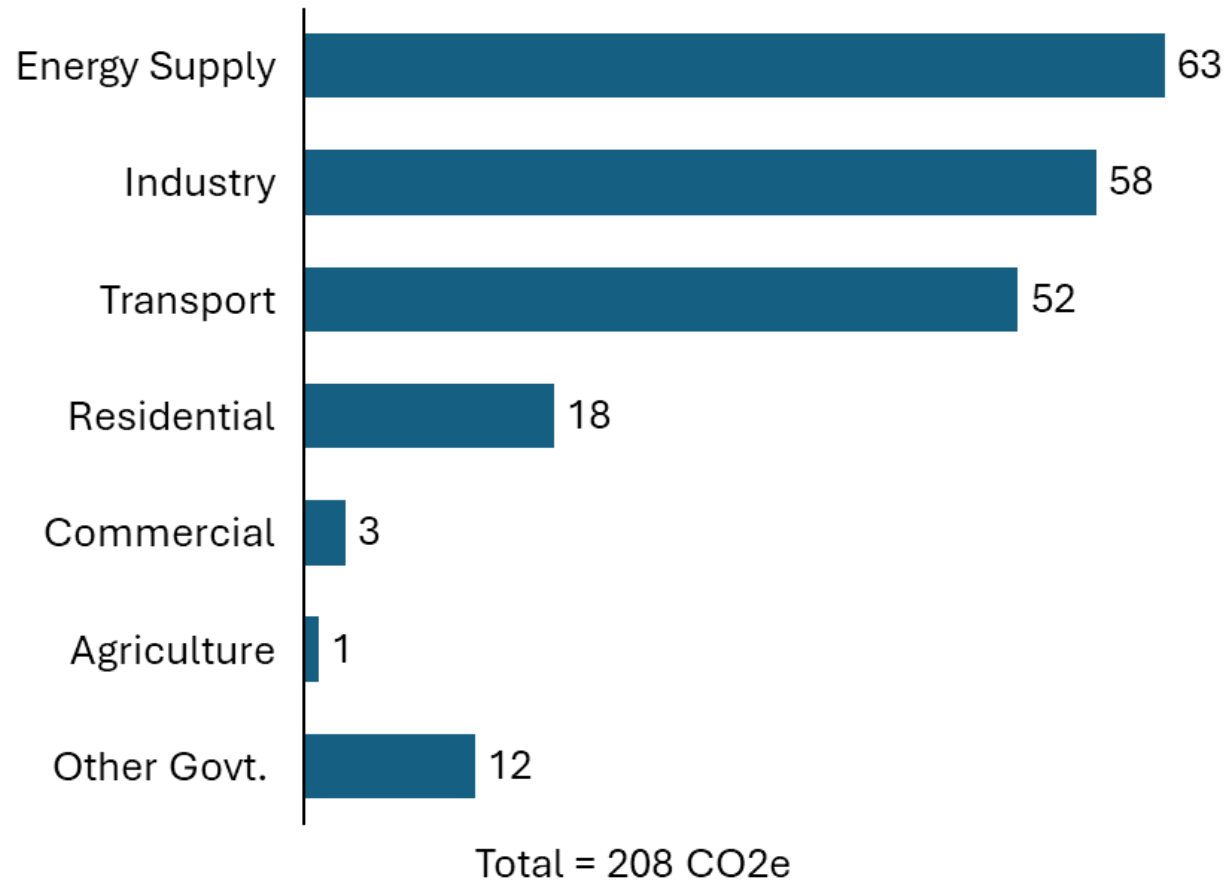
Final Energy Demands



Methodology



Model Calibration



Energy modelling tools cannot be appropriately validated; the models are calibrated by checking the consistency of model results concerning a past or present state using a reference year.

