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NAVIGATING THE ENERGY TRANSITION PATHWAYS TO NET ZERO IN ITALY

A study by GE Vernova's Consulting Services

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AIEE ASSOCIAZIONE ITALIANA ECONOMISTI DELL'ENERGIA

IAEE International Association for Energy Economics

Driving the energy transition

POWER

GAS POWER

- Gas turbines for utilities, power producers & industries, from mobile units to plants.
- Full maintenance & lifecycle services.

HYDRO POWER

- Efficiency upgrades increase lifecycle and TWh of renewable hydro
- Pumped storage projects enable grid stability

NUCLEAR POWER

- Nuclear solutions for boiling water reactors, fuel, services & small modular reactor development with Hitachi joint ventures.

STEAM POWER

- Upgrade/extend life of nuclear plants and maintain a largely renewable industrial fleet in the Americas
- Support global customers with best-in-class services including end of life as they transition away from coal

WIND

WIND BLADES

- Blade technology vital to higher capacity factors
- Two-piece blades reduce transport logistics (and associated indirect emissions)

ONSHORE WIND

- Provides onshore wind turbines & services, optimizing performance with digital tech for cost, capacity & efficiency improvements.

OFFSHORE WIND

- Provides offshore wind tech & farm development, featuring the Haliade-X 220m turbine.

ELECTRIFICATION

ELECTRIFICATION SOFTWARE

- Orchestrates the complexity of the sustainable energy grid while driving reliability and resilience
- Accelerates decarbonization across the energy lifecycle
- Optimizes the measurement and reporting of progress to net-zero goals

ELECTRIFICATION SYSTEMS – GRID SOLUTIONS

- Enables necessary grid modernization, expansion, stability and flexibility to renewables growth in the power system

ELECTRIFICATION SYSTEMS – POWER CONVERSION & STORAGE

- Enables decarbonization of mission-critical industrial applications.
- Batteries and hybrids extend dispatch of renewables enabling reduction of fossil generation for short-durations.

ACCELERATORS

ADVANCED RESEARCH

- A hub for innovation, collaborating with top energy thought leaders to develop and demonstrate breakthrough technologies that enable the deployment of reliable, affordable, and sustainable energy solutions at scale

CONSULTING SERVICES

- Policy, planning and investment decision expertise to help with holistic decarbonization planning.

FINANCIAL SERVICES

- Financing and securing tax equity are key enablers for zero-carbon projects
- Project development and carbon monetization schemes vital to early carbon capture demonstration pilots

