8th AIEE Energy Symposium
Current and Future Challenges to Energy Security
Padova, 28-30 November 2024

A soft-link TIMES Italia-Plexos approach to develop Italian transition pathway scenarios

Marco Agostini
PhD in Fusion Science and Engineering

Umberto Giuliani, Consorzio RFX
Francesco Gracceva, ENEA
Chiara Bustreo, Consorzio RFX
Bruno Baldissara, **Vittoria Battaglia**, **Livio De Chicchis**, ENEA
Giuseppe Zollino, University of Padua, Department of Industrial Engineering

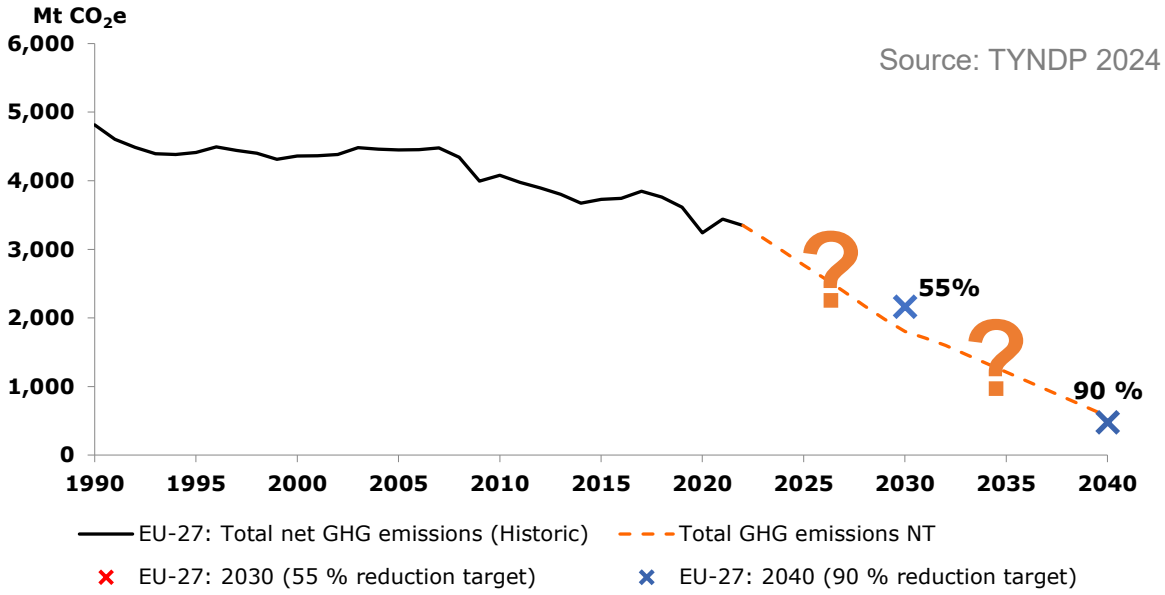
Research question

Transition pathway scenarios

Insights into the long-term impacts of energy policy choices by modelling potential system evolutions over several decades.

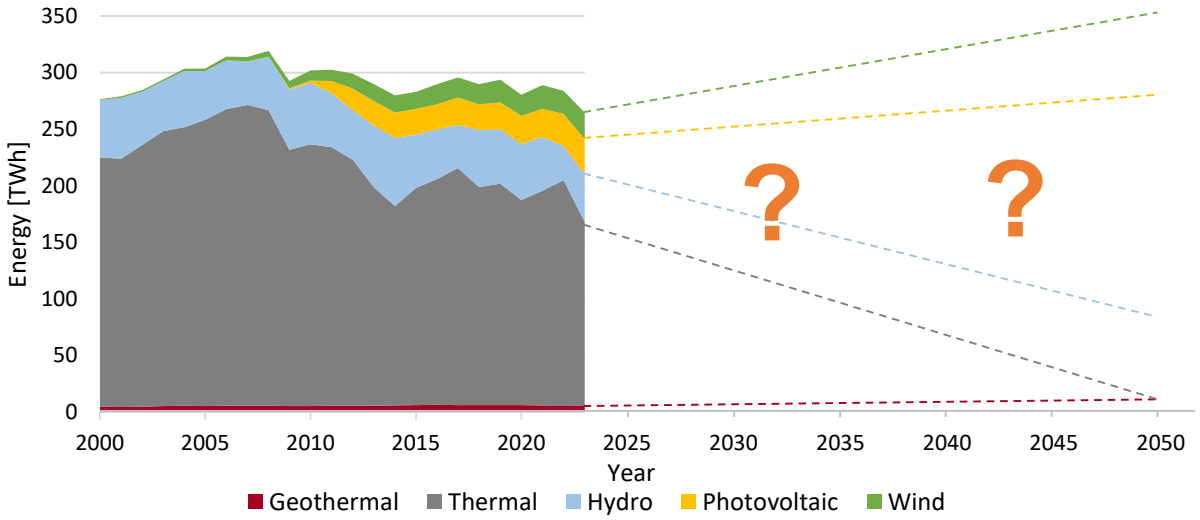
Which is the cost optimal energy mix throughout the years?

Which is the optimal CO2 decrease trajectory?