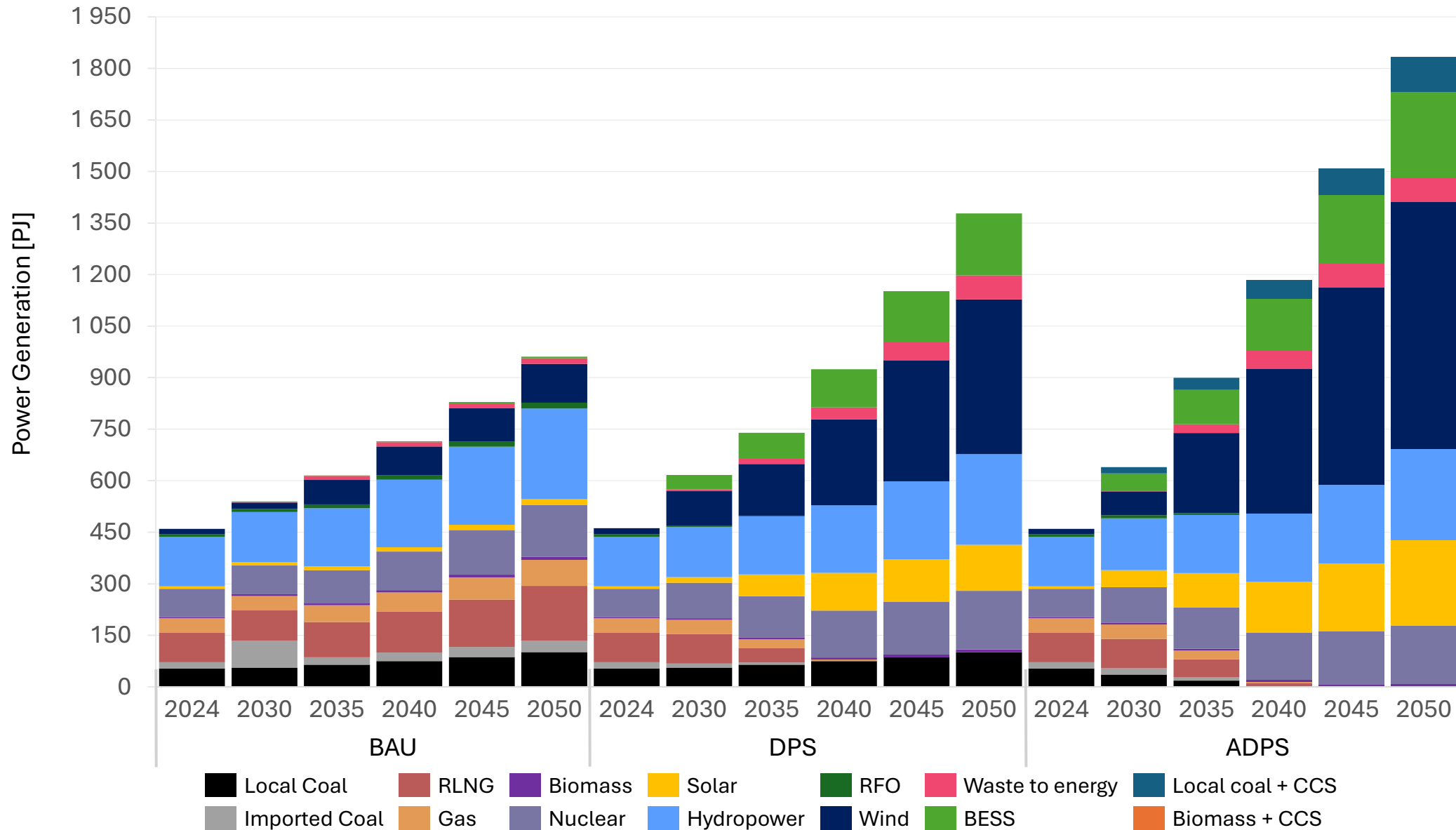
We compared the model results and the end-use energy reported by the Pakistan energy balance in 2024. The model outcome was 208 MtCO₂e and the reference value was 213 MtCO₂e , representing a relative error of 5.6%.

Scenario Analysis

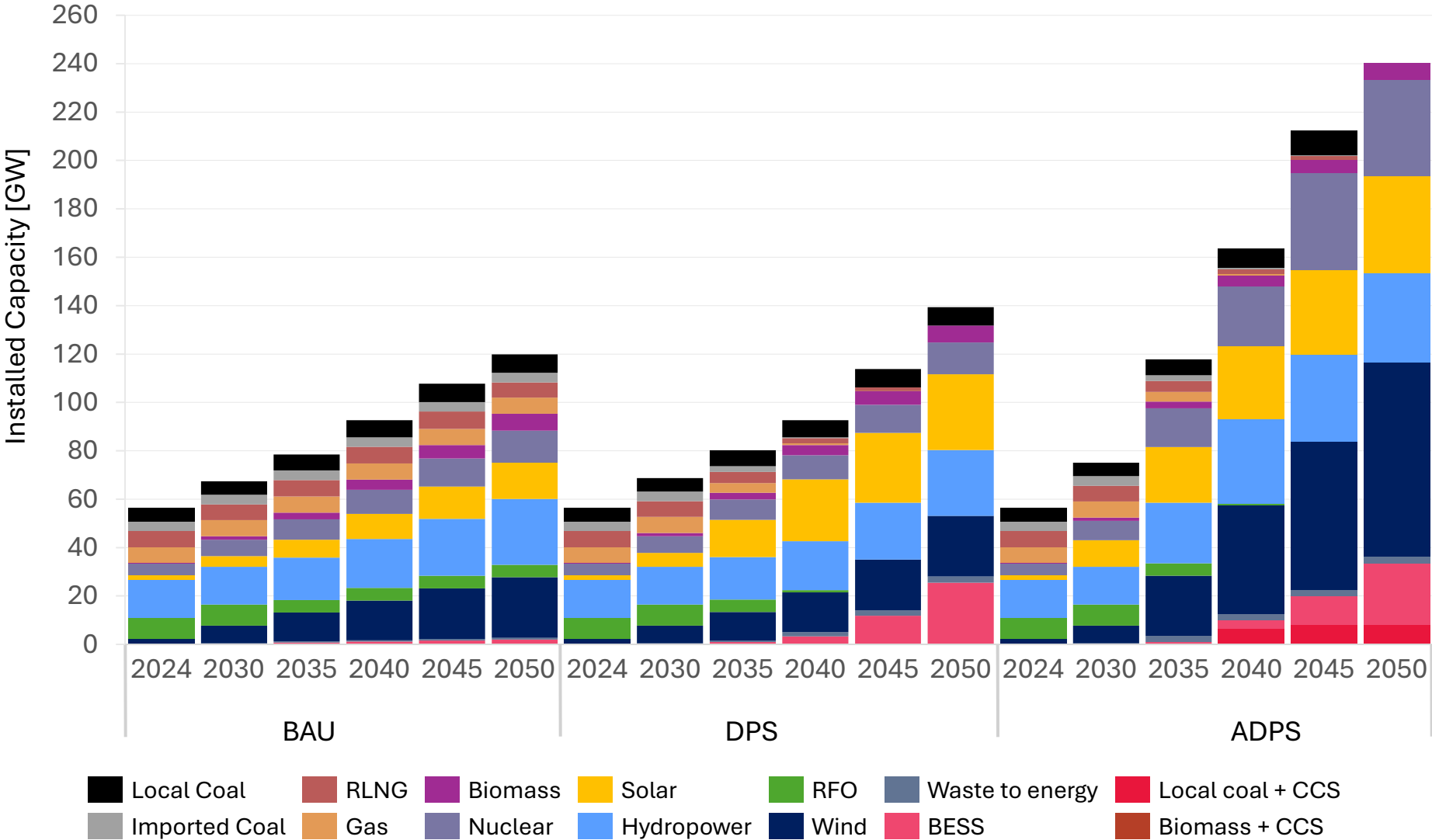
Business-as-usual	Baseline for comparison.	No significant policies to modify the current energy system.	Demand supplied keeping current technology proportions.	BAU
Decarbonization pathway	Most cost-efficient to meet NDC 3.0 targets.	CCS is attractive due to domestic coal/gas.	CCS technologies available from 2030 . Emissions limit by 2050: 37 MtCO_{2e} .	DPS
Alternative decarbonization pathway	Power sector emissions cap	Must retire old, polluting RFO, NGS, and most local coal plants. Uses Local Coal CCG (super-efficient) for remaining coal.	Emissions limit by 2050: 2 MtCO_{2e} .	ADPS



