SEERC COLLOQUIUM

OVERVIEW OF THE INTEGRATION OF PHOTOVOLTAIC POWER PLANTS, WIND FARMS AND STORAGE

NATIONAL COMMITTEE OF ITALY

Enrico Maria Carlini

Head of Power System Planning & Permitting • Terna SpA

Massimo Pompili

Full professor at Sapienza University of Rome

Ljubljana

February 29th, 2024

SAPIENZA UNIVERSITÀ DI ROMA

Terna Driving Energy

Agenda

1. **Energy transition in Italy**
2. Renewable connection requests
3. Italian NDP 2023 and Hypergrid project

European and National packages for Climate and Energy

Europe 2020

Within 2020:

-20% GHG emission vs 1990 levels
20% RES share in energy consumption
20% energy efficiency

Green Deal/ Fit for 55

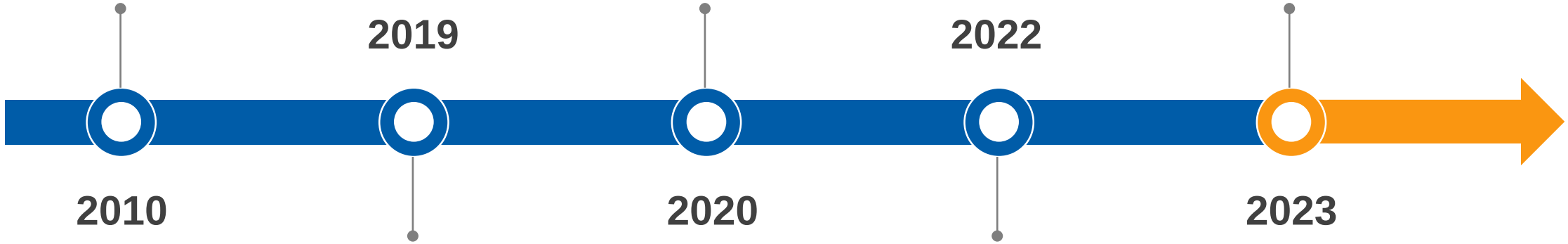
Within 2030:

-55% GHG emissions vs 1990 levels
40% RES share in energy consumption
Climate neutrality within 2050

Draft updated NECP[1]

Within 2030:

-62% GHG emissions for the ETS sectors vs 2005 levels
65% RES share in energy consumption



Clean Energy Package

Within 2030:

-40% GHG emissions vs 1990 levels
32% RES share in energy consumption
32,5% energy efficiency

REPowerEu

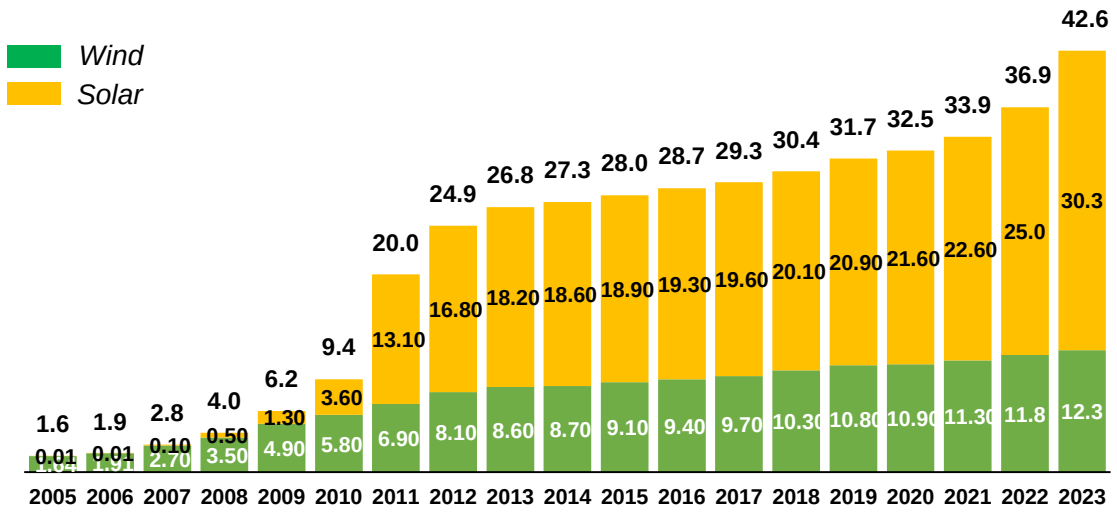
Extraordinary measures to make Eu independent from Russia. Within 2030:

45% RES share in energy consumption
300 bln€ of investments

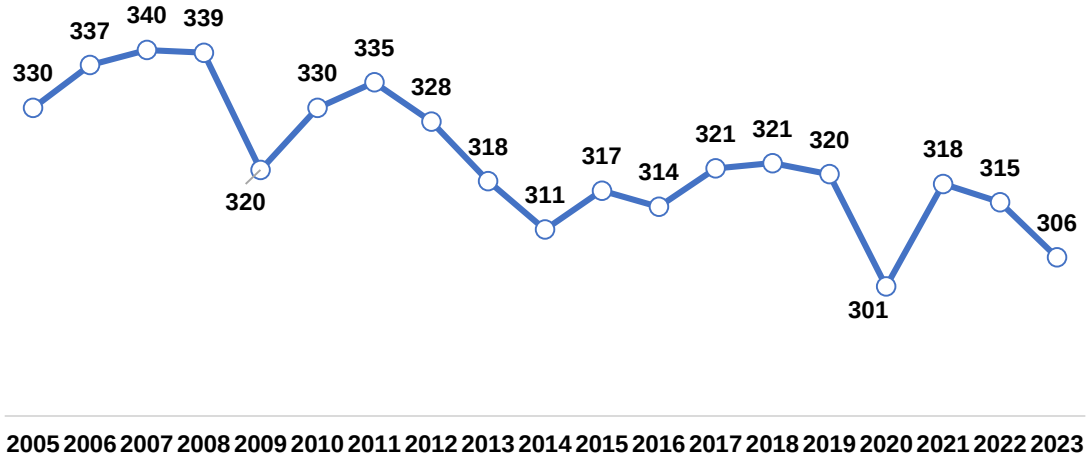
1. *These will be analysed by the Commission with an overall assessment and country-specific recommendations published in December 2023.*
2. *Taking these recommendations into account, Italy is then required to submit its final NECP by 31 December 2024.*