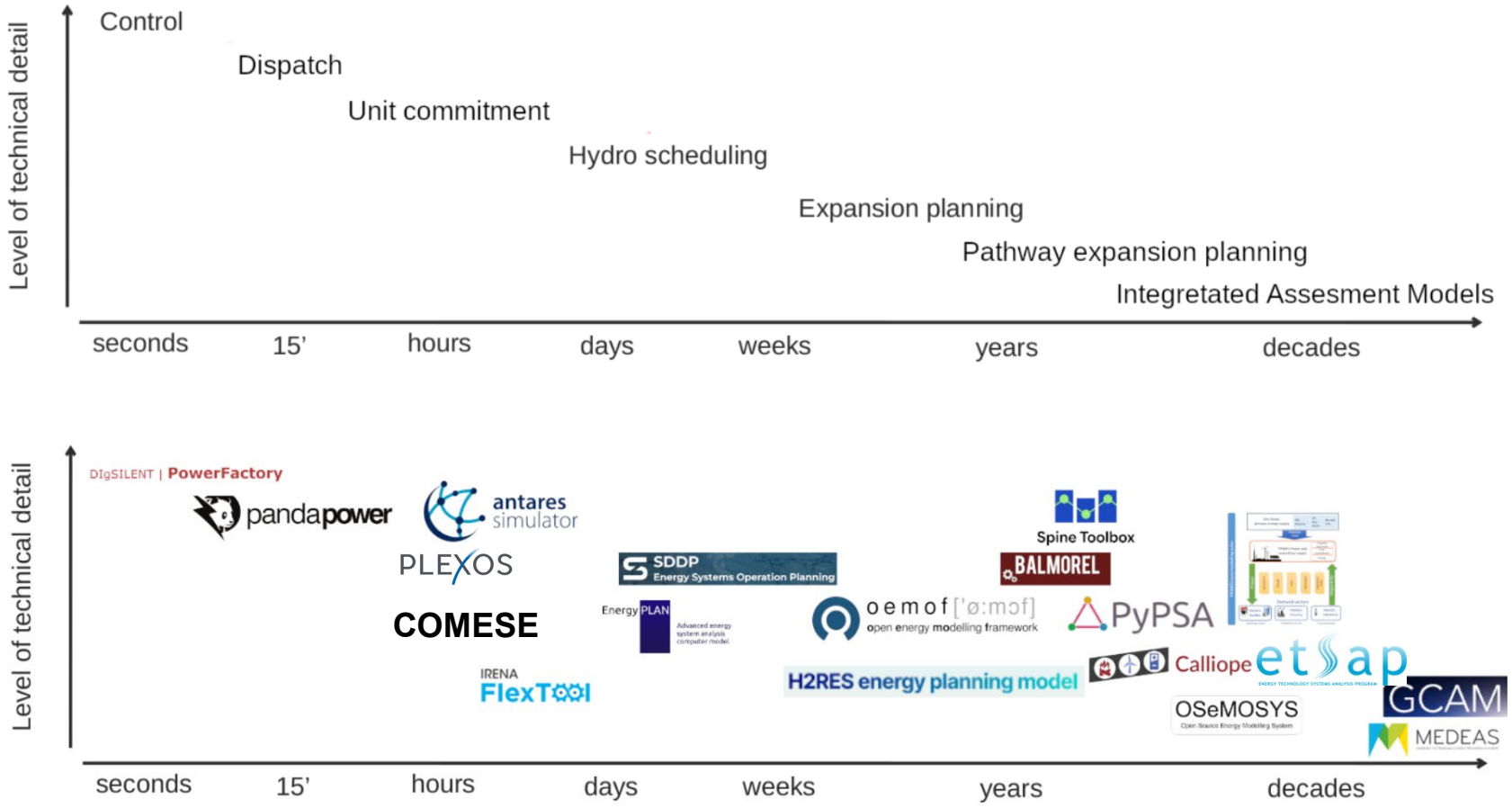
BUT

the **computational complexity** of these models often necessitates simplifications that can compromise their accuracy and reliability



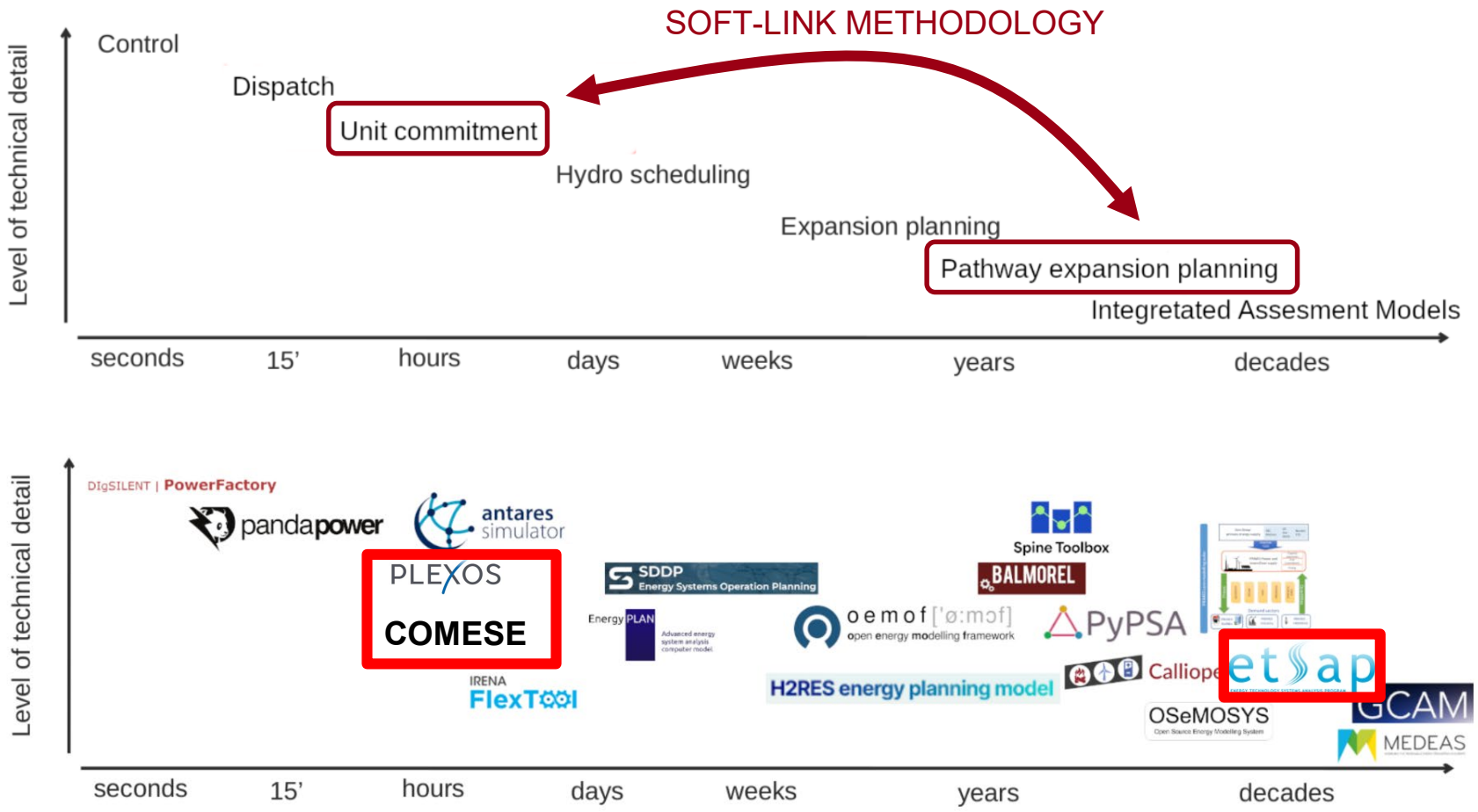
Research question

Which is the most suitable time/technical resolution and horizon for transition pathway scenarios?



Research question

Which is the most suitable time/technical resolution and horizon for transition pathway scenarios?