Energy Generation [PJ]

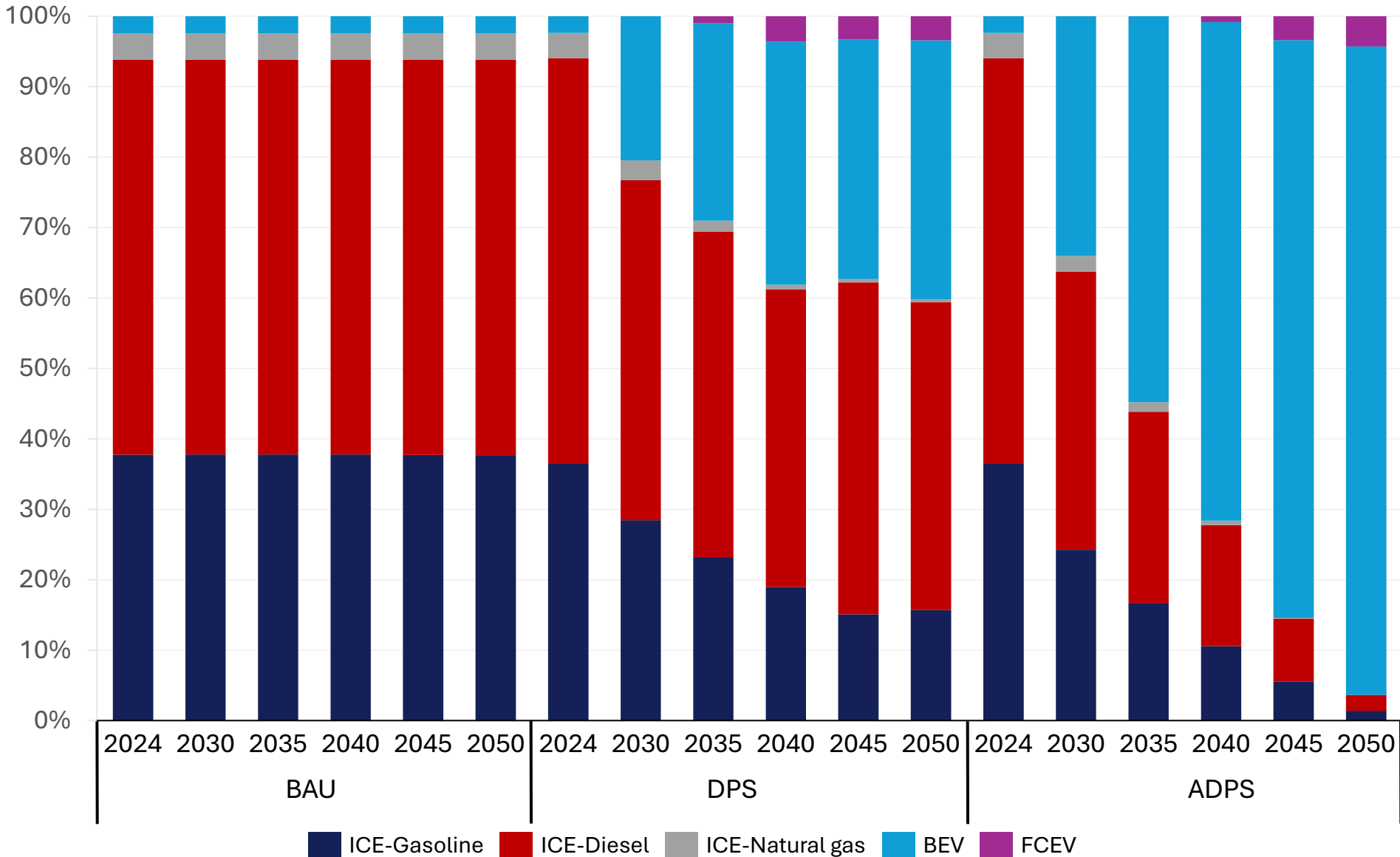


Installed Capacity [GW]