Where we are in terms of renewables

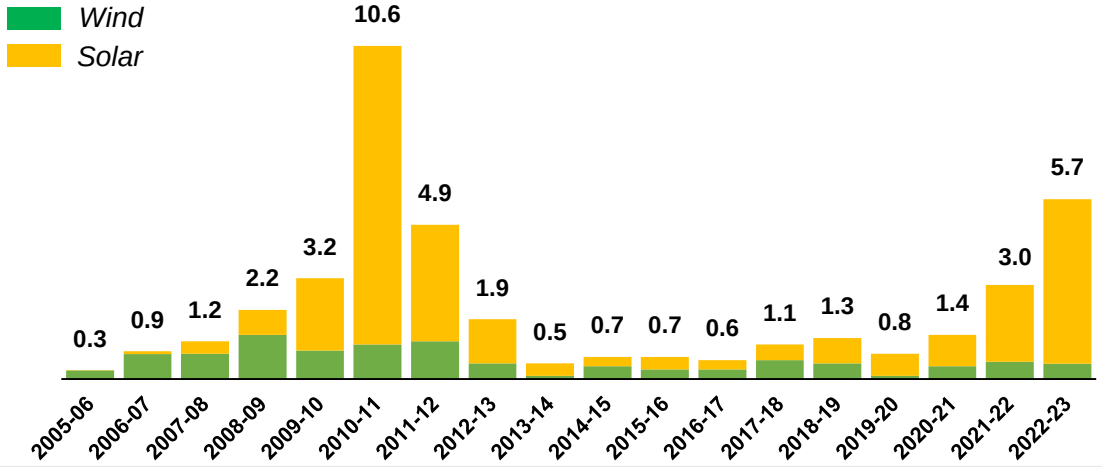
Total installed capacity of wind & solar (GW)



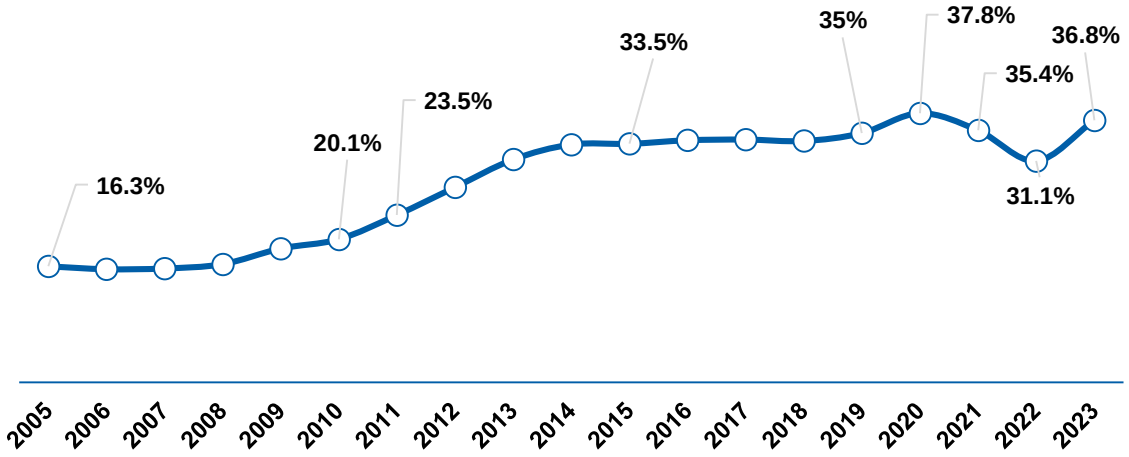
Electricity demand (TWh)



Annual installations of wind & solar (GW)



RES-E share (%)

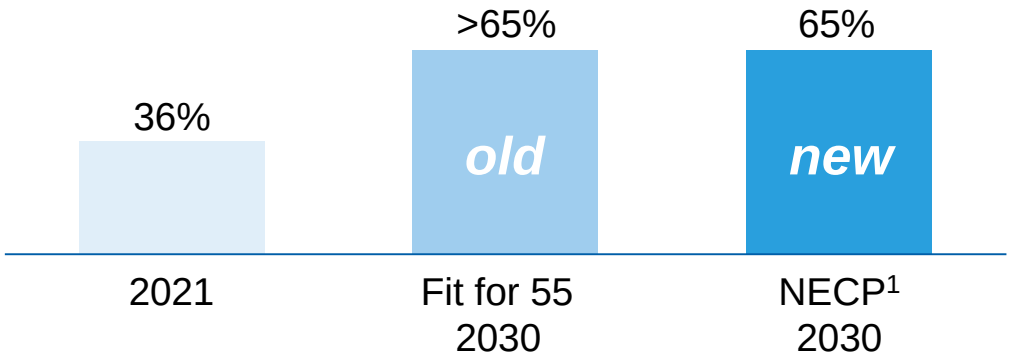


Note: source data Terna. 2023 and RES-E share data for 2022 is provisional and potentially subject to updates

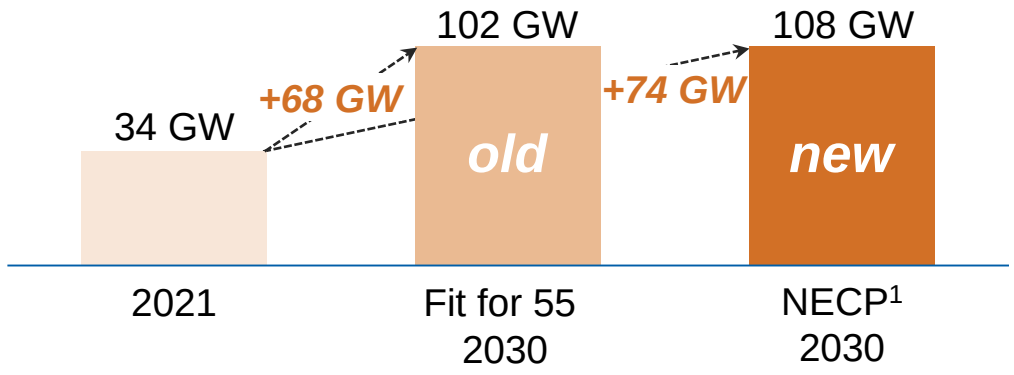
Italian RES increase to meet Eu climate targets