Methodology

Soft-link methodology that integrates the multi-year analysis capabilities of TIMES Italia with the detailed technical analysis of PLEXOS

TIMES ITALIA

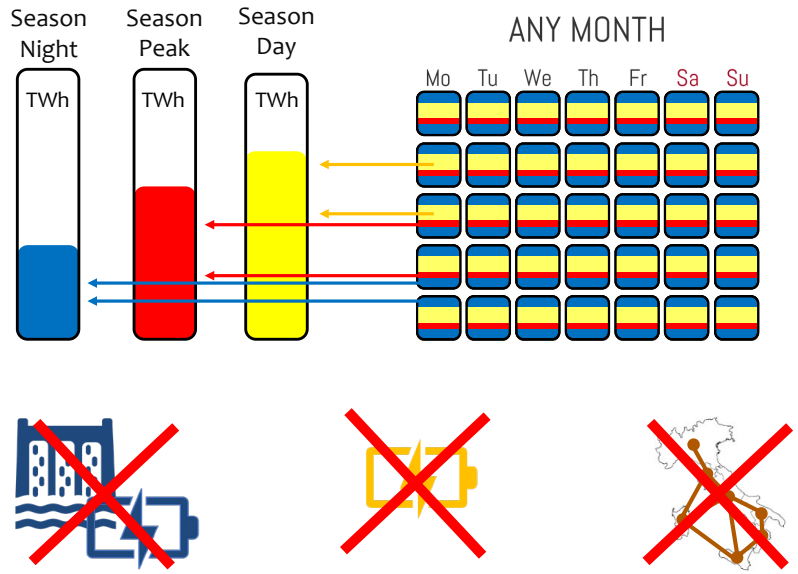
Technology-rich models of the whole energy system

Useful tools to assess the **technical** and **economic** impacts of alternative strategies over very long term horizons

Typically optimizes 20-50 or more years into future

Identifies most cost-effective mix of resource use and technology deployment over time under varying constraints and alternate futures

Limitations in terms of temporal resolution and technical detail to characterize the power system.



Methodology

Soft-link methodology that integrates the multi-year analysis capabilities of TIMES Italia with the detailed technical analysis of PLEXOS

PLEXOS

Commercial dispatch model and capacity expansion model

Hourly operation of the power system

High geographical resolution, simulates the entire European power system

Typically optimizes over 1 year or less

Optimize the dispatchable power plants and storage systems operation to meet demand at the lowest system cost

Limitations in terms of computational burden

⇩

Not suitable to optimize over a several decades long optimization horizon

Requires exogenous final demand

Methodology

Soft-link methodology that integrates the multi-year analysis capabilities of TIMES Italia with the detailed technical analysis of PLEXOS

COMESE

Dispatch model developed at Consorzio RFX

Hourly operation of the power system

Geographical resolution going from market zones to copper plate analysis

Typically optimizes over 1 year or less

Optimize the dispatchable power plants and storage systems operation to meet demand at the lowest system cost LCOTE (Levelized Cost of Timely Electricity)

$$\mathrm{LCOTE} = \frac{C_{gen} + C_{stor} + C_{grid}}{E_{load}}$$

Limitations in terms of computational burden

Not suitable to optimize over a several decades long optimization horizon

Requires exogenous final demand

Simulates and optimizes only the electricity sector

Simulates only the Italian power system

Methodology Soft-link

INPUTS

- Technology **cost projections**
- Capacity **potential**
- Final demand evolution
- **Timeslice** RES generation profiles
- Exogenous **import** & **export**
- **Policies** to be applied to the system

- **Hourly** RES generation profiles
- **Hourly** demand profiles
- Transmission network capacity
- European power system

etsap

ENERGY TECHNOLOGY SYSTEMS ANALYSIS PROGRAM

2025 2030 2035 2040 2045 2050

- Power system configuration
- Techno-economic attributes
- RES availability
- Import export
- Total electricity demand