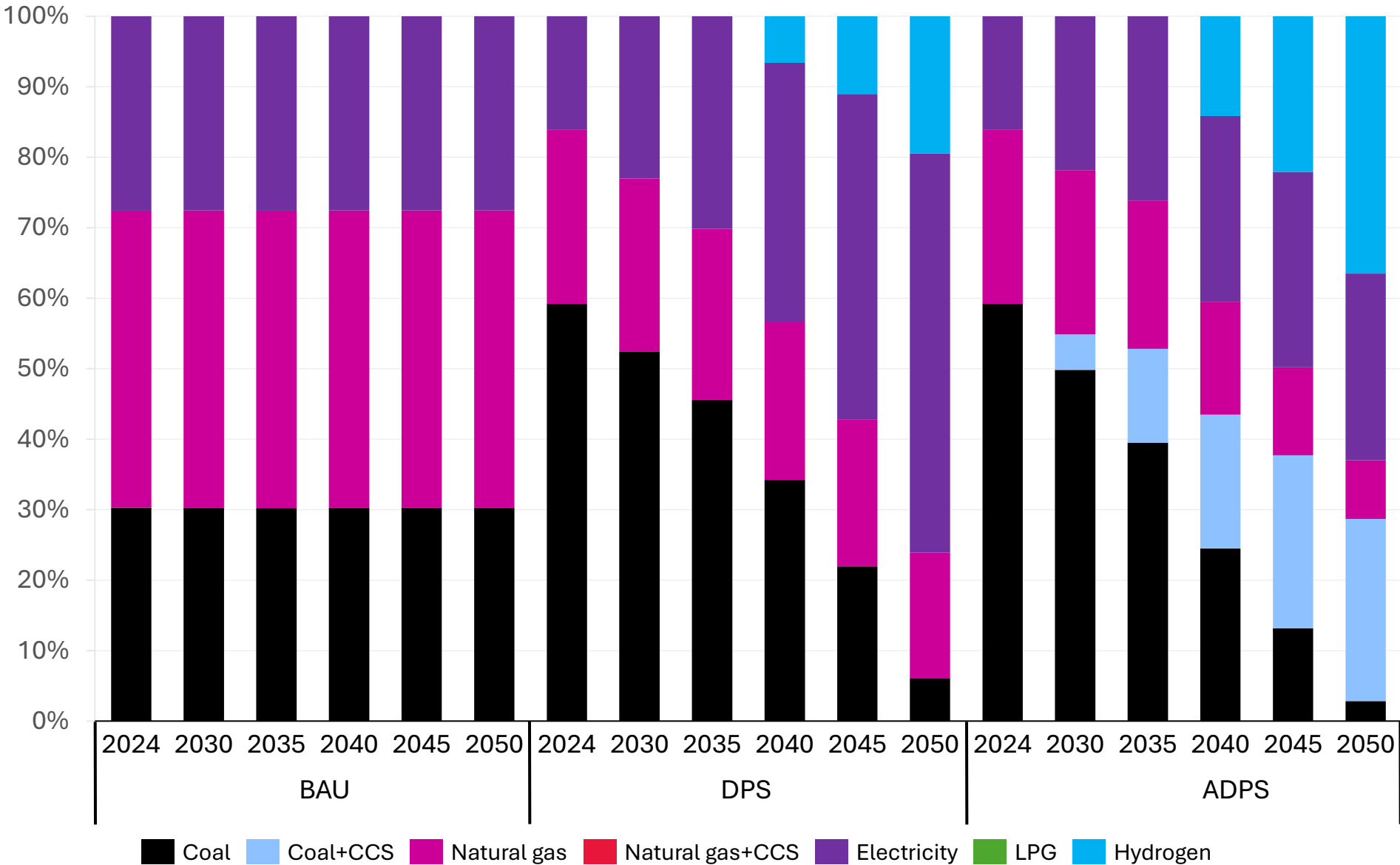
Installed Capacity by Technology

a) Road Transport Sector



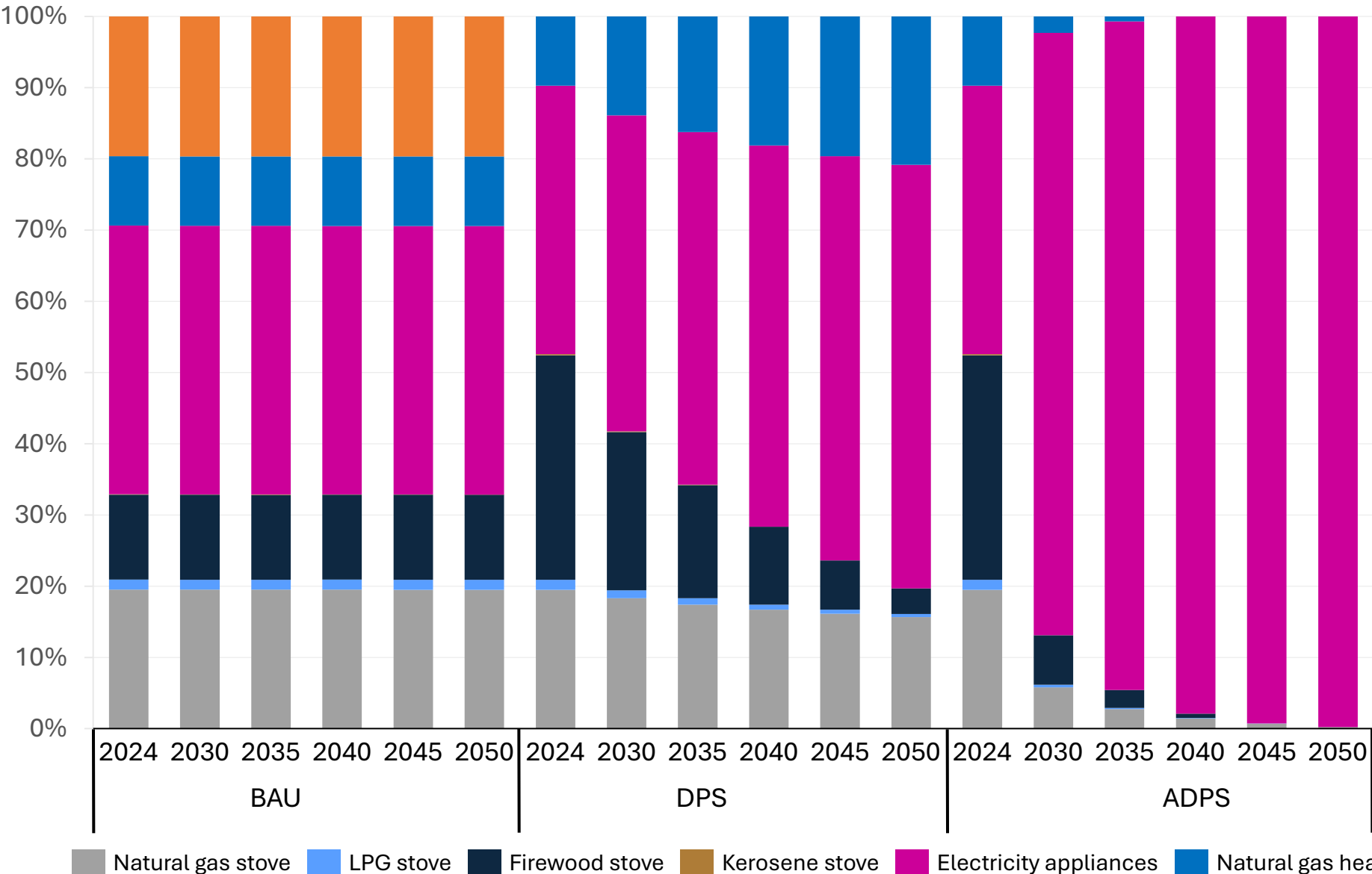
Installed Capacity by Technology