1 Total electricity demand

2 RES share in electricity consumption



3 PV and wind capacity



2030 targets for electricity sector

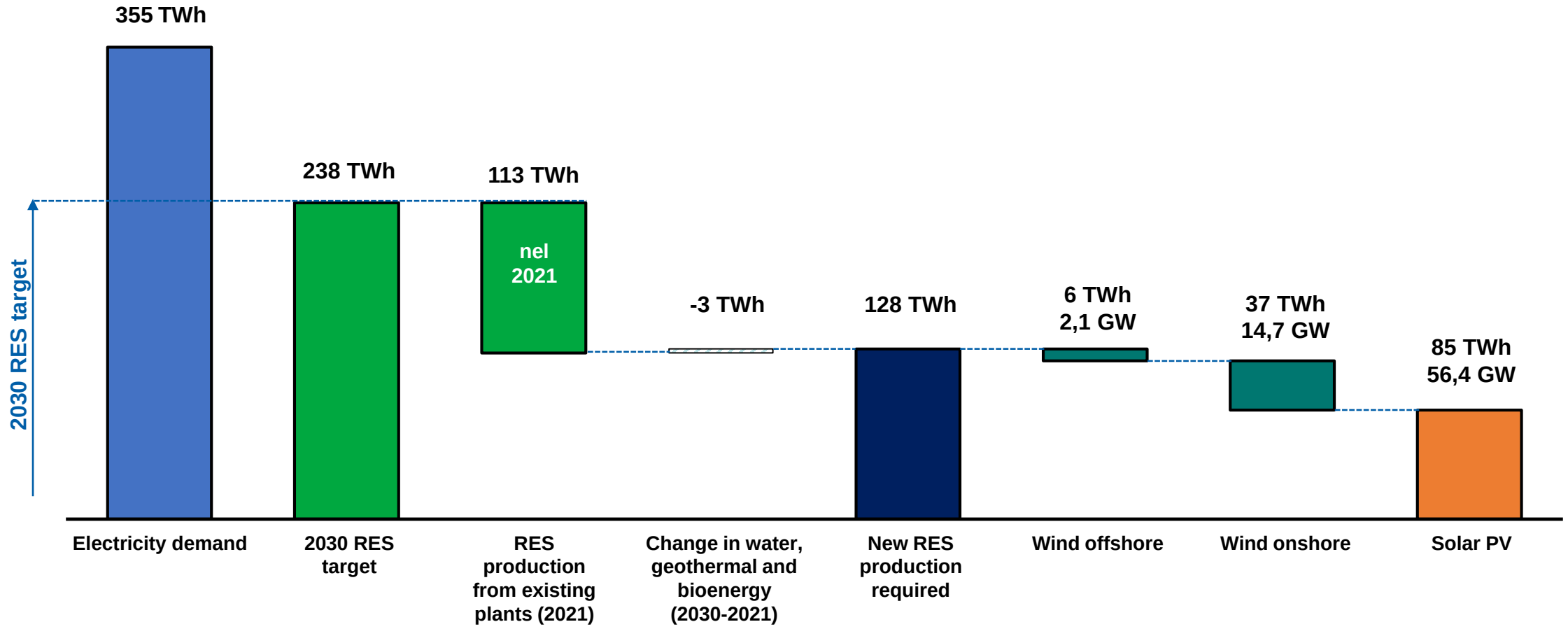
On 30 June 2023, the Italian Ministry of Environment and Energy Security (MASE) submitted to the Commission the draft updated integrated National Energy and Climate Plans (NECP) for the period 2021-2030.

Updated national targets for 2030[2]:

- *Reduction of GHG by 62% (as compared to 2005 levels) for all plants subject to the EU ETS*
- *RES share in electricity consumption of 65%*
- *Total wind and solar installed capacity of ≈108 GW*

1. *Draft updated NECP submitted to the Eu Commission in June 2023*
2. *NECP 2023: Policy scenario. The scenario developed considering the measures planned in June 2023, will be updated with the submission of the final NECP by June 2024*