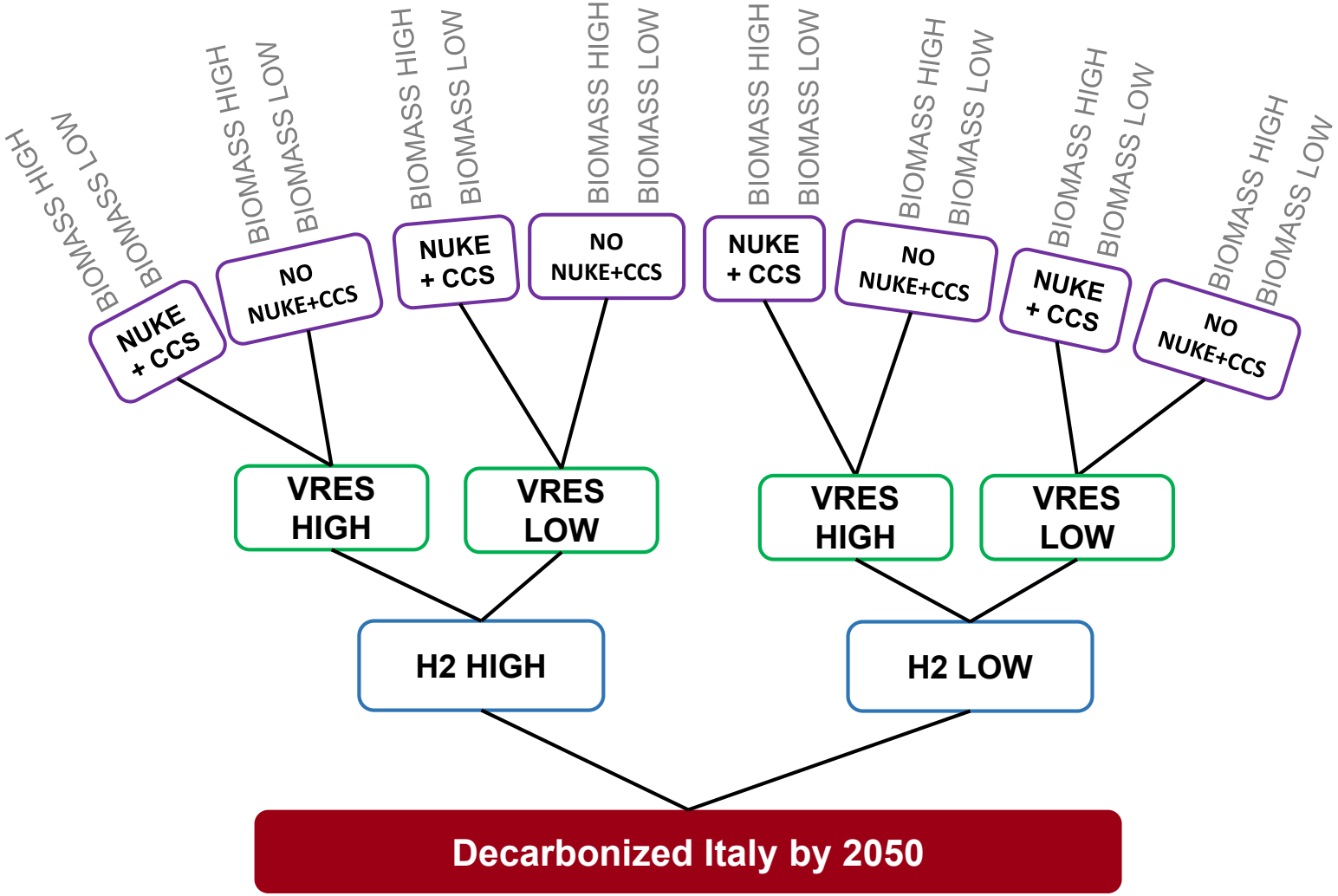
COMESE + PLEXOS

OUTPUTS

- Production and consumption of commodities
- Total system cost
- Final energy demand

- Adequacy assessment
- Hourly operation of the power system
- Total system cost
- Unserved demand
- Curtailed generation

TIMES Inputs



PWER SECTOR ASSUMPTIONS

Biomass resource availability
High → 1100 PJ (from ENSPRESO High)
Low → 800 PJ (from ENSPRESO Medium)

Nuclear technology and CCS technology availability
Max nuclear: 15 GW in 2050

VRES availability:
High → PV: 236 GW / Wind: 46 GW
Low → PV: 120 GW / Wind: 35 GW

Hydrogen supply chain
Varying costs and efficiencies (generation, transport and storage)

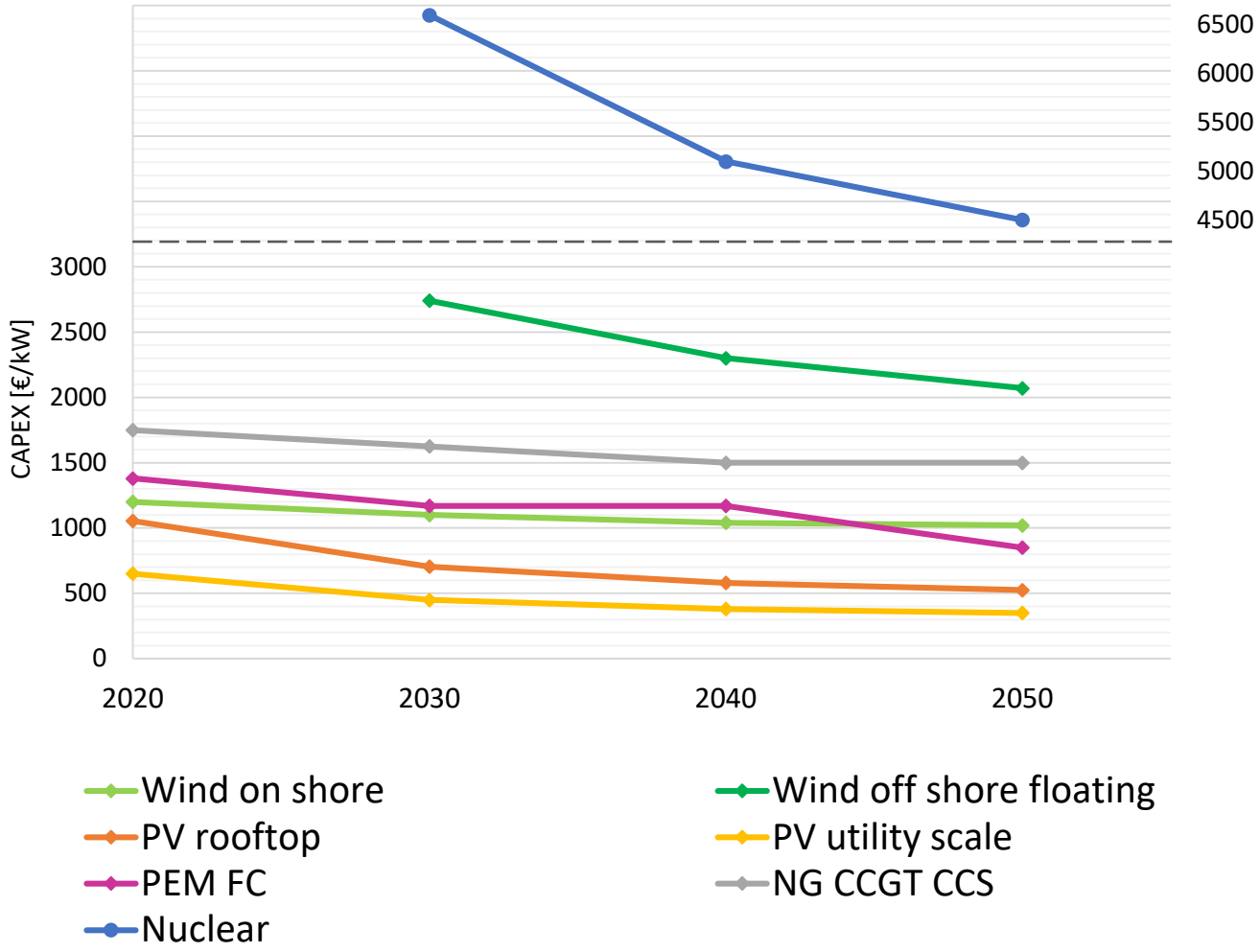
Maximum allowed emissions ~25 Mton CO2eq
95% reduction compared to 1990