OUR LEGACY AND PRESENCE IN ITALY

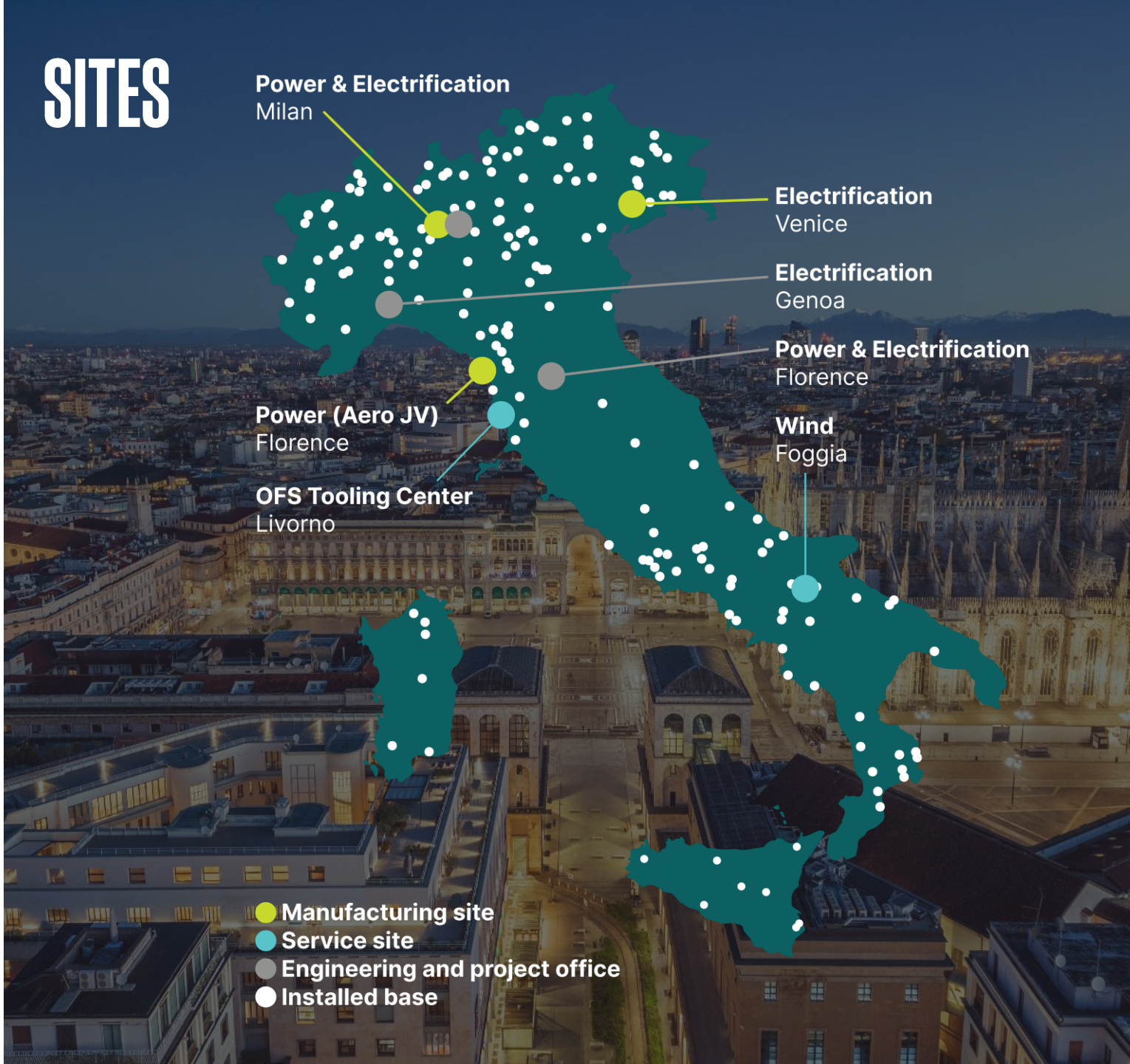
5 Major sites

100+ Years of local experience

~27 GW of GE Vernova power generating capacity in Italy

~24% of Italy's electricity is generated by our equipment

SITES



AGENDA

1. Study background & context
2. Modelling the Italy electricity system
3. Key findings
4. Recommendations

The milestones for achieving 2050 net zero goal in Italy

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2020

European Green Deal: introduced as a set of policy initiatives to reach climate neutrality in the EU by 2050.

2030

"Fit for 55" package set a 55% GHG reduction target (vs 1990)

Italy National Energy Climate Plan (NECP)* set out planned measures to reduce CO_2 emissions in the power sector by 58-66% (vs 2005).

2040

90% GHG reduction target (vs 1990): European Commission (EC) proposed an amendment to the EU Climate Law, setting a new EU climate target of a 90% reduction in net GHG emissions by 2040.

**Also referred as Piano Nazionale Integrato per l'Energia e il Clima (PNIEC)*

OBJECTIVES

- Explore how decarbonisation goals[1] can be achieved in Italy through an efficient transformation of the power sector
- Identify critical aspects of the power system, including transmission, that are necessary to support the transition
- Highlight the opportunities and potential risks associated with relevant power generation technologies and propose mitigation strategies

[1]across the electricity, transport and heating sectors

The challenges for achieving 2050 net zero goal in Italy

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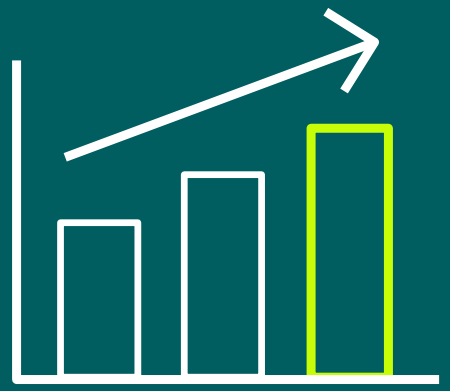


AN INCREASE OF

60%

Demand growth by 2050

MORE THAN

200 GW

Of new capacity will be required by 2050

~4X

The currently installed wind and solar in Italy

- From 2010, power demand in Italy declined 5% to 312 TWh in 2024
- By 2050, power demand is projected to grow 60% to just over 500 TWh, with additional:
  - 127 TWh of Electric Vehicle (EV) load
  - 30 TWh of Heat Pump load, and
  - 21 TWh of Data Centre load

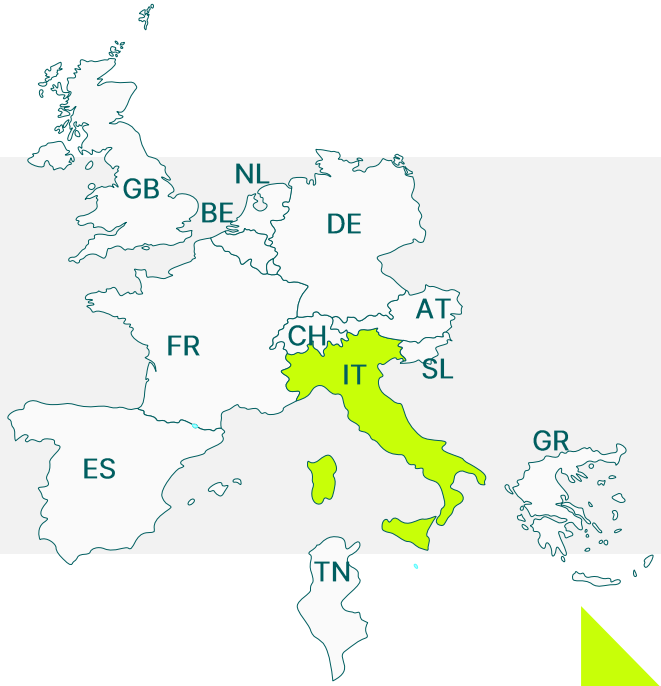
- The rate of PV additions increased to 6.8 GW in 2024, still below 8.5 GW/yr required to reach NECP 2030 target
- Wind additions remained below 1 GW/yr, significantly below 3 GW/yr prescribed by NECP
- Battery additions were around 2 GW in 2024 and would need to remain at this rate to achieve Terna 2030 target.
- Thermal addition (CCGT w CCS & Nuclear SMR) strategy remains under discussion.