Additional RES production to meet 2030 targets set by the new NECP

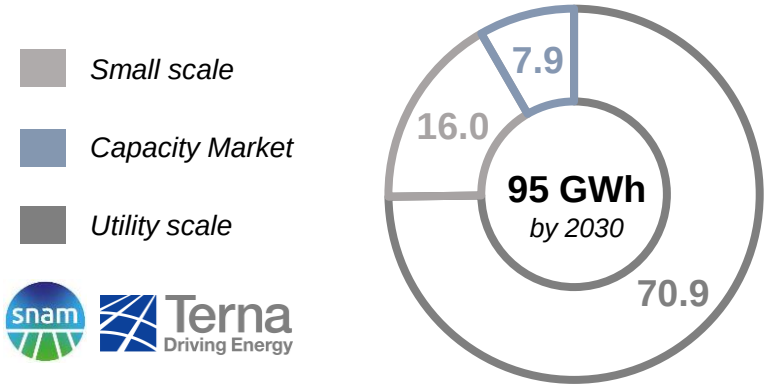


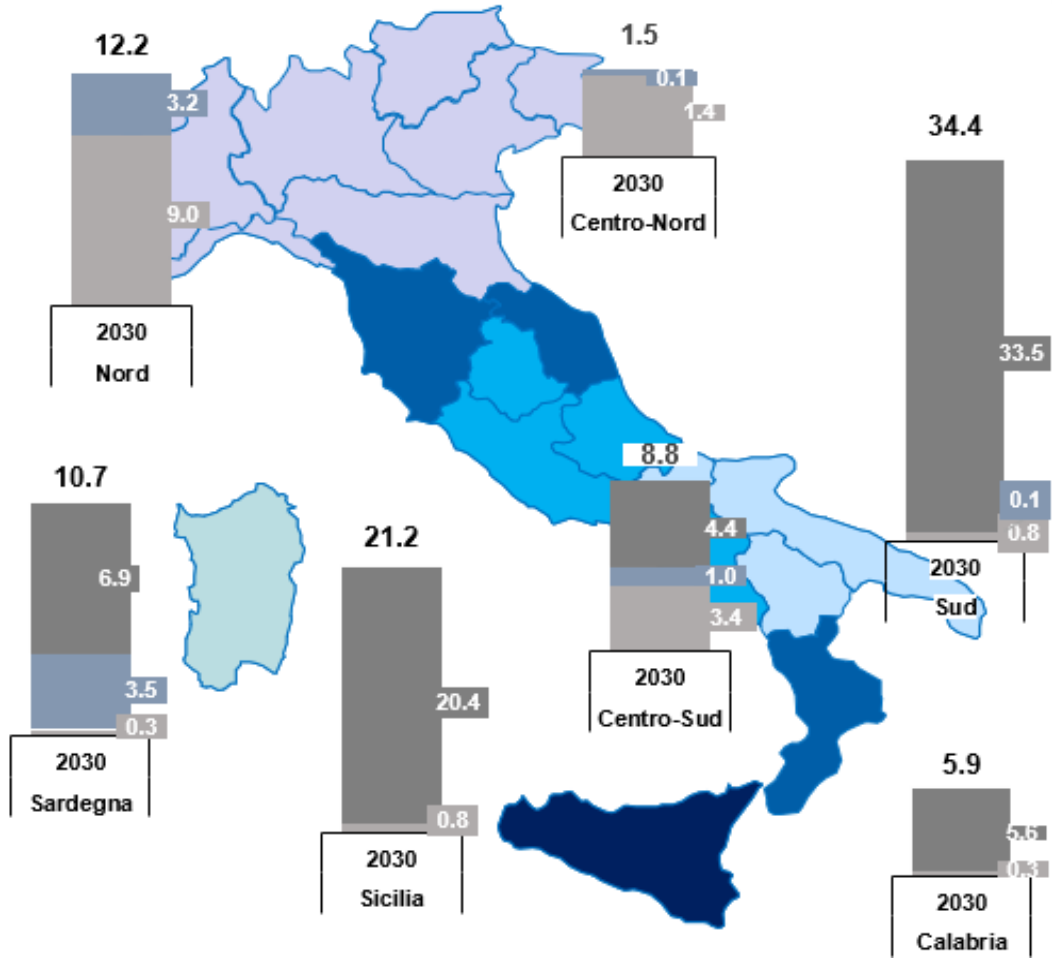
To reach the decarbonisation targets of the new National Energy and Climate Plan (NECP), in Italy it will be necessary to double the total renewable production and quadruple the photovoltaic one. The geographical location of such significant volumes must also be addressed through ad-hoc policy measures.

New capacity from Energy Storage System to reach the Fit-for-55 targets

ENERGY STORAGE NEED IN THE FF55 2030 SCENARIO[1] (GWh)

- Additional 95[2] GWh storage installations are required in the FF55 2030 scenario.
- The optimal dimensioning of new storage capacity and its location depend both on the evolution of the RES requests and on the timing of the development of the network infrastructure.
- Coordinated resource planning (RES, storage grid infrastructures) is needed to minimize the overall system costs.
- The increase in RES requires, and is enabled by, a coherent increase in the available storage capacity.





1. *Delta between 2019 and 2030 scenario «Fit-for-55» (FF55)*
2. *Corresponding to ~15 GW of energy storage (the calculation is made taking into account the different hours of operation of three technologies, on average equal to 6 operating hours)*

Agenda

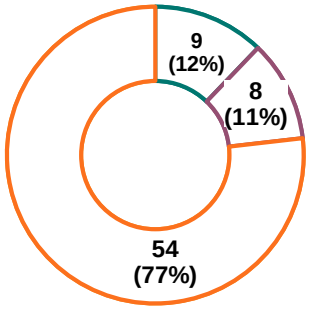
1. Energy transition in Italy
2. **Renewable connection requests**
3. Italian NDP 2023 and Hypergrid project

Grid connections request from renewable energy

SOLAR & WIND CONNECTION REQUEST

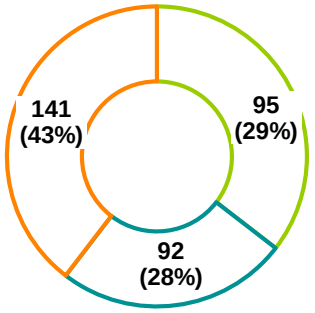
The **connection applications** to the national electricity transmission grid differs significantly from the «Fit-for-55» reference scenario in terms of **volume**, **distribution** and **technology mix**.

The effective realization of these projects may require additional network reinforcements.