TIMES Inputs

Technologies cost projections

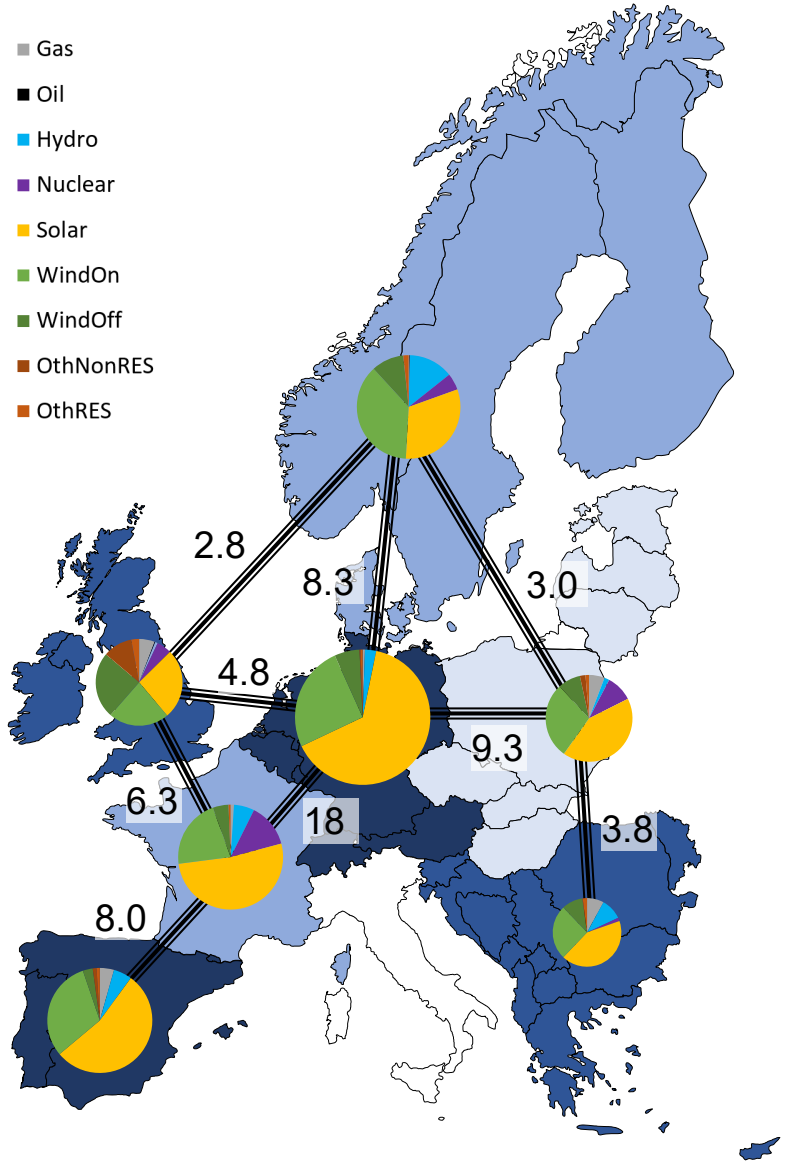
Cost projections in agreement with IEA, Danish Energy Agency and TYNDP estimations

Sharp decrease of technologies in early stage of deployment such as Wind off shore floating and PEM Fuel cells, or technologies with social and political barriers such as nuclear



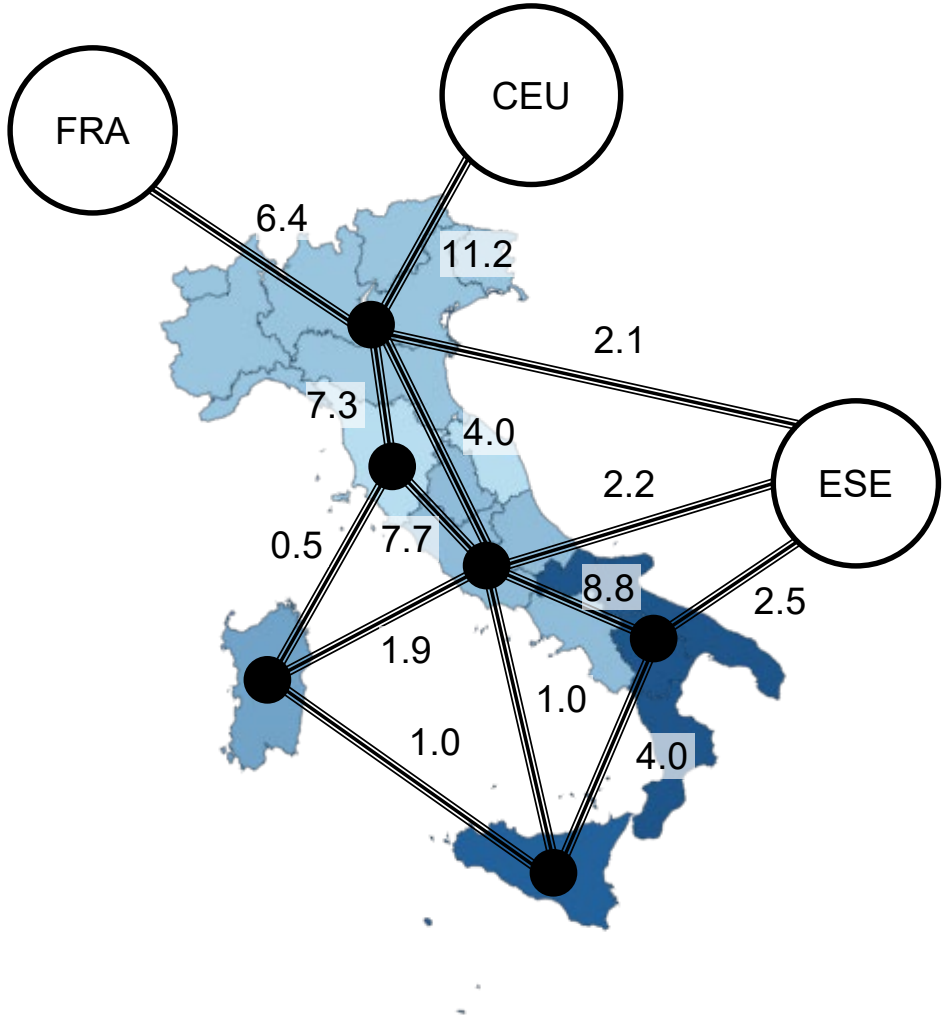
Inputs for the dispatch models

- 7 italian market zones + 7 european macrozones
  → PLEXOS
- European data from TYNDP 2024, Global Ambition scenario
  - Generation capacities
  - Hourly profiles, both generation and demand, from rappresentative year 2009
  - Transmission capacities between European macroareas