Investigating the role of various no- or low- carbon electricity generation technologies as well as the role of the electricity grid remains key to enable efficient transition of the Italian power sector.

Methodology

Modelling Italy electricity system including X-border interconnections.[1]

Perform long-term capacity expansion and hourly dispatch simulation of the entire system.



KEY INPUTS

- **Zonal model of Italy** with Terna transmission limits and expected expansions (including Hypergrid projects)
- **Zonal based wind and solar** ratings – based on ERA5 reanalysis dataset[2]
- **Potential new build** capacity technologies and their locations

TWO SCENARIOS

1. **Renewable Ambition (RA)**: assuming renewable additions can proceed at the pace required to achieve NECP 2030 targets.
2. **Business as Usual (BAU)**: restricting renewable additions to historically observed pace (observed up to 2024).

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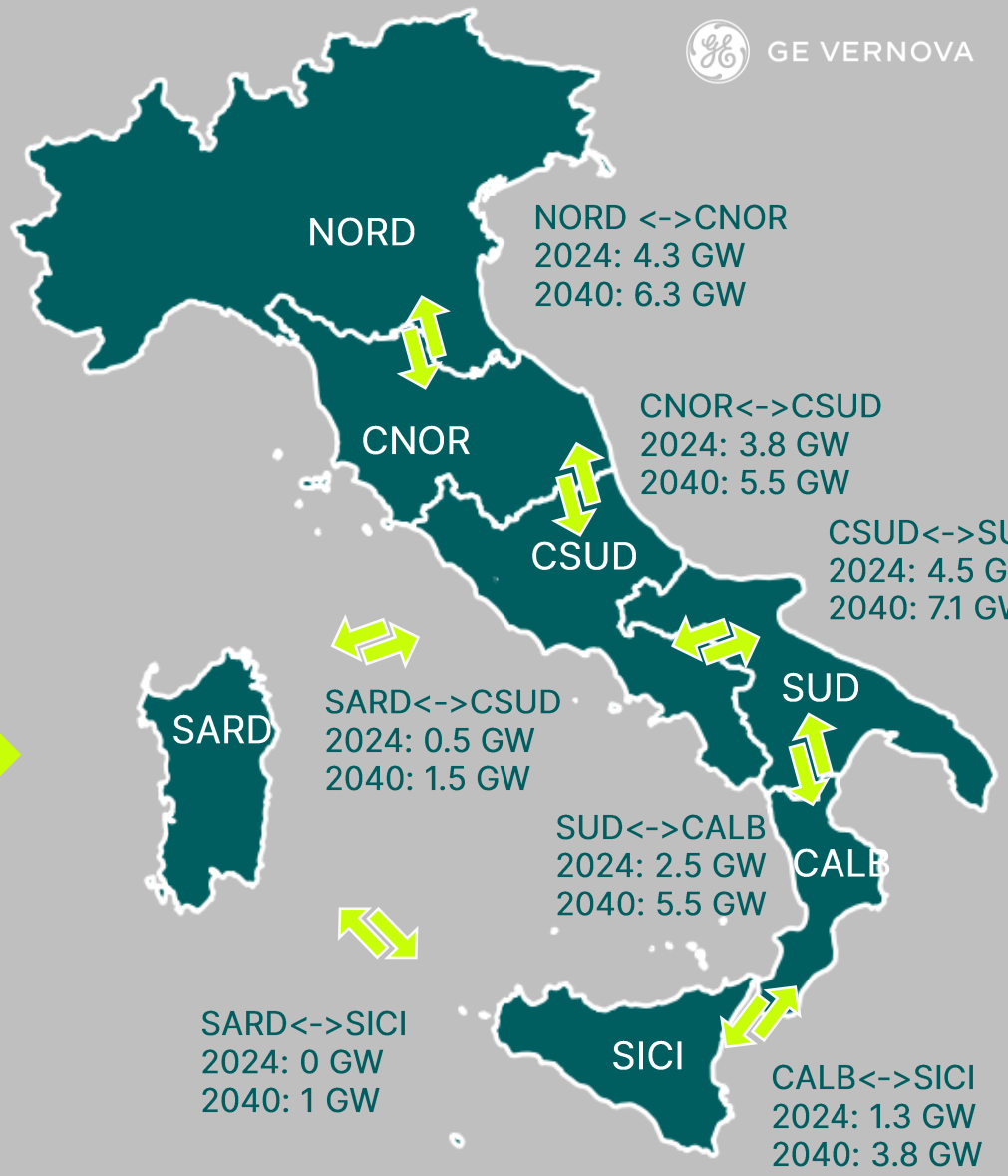