+70 GW

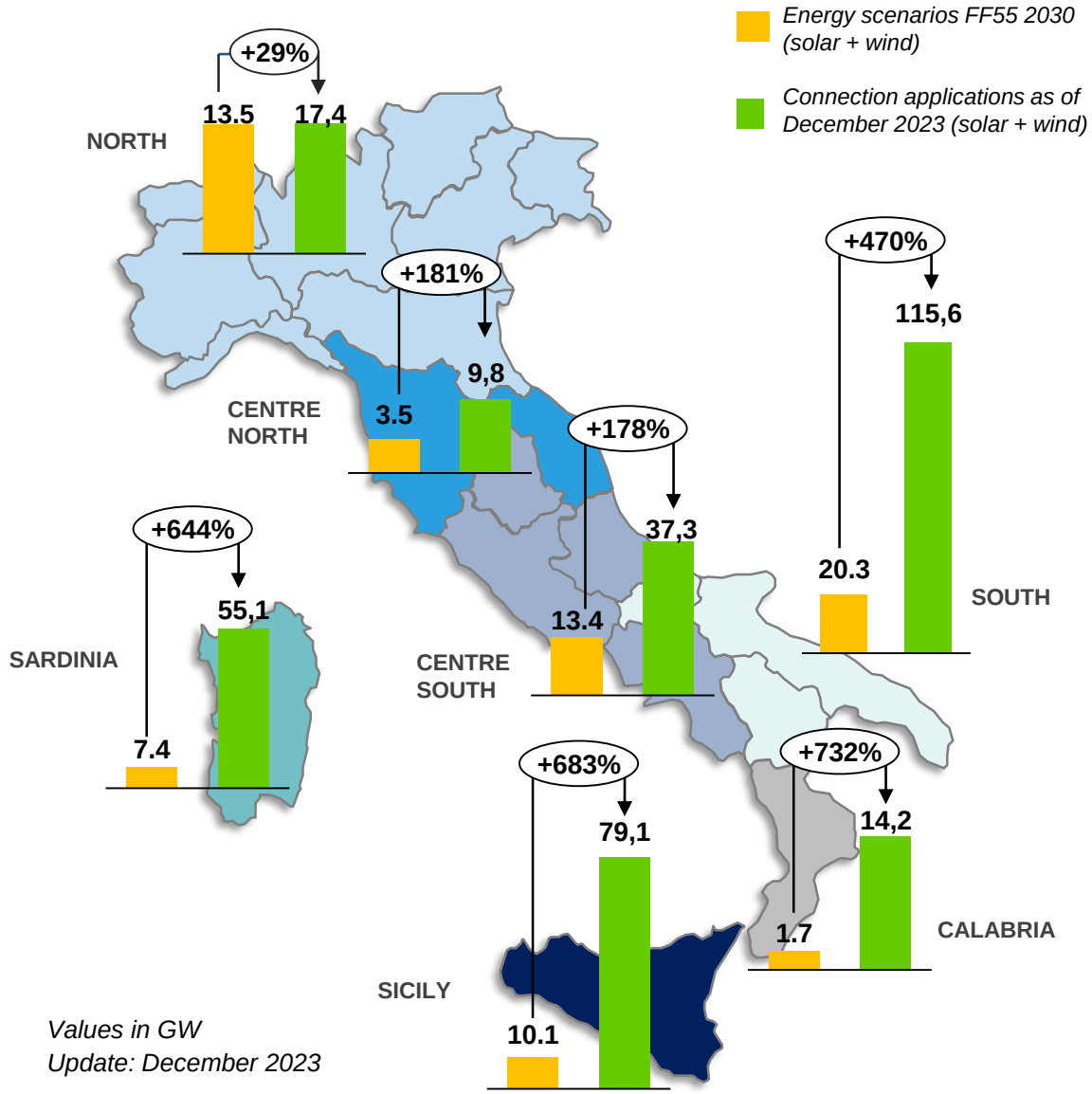
RES capacity increase «Fit-for-55» 2030[1]



+328 GW

Connection applications (December 2023)[2]

Wind offshore **Wind onshore** **Solar[3]**



1. *Delta between 2019 and 2030 scenario «Fit-for-55» (FF55)*
2. *Data net of connection requests received in MV/LV. For more information on the evolution of connection requests, see Econnextion*
3. *Sum of distributed solar and utility-scale*

Requests to connect off-shore wind parks

HIGHLIGHTS

- Wind off-shore connection applications are **11 times higher** than in 2030 policy scenario. As of june 2023, Terna received connection requests for ~**100 GW**, as compared to the 8.5 GW foreseen by the FF55 scenario
- The **average** size of wind offshore projects is **very large** (~45% > 700 MW)

- **Approx. 81% of the connection applications are in the Southern peninsula and main islands**, where the primary energy source is available and higher producibility is expected
- The regions showing most significant initiatives are **Apulia, Sicily and Sardinia**

- **The floating solutions** may be suitable for the bathymetry of the **Mediterranean Sea**, which is characterized by **depths of several hundred meters** just a few km away from the coast

ITALY - OFFSHORE WIND FARM PROJECTS MAP

Update: December 2023

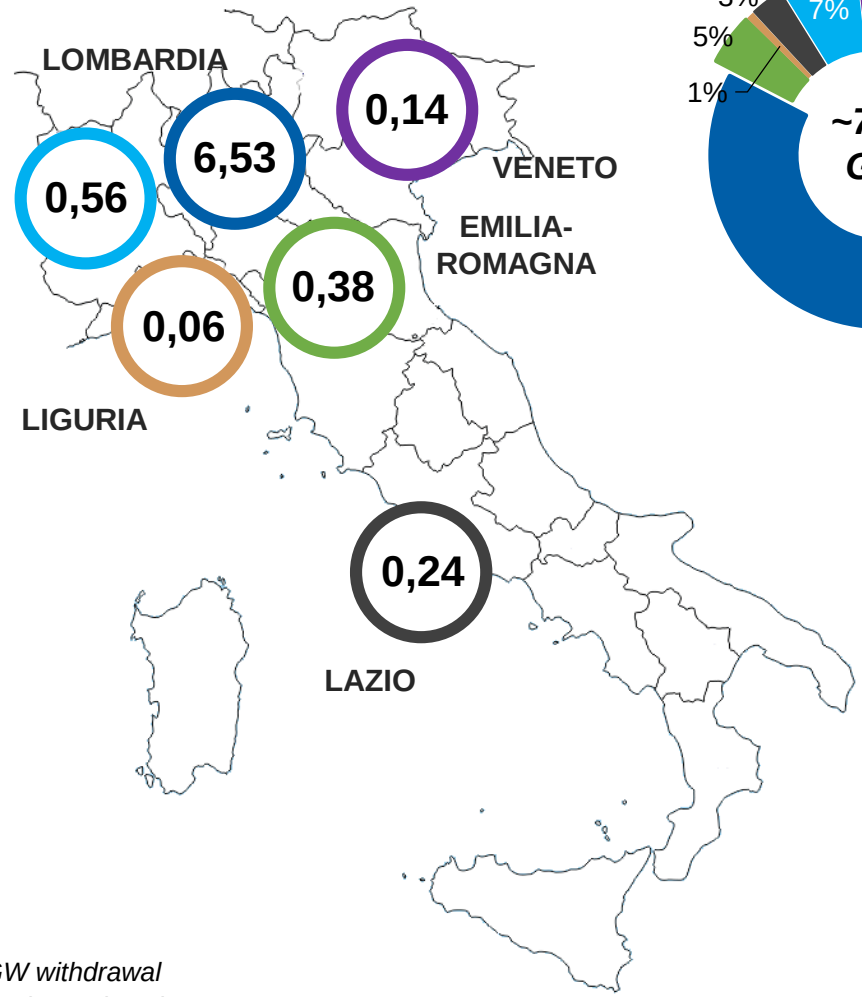
Connection requests for Data Centers

DATA CENTERS' TRENDS THAT WILL SHAPE THE FUTURE TRASMISSIN GRID

As pillars of digitalization, Data Center infrastructures are constantly growing. These energy consumers are characterized by very stringent connection requirements:

1. High power absorbed by the site in a rather constant way, requiring a **direct connection to the HV grid**
2. Power supply **continuity, with limited interruptions of service and outages**, such as to require a **dual HV grid connection**
3. Proximity to the telecommunications network
4. Geologically and thermally favourable environmental conditions.