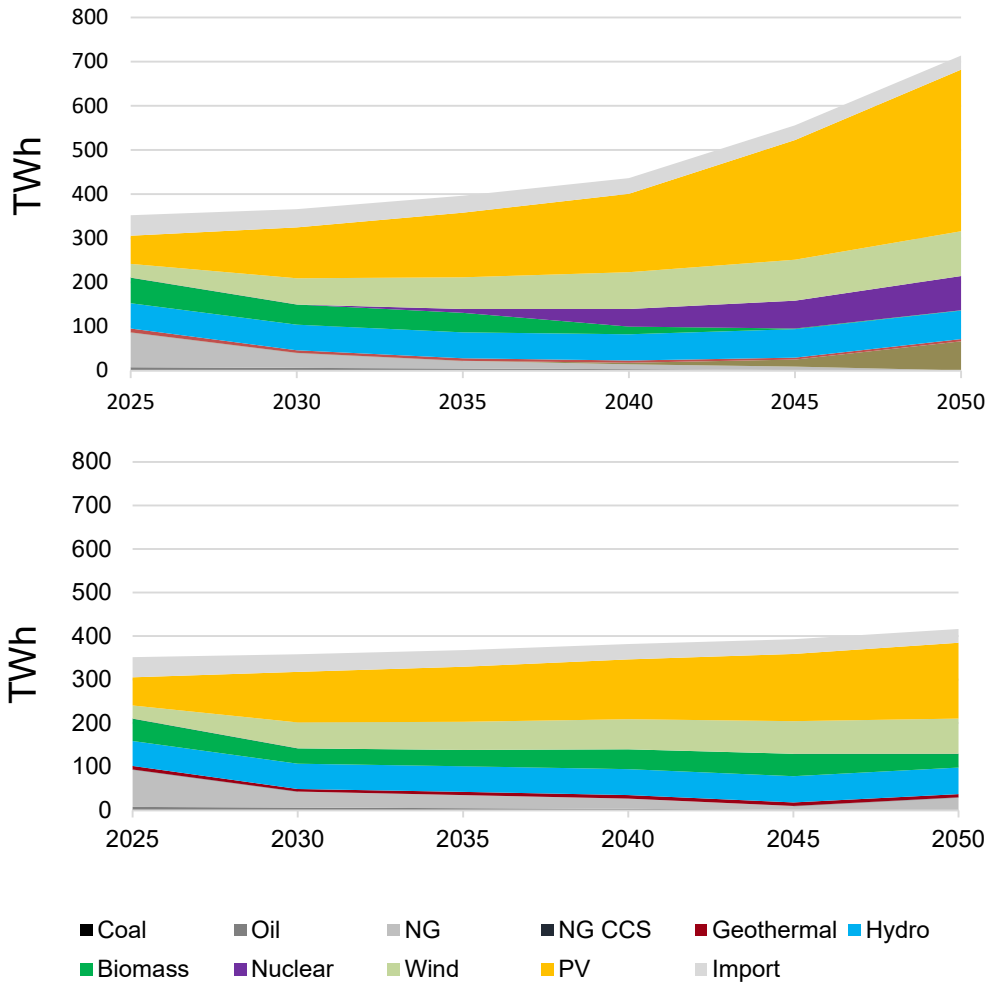
Inputs

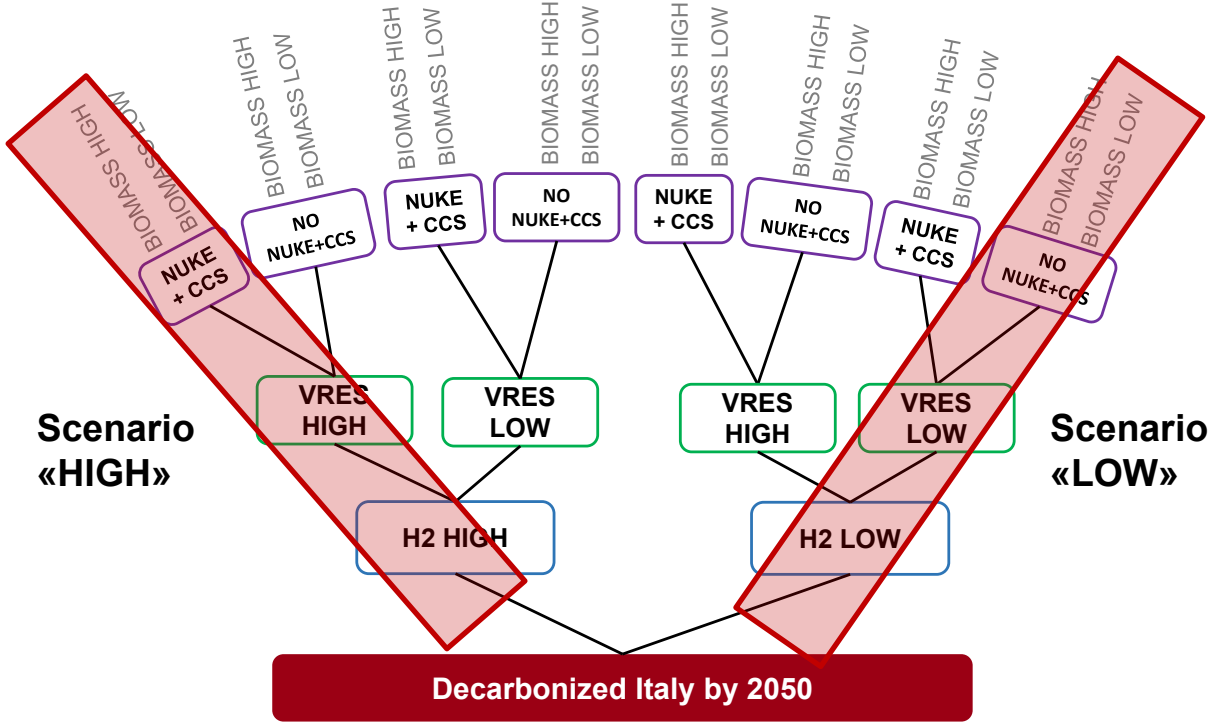
- 6 italian market zones
  → COMESE
- European data from TYNDP 2024, Global Ambition scenario
  - Generation capacities
  - Hourly profiles, both generation and demand, from rappresentative year 2009
  - Transmission capacities between European macroareas
  - Transmission capacities between Italian market zones
    - more than doubled compared to 2024
    - new connections such as Centre South - North