[1] Using Plexos (www.energyexemplay.com)
[2] Fifth-generation reanalysis dataset produced by ECMWF (European Centre for Medium-Range Weather Forecasts

Technologies and Build Constraints for New Capacity

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All potential lower carbon technologies are considered, and the simulation determines the most economic build.

Committed Capacity: all incl. Fusina (Ansaldo GT36), Ostiglia (SGT9000HL) and Montfalcone (SGT900HL).

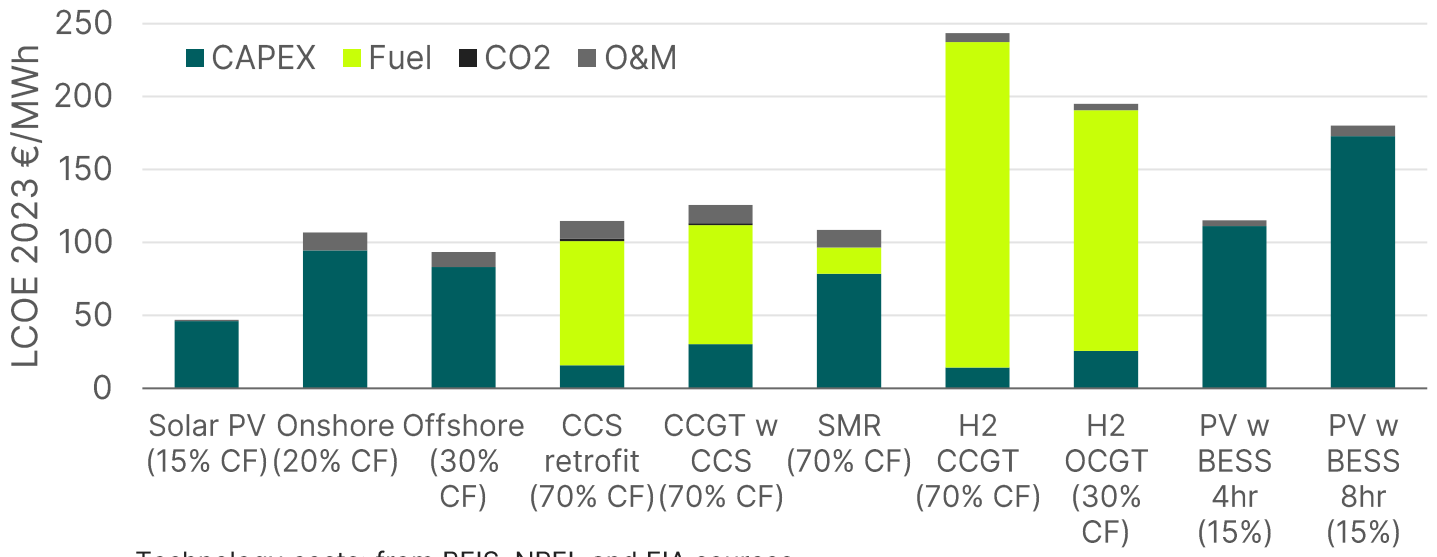
Future New Capacity: based on least cost economics. The candidates considered are:

Technologies	Build cost in 2035 (€2023/kW)	Max built per year (GW) RA	BAU
Solar PV	620	7**	5**
Onshore Wind	1560	2**	0.5**
Offshore Wind	2550	0.4**	0.4**
CCGT w CCS retrofit	1000	not set	not set
CCGT w CCS new	1900	4	4
Nuclear SMR	6100	0.6*	0.6*
CCGT H2-capable	900	not set	not set
OCGT H2-capable	690	not set	not set
BESS 4hr	880	3	3
BESS 8hr	1760		

RA – Renewable Ambition scenario
BAU – Business As Usual Scenario

*From 2035 onwards
**With zonal limits

Levelised Cost of Electricity for Capacity Built in 2035



Technology costs: from BEIS, NREL and EIA sources

- Emission targets, demand growth and plant retirements are driving capacity additions.
- Combination of economic parameters (CAPEX, economic life, WACC), reliable capacity during system stress (firm capacity) and expected rates for each technology determines the overall buildout.