For these reasons, the area of greatest interest is Northern Italy, specifically Lombardy with evidence of further developments in the North-West



GW withdrawal
Update: Dicember 2023

Agenda

1. Energy transition in Italy
2. Renewable connection requests
3. **Italian NDP 2023 and Hypergrid project**

Italian National Development Plan 2023

The 2023 Development Plan is issued in a historic moment that increasingly places the theme of energy at the center.

In this context, Terna must design a network capable of supporting progressive decarbonization and increasing **integration of renewables** while ensuring **efficiency, security and resilience** of the electricity system.

This challenge requires an effort to **plan, authorize and realize** grid infrastructures that is unprecedented in Italy.

The big news is the introduction of the innovative **Hypergrid project**, which will use the technologies of high-voltage direct current power transmission (HVDC) to achieve the goals of transition and energy security set by the European directive «Fit-for-55».

To meet these challenging goals, the 2023 NDP foresees **innovative and enabling solutions** (DC circuit breakers, 5-phases pylons, series compensation, capital light, etc.)

>21 Mld€

Network Development Plan 2023

+17%

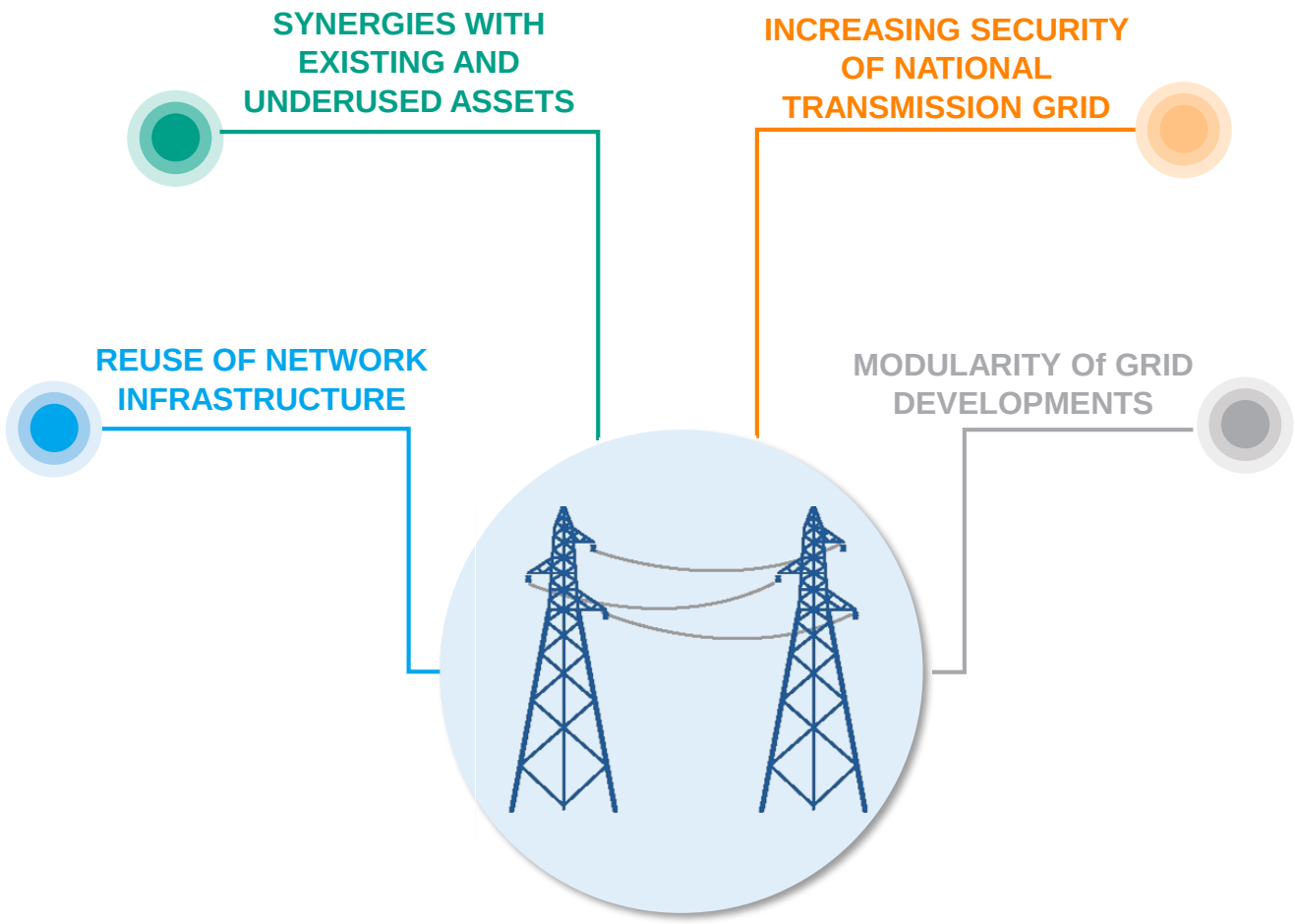
Compared to the NDP 2021

Italian National Development Plan 2023

MAIN DRIVERS

The NDP 2023 applies an **integrated and holistic planning approach** taking into account the whole electric power system.