b) Industry Sector



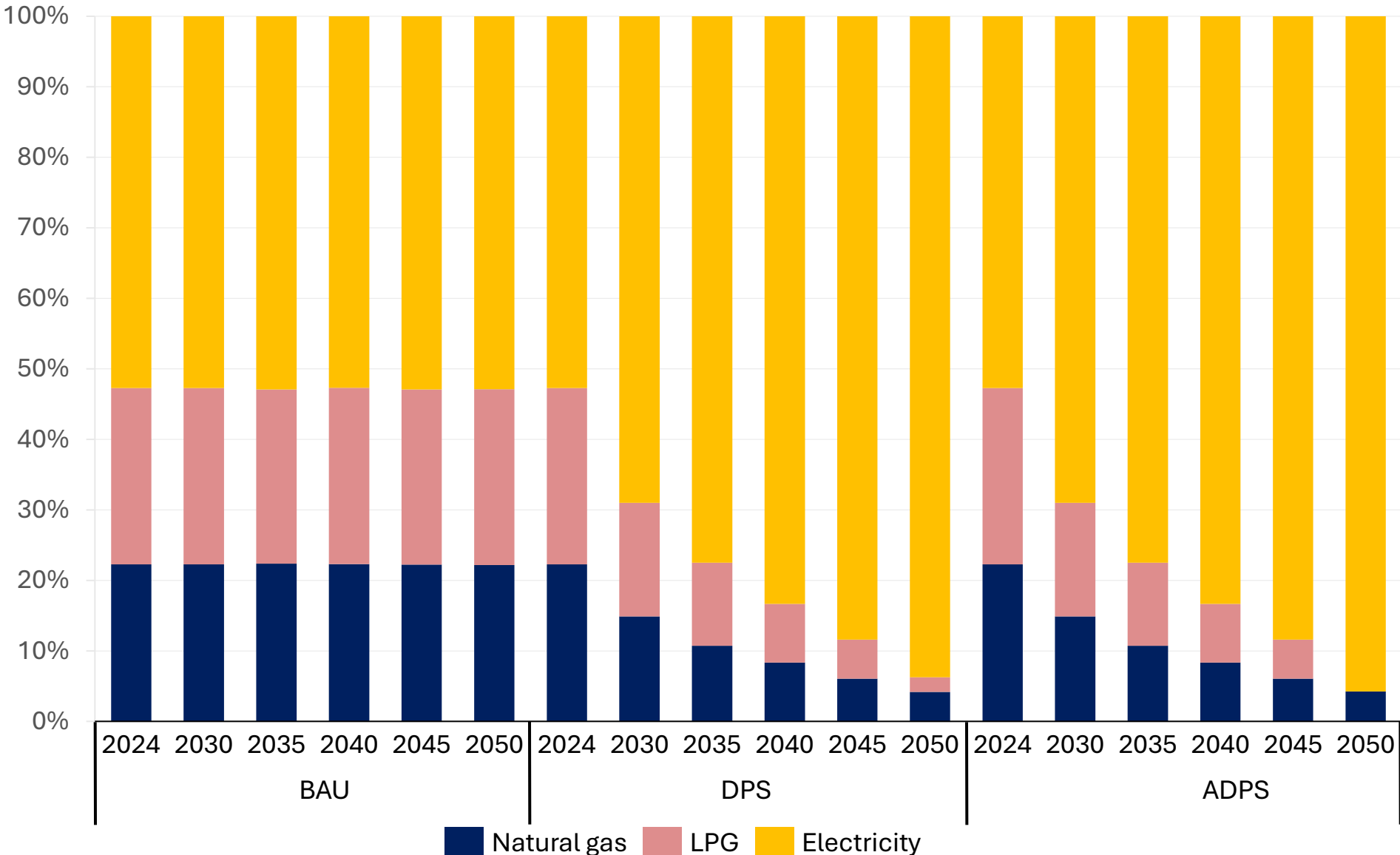
Installed Capacity by Technology

c) Residential Sector

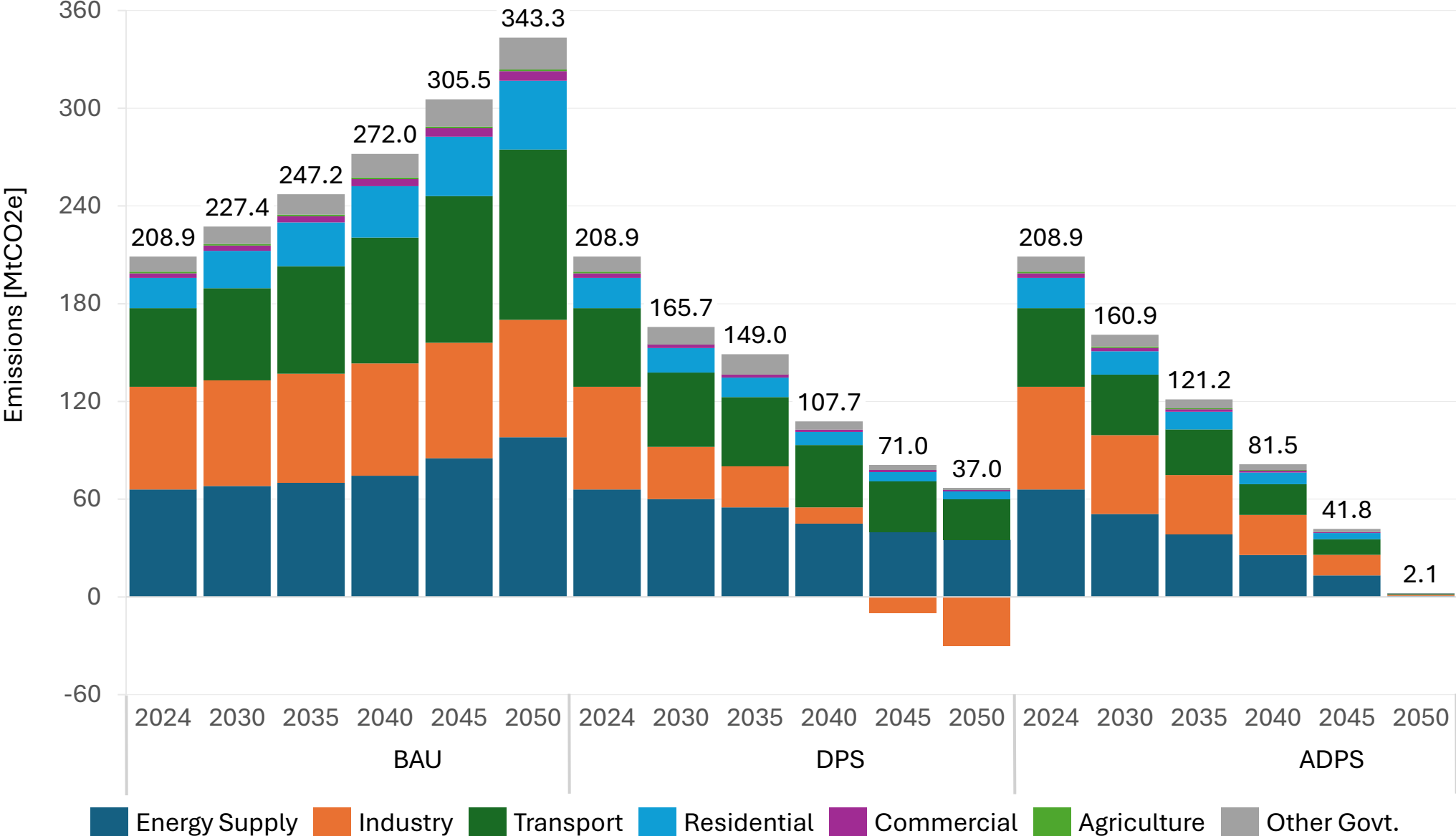