KEY RESULTS

Pathway to net zero: capacity expansion pathways

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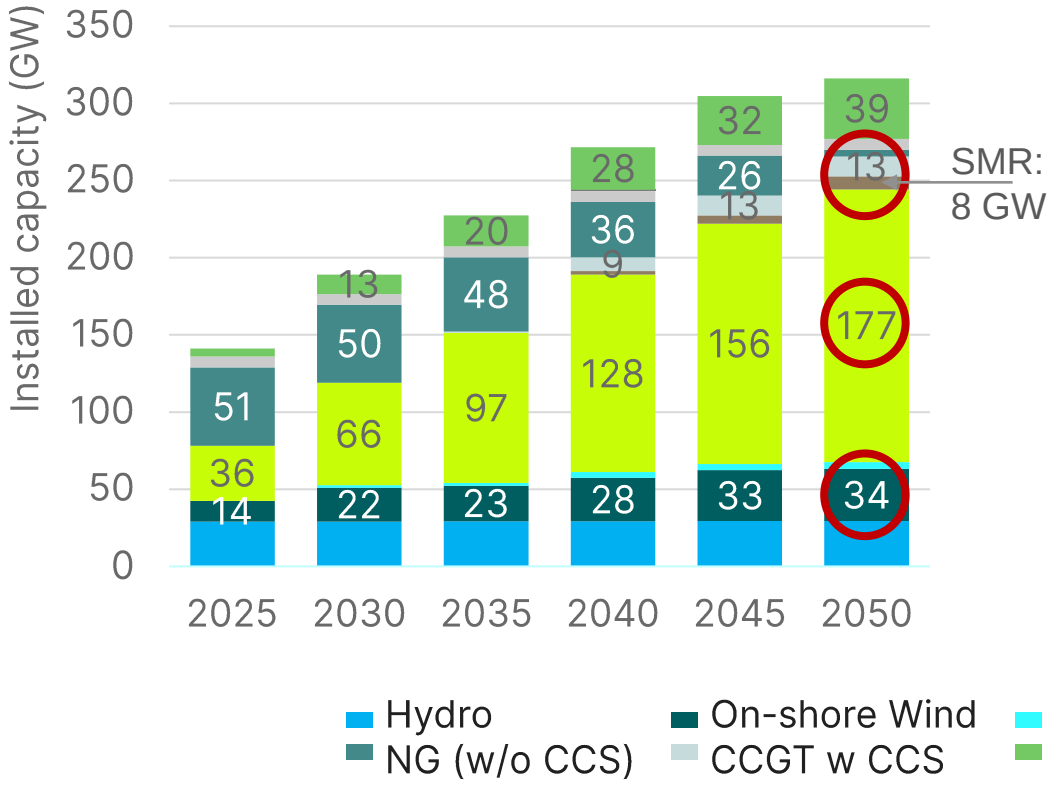
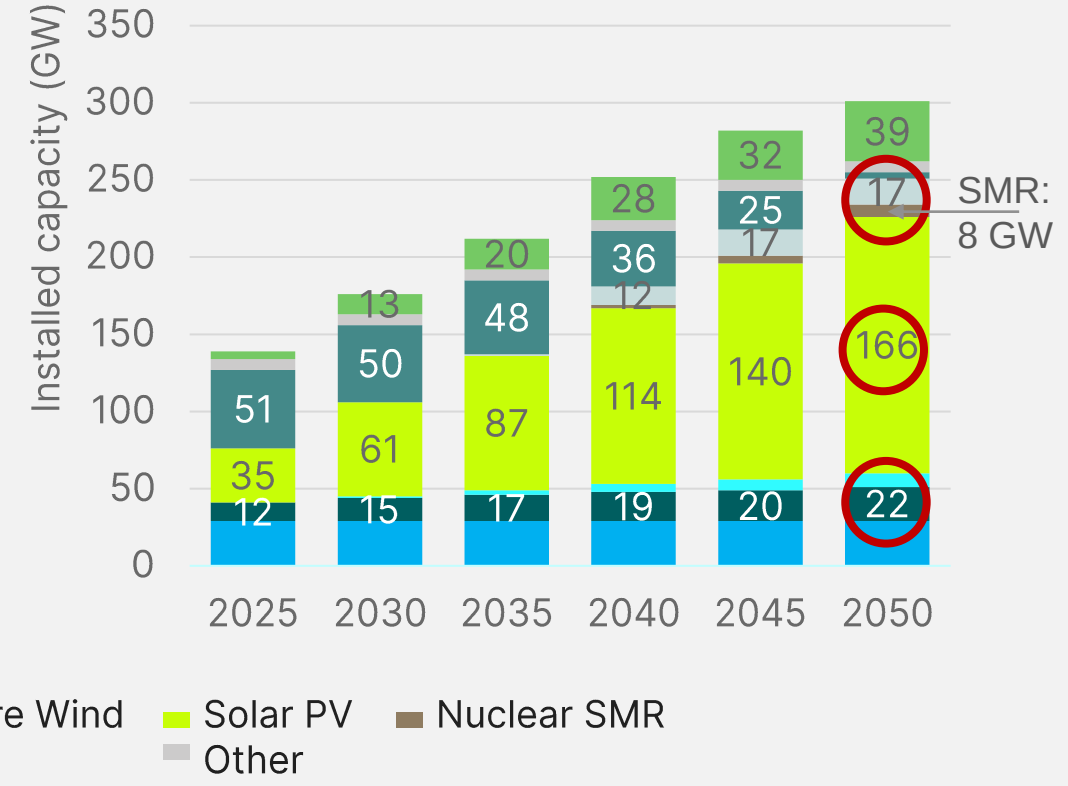
RENEWABLE AMBITION (RA)