- **Synergies with existing and not fully exploited assets**, enhancing the use of existing corridors through innovative DC or AC solutions with increased transport capacity
- **Reuse of network infrastructures** already decommissioned or in decommissioning, located in the area of strong network nodes
- **Increasing security of National Transmission Grid**, strengthening the grid with DC technology to increase the grid transfer capacity
- **Grid developments modularity** according to the amount of RES power plants in commissioning and expected to be connected to the grid



Italian National Development Plan 2023

HYPERGRID PROJECT

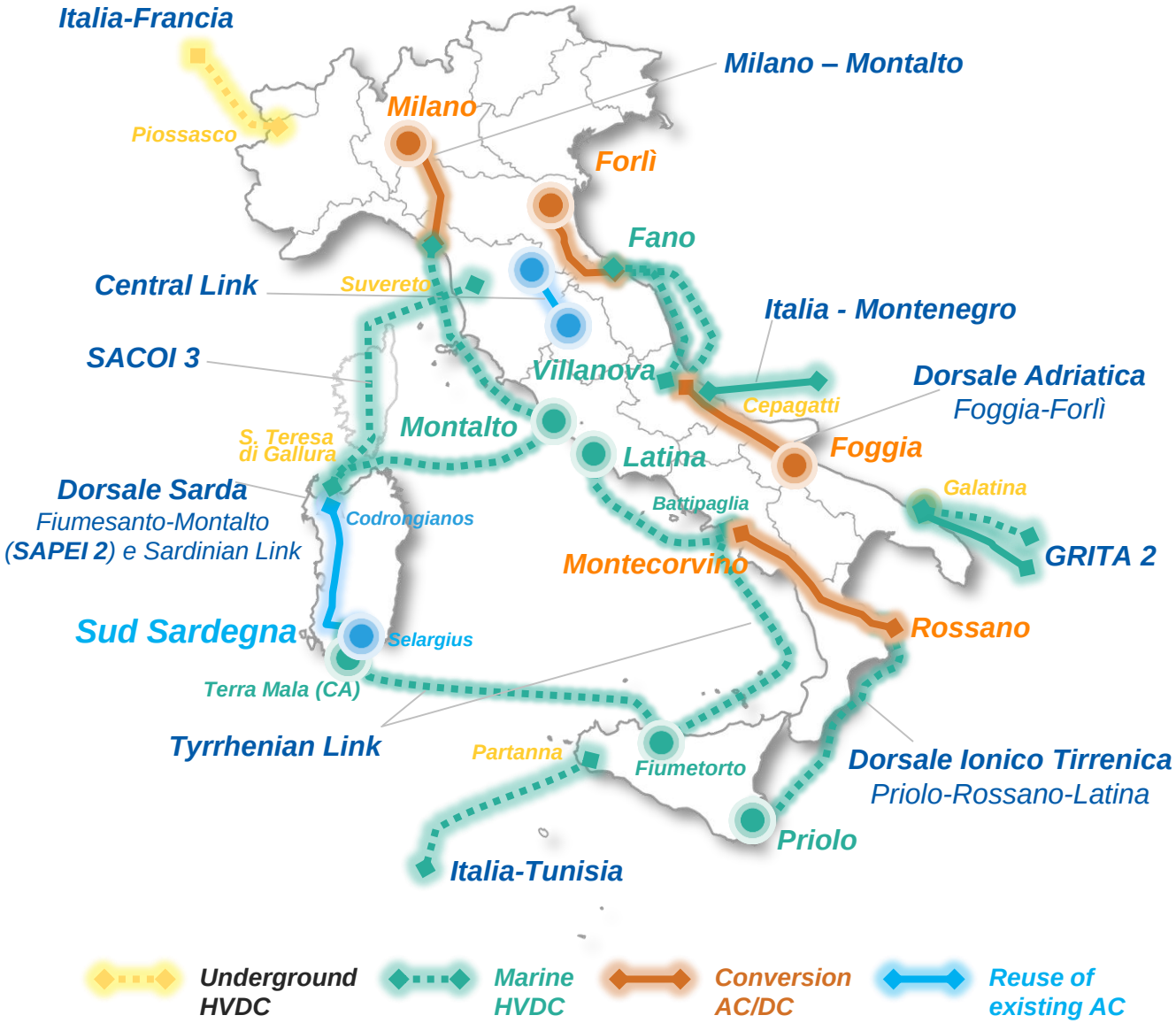
- Hypergrid will support and accelerate energy source diversification and climate neutrality, **increasing the NTC bidirectionality** among all the Italian market zones. The new HVDC layer will ensure operational flexibility, strengthening the grid in synergy with existing and underexploited assets and allowing a modular configuration.
- The planned corridors are:
  - ✓ **HVDC Milano - Montalto**
  - ✓ **Central Link**
  - ✓ **Sardinian** Corridor[1]
  - ✓ **Ionian – Tyrrhenian** Corridor[2]
  - ✓ **Adriatic** Corridor[3]