Installed Capacity by Technology

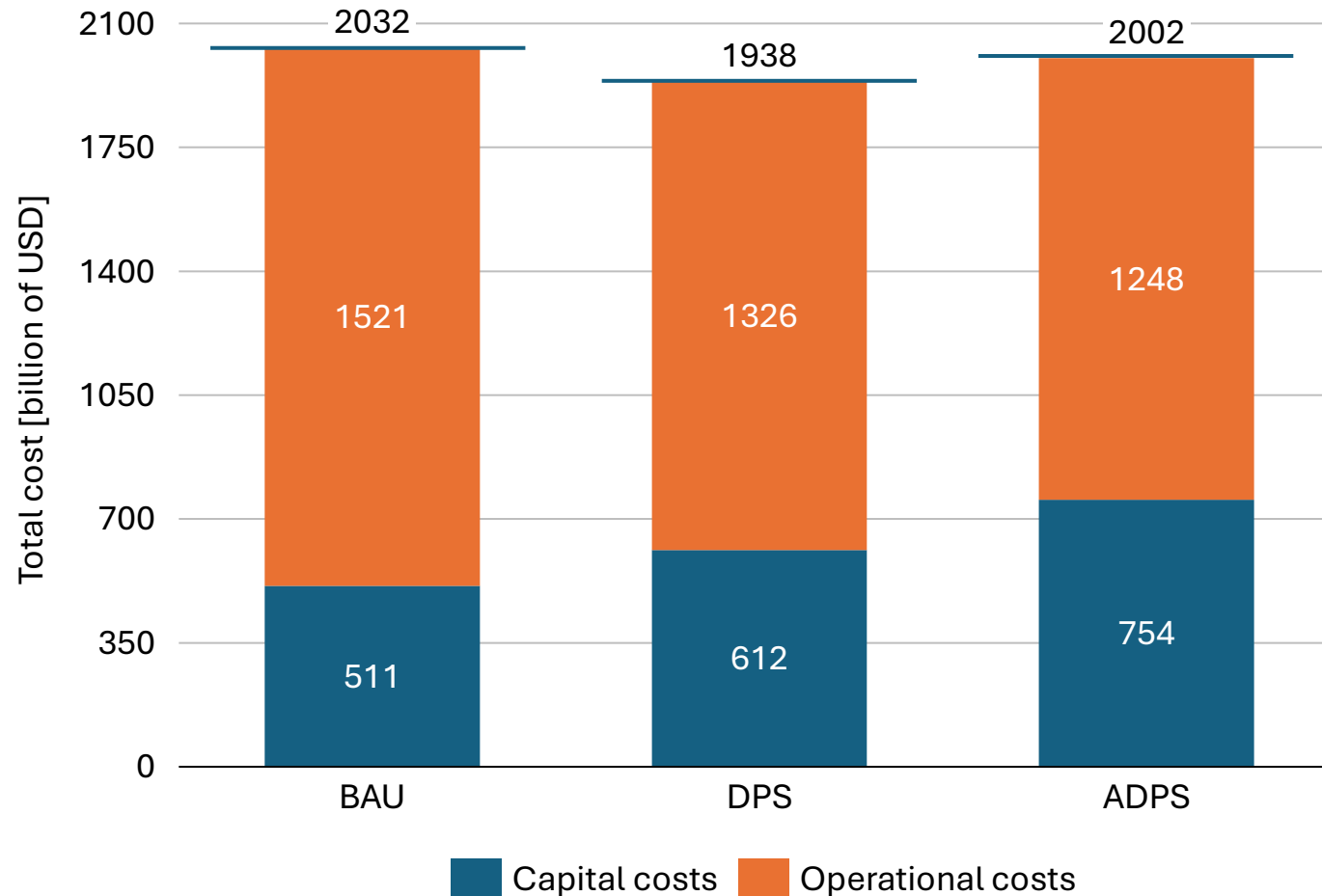
d) Commercial and public sector



Annual GHG emissions by sector



Cost comparison by scenario



Key findings

BAU: Contribute by imports of petroleum products, RLNG, as its capacity is not sufficient.

DPS: Invest in carbon capture COACCS to reduce emissions. Cheaper in terms of $\$/tCO_2$