Assuming renewable additions can proceed at the pace required to achieve NECP 2030 targets



BUSINESS AS USUAL (BAU)

Assuming renewable additions can proceed at maximum historically observed pace



Hydro
NG (w/o CCS)
On-shore Wind
CCGT w CCS
Off-shore Wind
BESS
Solar PV
Other
Nuclear SMR

With current rate of solar and wind additions (Business as Usual), Italy can still achieve net zero 2050 target, contingent on high utilization on CCGT with CCS (subject to injection limits) and potentially higher power imports.

Projected capacity additions 2025-2050 by category

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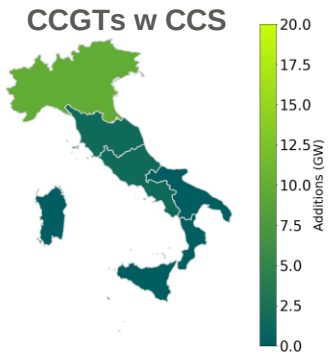
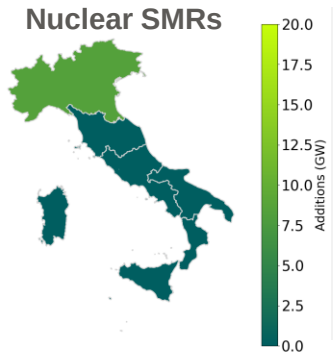
Total projected capacity additions under RA are over 220 GW by 2050, more than 60% growth from current capacity.

+13 GW

Concentrated in the NORD, where largest demands centers are located, as well as existing CCS projects (Ravenna)



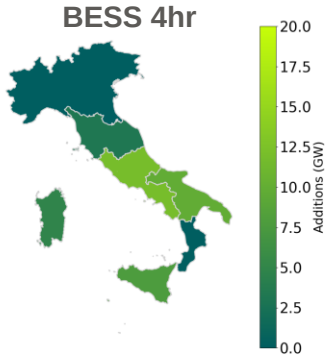


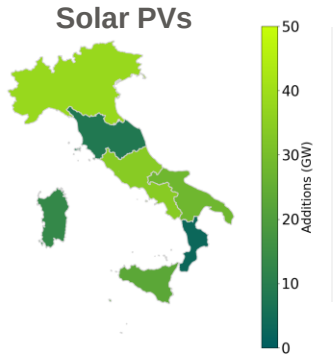
All in the NORD, where largest demands centers are located, as well as largest decommissioned Nuclear site (Caorso) is located.

+8 GW

+38 GW

Installed in the zones where most of the PVs will be located, except for the NORD where hydro and thermal units can provide flexibility.



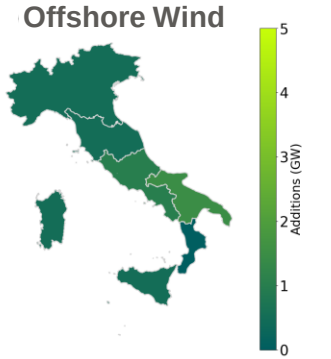


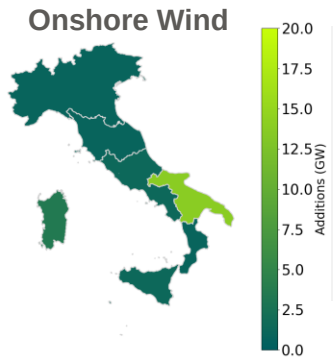
Higher PV additions in the NORD, CSUD and SUD zones, aligned with Terna development plan.[1]

+140 GW

+4 GW

Off-shore wind distribution is weighted towards CSUD and SUD power zones where capacity factor will be highest.