Results

Let's take a look at the two extremes scenarios



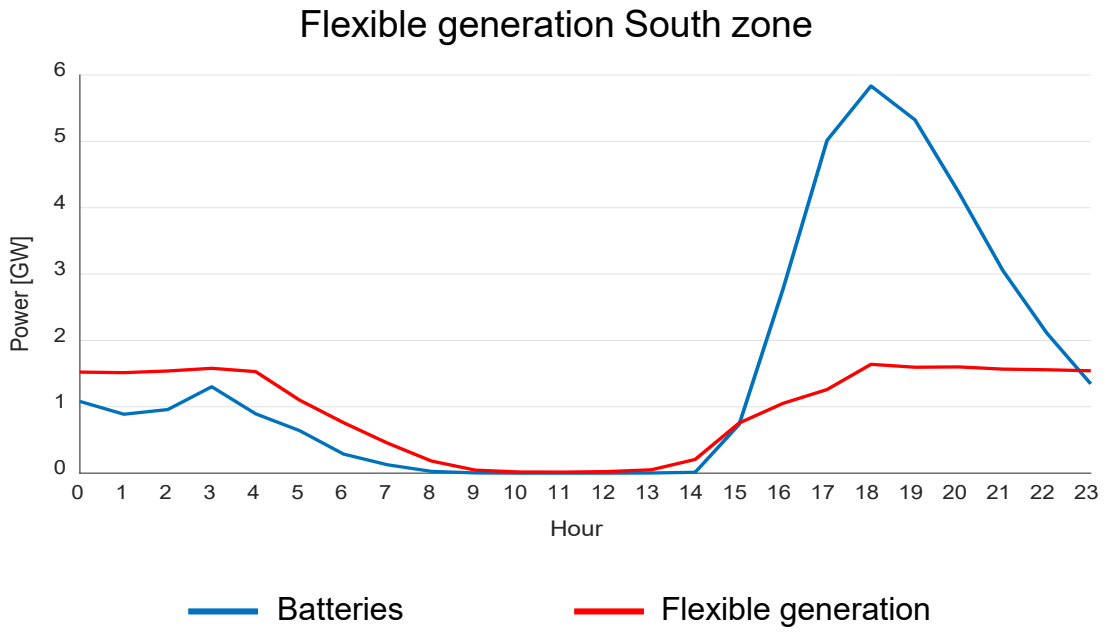


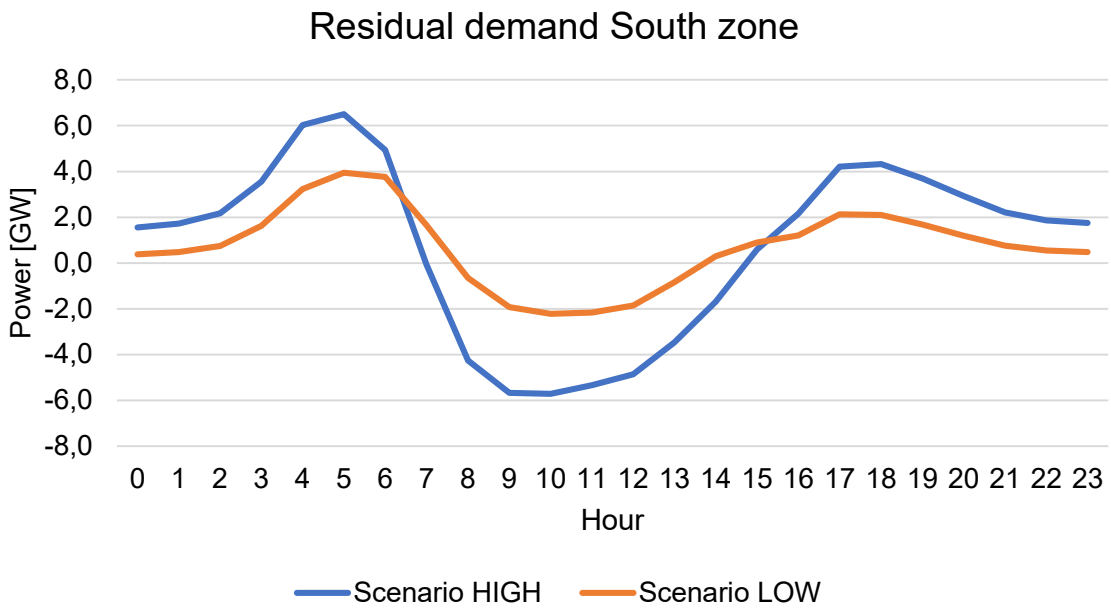
- Scenario HIGH: high use of hydrogen as an energy carrier. Abundance of cheap electricity (Nuclear + VRES availability) that promotes the adoption of electrolysers.
- Scenario LOW presents an higher electrification compared to Scenario HIGH
- Scenario LOW presents high shares of biofuels, efficiency e direct capture from atmosphere of CO_2

Results COMESE/PLEXOS

Let's validate TIMES results with a dispatch model for year 2050

Both scenarios are challeging from the point of view of power grid management:
→ Demand ramp from PLEXOS in South market zone oscillates between 12 GW and 6 GW
→ Batteries and flexible generation from COMESE ramp sharply on average





Results COMESE

Let's validate TIMES results with a dispatch model for year 2050

↔ as in TIMES ↗relaxed constraint in COMESE

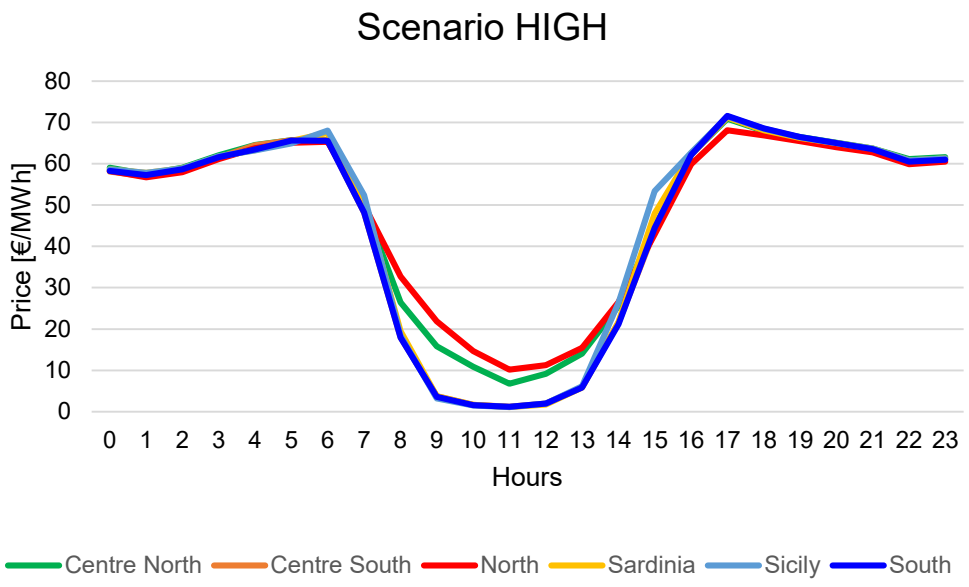
Scenario	Grid	BESS scenario	Flexible generation scenario	PV and BESS location	Unserved energy [h]	Curtailed energy [TWh]	Unserved energy [TWh]	BESS capacity [GW]	Flexible generation [TWh]	LCOTE [c€/kWh]
HIGH	↔	↔	↔	-	5428	85.4	70.0	0	66.7	9.2
	↔	↗	↗	-	0	31.9	0	30	91.1	10.0
	↗	↗	↗	-	0	35.6	0	36	95.4	10.4
LOW	↔	↔	↔	-	1965	16.5	9.1	0	66.0	9.9
	↔	↗	↗	-	0	12.1	0	4	71.4	10.1
	↗	↗	↗	-	0	10.3	0	6	70.5	11.2