removed

ADPS: Cost of electrification in transportation is high

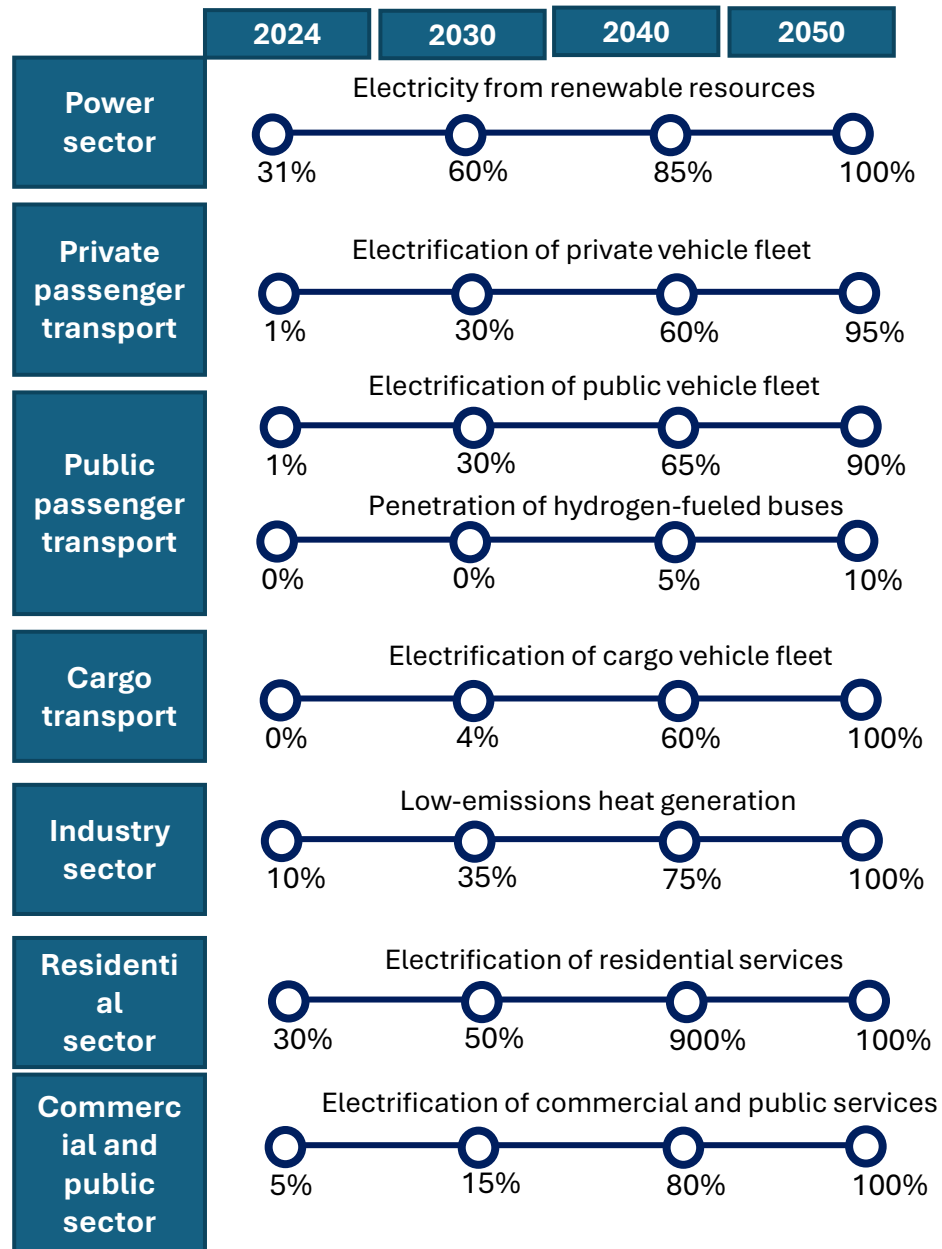
Total Cost per GDP

BAU: **5.42×** of GDP 2024

RES: **5.17×** of GDP 2024

CTS: **5.34×** of GDP 2024

Sectoral targets for an effective decarbonization pathway in Pakistan



Key findings

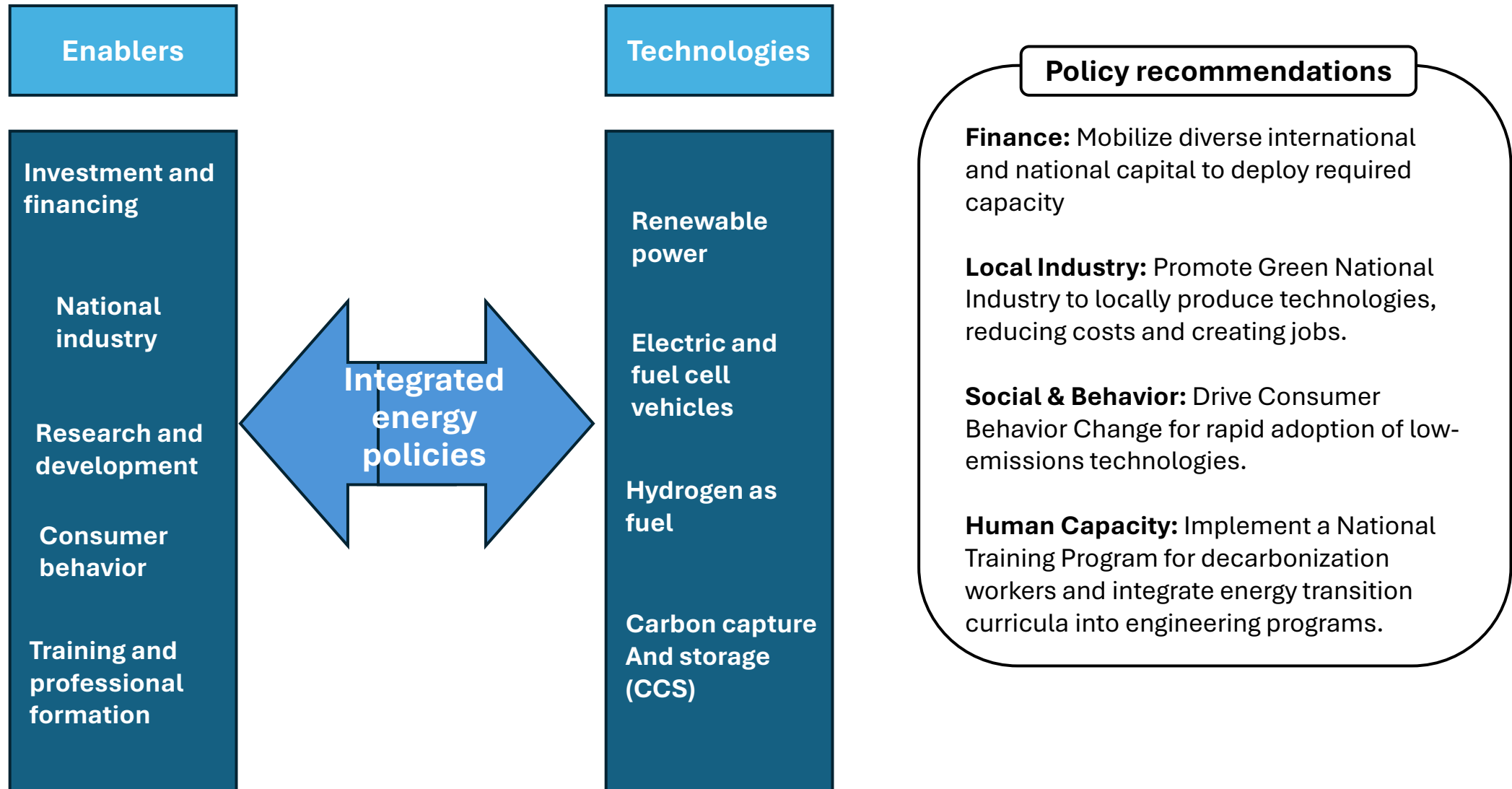
Power Sector: 100% Renewable Grid by 2050 (Must hit 60% clean energy by 2030).

Mass Electrification: Requires 100% electrification of all passenger transport, residential, and commercial services by 2050.

Industry Transformation: 75% of industrial heat must switch to low-emissions sources (electricity/H₂) by 2050.

Timeline Urgency: Requires immediate, high-volume VRE deployment and grid hardening to meet the 2030 NDC target.

Conclusion



Thank you

Any Questions, Feedback, Suggestions



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