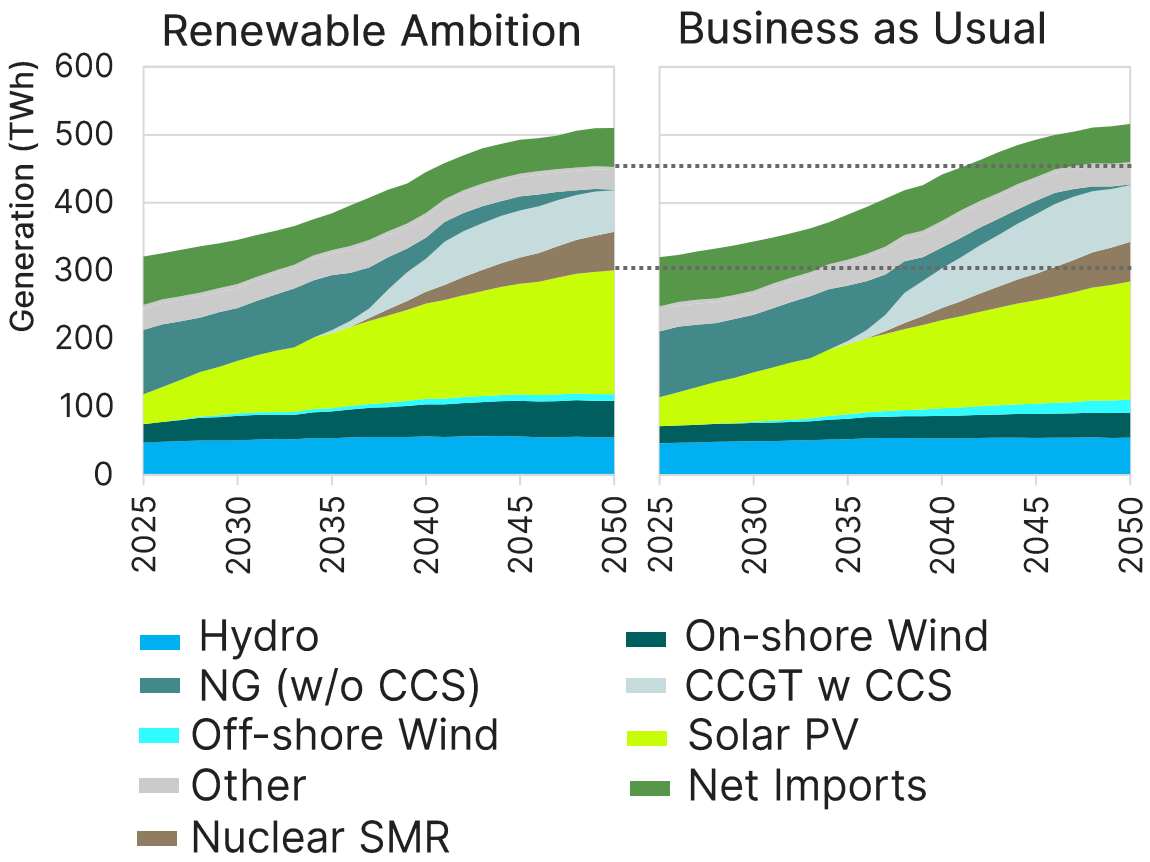


Onshore wind distribution is weighted towards SUD power zone where capacity factor will be highest.

+20 GW

[1] https://www.terna.it/en/electric-system/grid/national-electricity-transmission-grid-development-plan

Electricity generation mix



- Hydrogen-capable units were considered but not selected by the model based on economics.
- Total system cost was estimated to be similar in both scenarios in the 2025-50 timeframe.

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RENEWABLE AMBITION

- Solar PV becomes dominant, increasing from 14% in 2025 to 22% in 2030 and 36% by 2050, driving new capacity growth and replacing aging thermal plants before CCS deployment.
- Gas generation declines from 30% (2025) to 22% (2030), with unabated gas largely phased out by 2040. CCS-equipped gas reaches 14% by 2045, then falls to 12% by 2050 as SMR nuclear expands, equivalent to a ~50% drop in absolute gas output vs today.
- Imports stay near historic levels until ~2035, rise temporarily with electrification, then decline after 2040 as domestic SMR and CCS capacity strengthens Italy's baseload and mid-merit supply.

• BUSINESS AS USUAL

- Solar PV and wind expand only at historical rates, limiting renewable growth to 53% by 2030 – well below the 63% Policy target.
- Gas generation and imports compensate for slower renewable deployment, with CCGTs and imported electricity meeting a larger share of demand by 2030. CCS generation rises to meet ~20% of demand by 2045, later partly replaced by nuclear SMRs toward 2050.

Role of transmission network in decarbonisation

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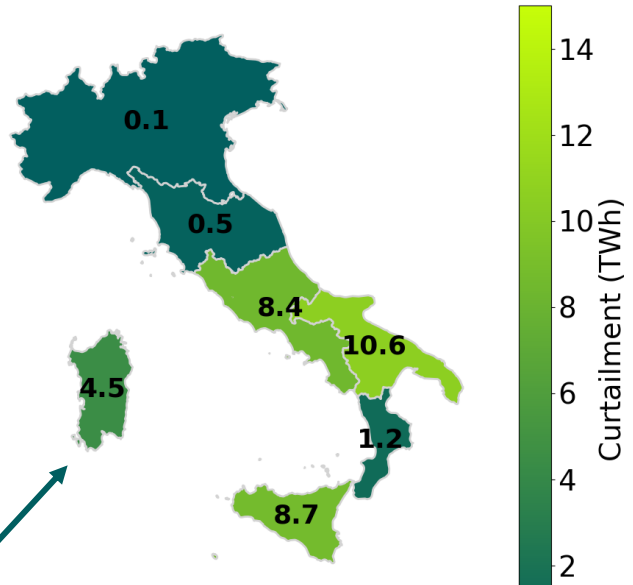
Adequacy of electricity network is key for integrating new renewable capacity while minimizing curtailment:

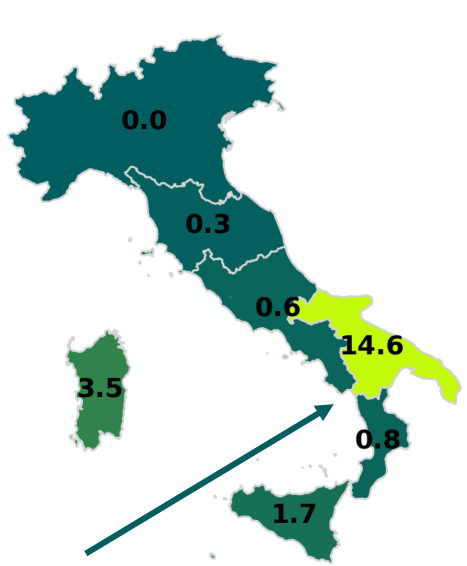
The total energy curtailment is quantified to be around 55 TWh in 2050 with planned transmission upgrades but will increase to 70 TWh (15% of total demand) if Hypergrid projects are not completed.

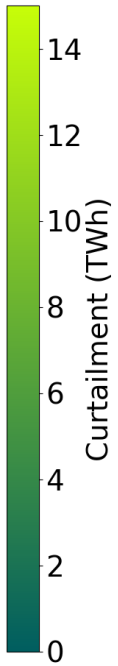
Solar PV in 2050



Sardinia (SARD) is expected to become a significant renewable hub, but with up to 70% of 16 GW PV capacity in 2050 curtailed in some periods, strengthening HVDC Fiumesanto-Montalto interconnection is critical.

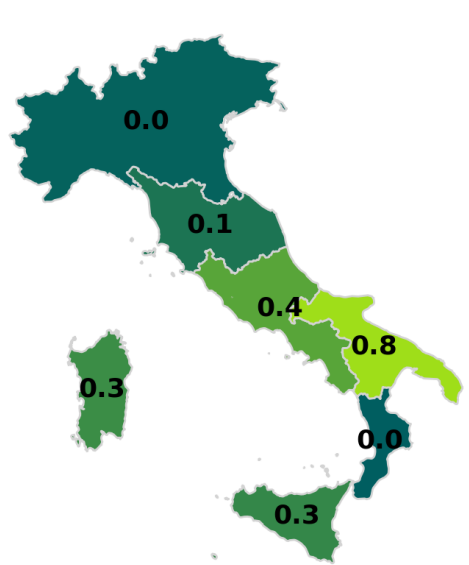
On-shore Wind in 2050

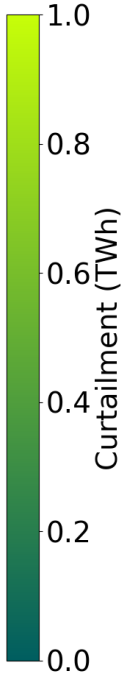




Onshore wind will experience particularly high curtailment in the SUD power zone with entire 20 GW capacity curtailed in some periods, which highlights importance of strengthening HVDC Foggia-Forli interconnection.

Off-shore Wind in 2050





It is critical to accelerate transmission upgrades and further reinforce SUD and SARD links.

KEY RECOMMENDATIONS

Conclusions & Recommendations

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Ensuring required deployment of renewable energy

- Accelerate the deployment of **solar PV and wind power** to achieve around 90 GW of total by 2030, over 2X the 2024 wind and solar capacity
- Keep existing 29 GW **hydropower** capacity (and explore additional potential)
- An accelerated growth in onshore wind and solar PV will require **streamlining administrative processes** and incentivizing investment

Flexible technologies as key enabler for Net Zero

- Approx 10% of installed capacity base will be **SMR and CCGT w CCS** by 2050, meeting 25% of demand
- Mix of CCGTs with **carbon capture and sequestration** CCS (16-18 GW) and **nuclear SMR** (8 GW) are key for providing system flexibility and part of the increased electricity demand
- **40 GW of battery energy storage** (BESS) capacity needed for daily peak shaving and reduction of energy curtailment

Electrification transmission upgrades

- Accelerating **transmission infrastructure upgrades** and further reinforcements in the south of Italy to avoid curtailment of 70 TWh, approximately 15% of electricity demand by 2050
- **Terna's Hypergrid projects** are a vital investment, however most of them will be realized post 2035, not addressing the energy curtailment issues in earlier years

Decarbonisation goals across the electricity, transport and heating sectors can be achieved in Italy through an efficient transformation of the power sector