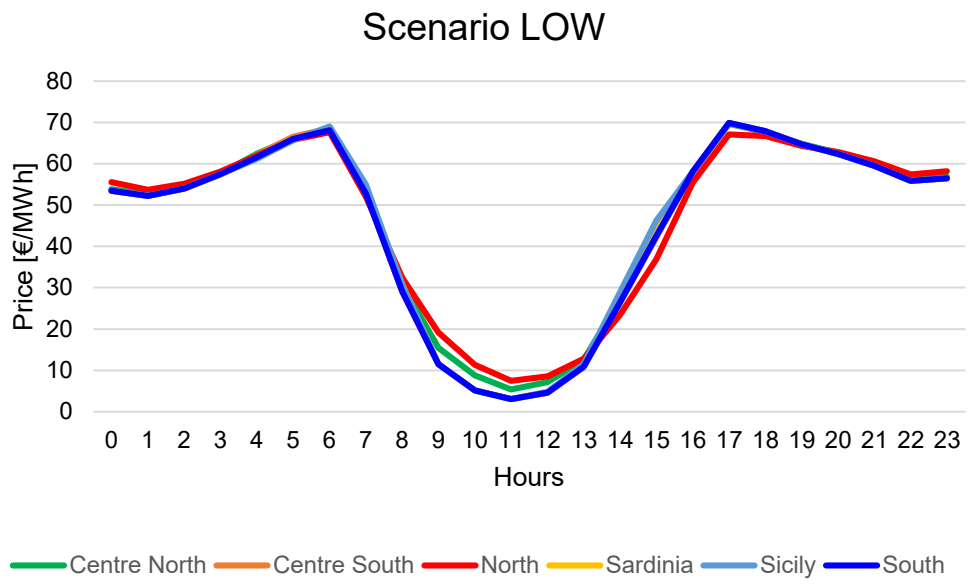
TIMES power system, without **BESS** and **capped flexible generation** is not feasible when it is simulated with hourly time steps.

COMESE allows to estimate the optimal need for BESS and flexible generation to ensure the scenario feasibility

Results PLEXOS

Let's validate TIMES results with a dispatch model for year 2050





Energy prices curve is similar in scenario HIGH and LOW scenario

Both present near zero values in the midday hours → high penetration on PV

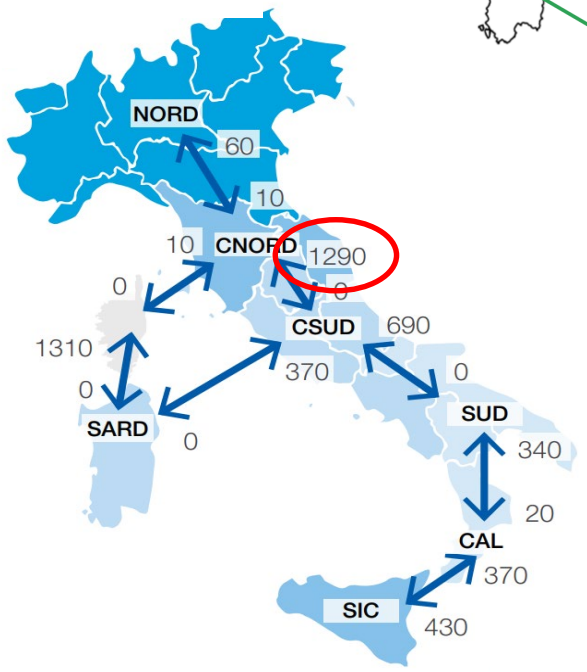
Results COMESE

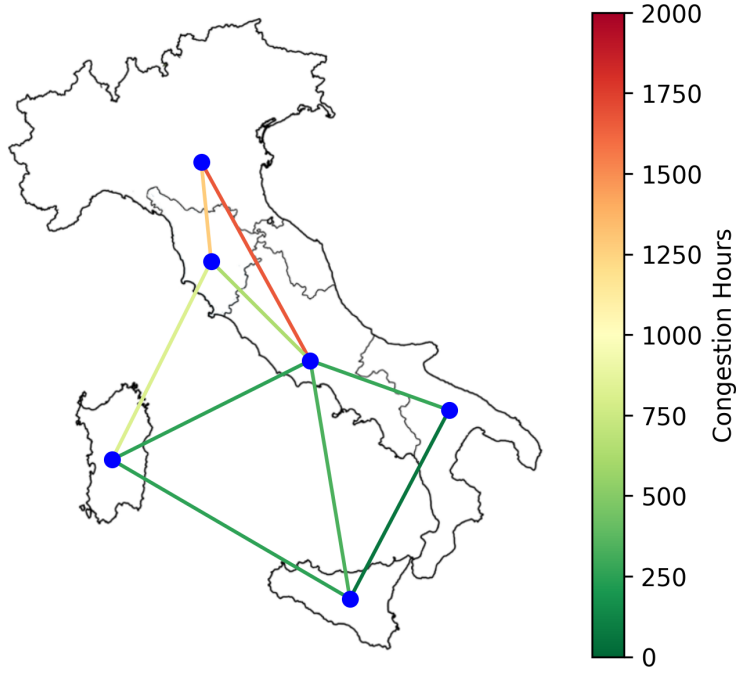
In scenario HIGH, the most critical connection is the Centre South – North one.
It is congested for around **1670** hours

It relieves the North – South power grid backbone

Still together with Centre North – North connection, it proves to be the most stressed even more than in 2022 despite the considerable increase in transmission capacity

In scenario LOW the grid proves to be far too increased with congestion hours as high as 69 hours. Far less than 2022.





Congestion hours as of 2022

Conclusion

- In TIMES we recognized 16 scenarios with two extreme scenarios with a wide difference in electricity demand
- In high electricity demand scenarios, a mix of renewables and firm dispatchable resources such as NG CCS and nuclear are selected
- TIMES Italia is a powerful tool, but its results must be validated with a technically detailed dispatch model
- TIMES scenarios proved to be infeasible if tested with an hourly simulation

Future work

- Higher technical technology detail (ramps, mun up-down time etc.) in PLEXOS
- Higher technical detail of the European system in PLEXOS
- Expand this analysis to all TIMES scenarios and all years from 2025 to 2050

Thank you for the attention!

Marco Agostini

marco.agostini.5@phd.unipd.it

UNIVERSITÀ DEGLI STUDI DI PADOVA

CONSORZIO RFX

Ricerca Formazione Innovazione