+16 GW

Transfer capacity across all bidding zones

~11 Bln€

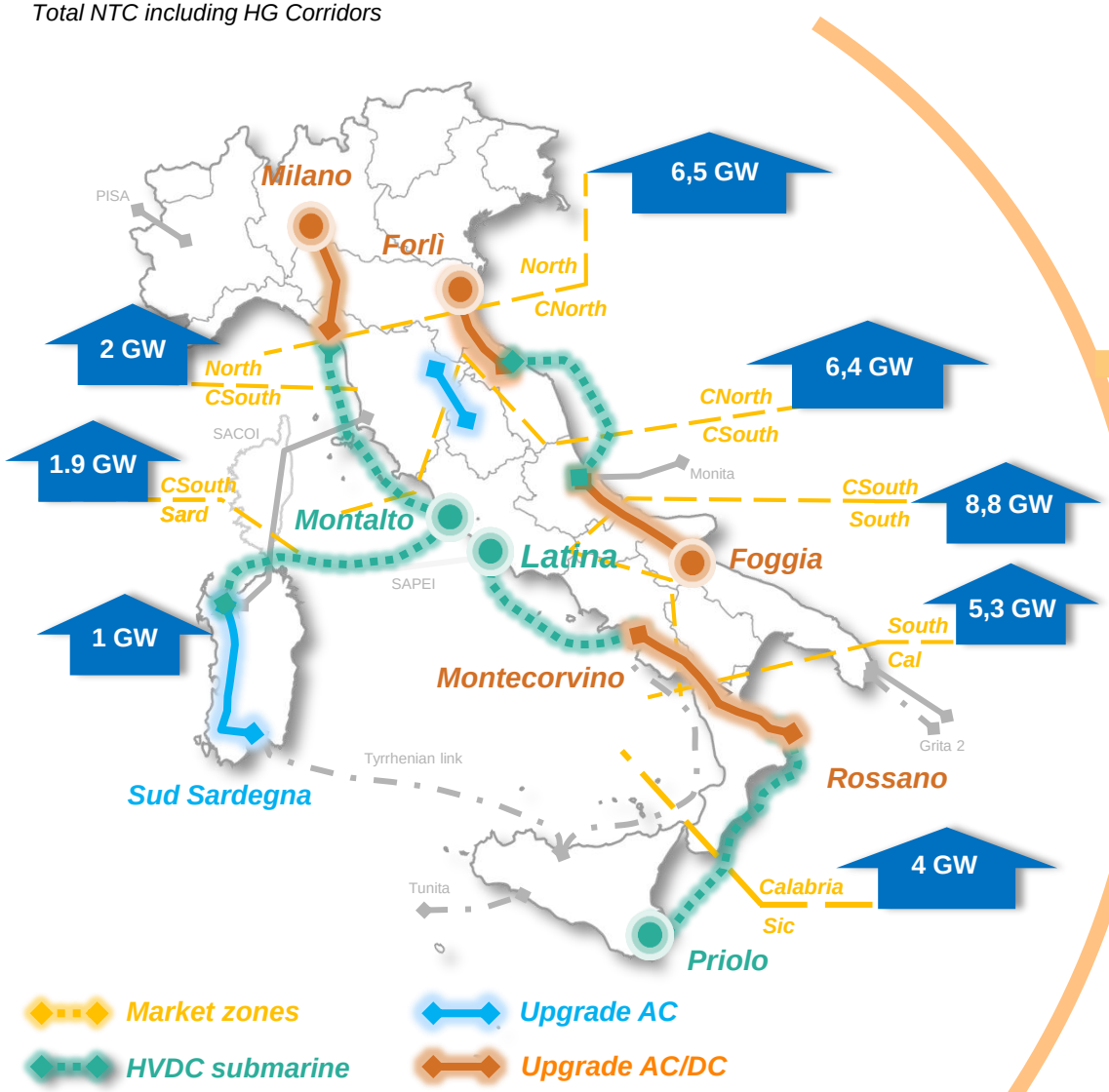
Total value over ten-year horizon (23-32) and beyond



1. *SA.PE.I 2 and Sardinian*
2. *HVDC Priolo-Rossano and HVDC Rossano – Montecorvino - Latina*
3. *HVDC Foggia-Villanova-Fano-Forlì*

Key features of the new Hypergrid project

Total NTC including HG Corridors



Double transfer capacity between bidding zones (up to +30 GW)

Improving **investments efficiency** (per unit cost of 0.7 Bln€/GW)

400+ km of AC power lines upgraded with new infrastructure technology

2500+ km of new DC overhead lines and cables

New AC/DC **converter station in VSC technology (**up to 13 GW)

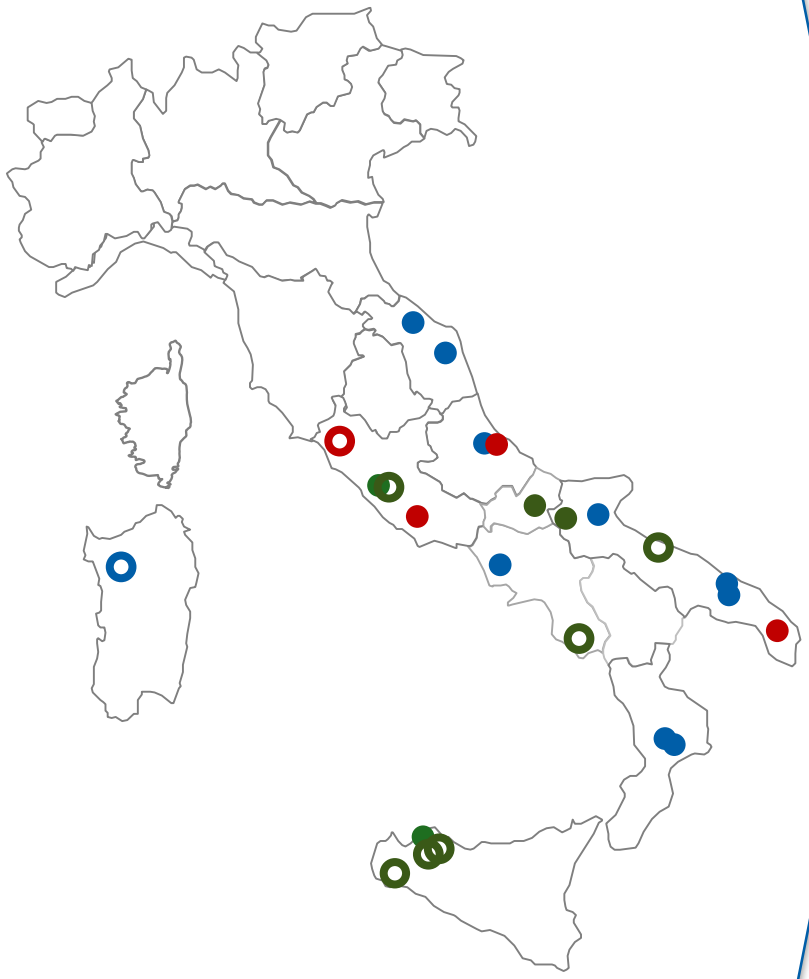
Preparing electricity grids for the challenges that lie ahead (**System Strength, Flexibility**)

Stability and voltage profile

INSTALLED EQUIPMENT UNTIL DECEMBER 2023 IN THE 400 kV NETWORK

- **Reactors**
- **Synchronous condensers**
- **STATCOM**

- **Reactors** (*Entry into operation in 2023*)
- **Synchronous condensers** (*Entry into operation in 2023*)
- **STATCOM** (*Entry into operation in 2023*)



ACTUAL AVAILABLE CAPACITY

SC

10

2500 MVAr

Reactors

11

2148 MVAr

STATCOM

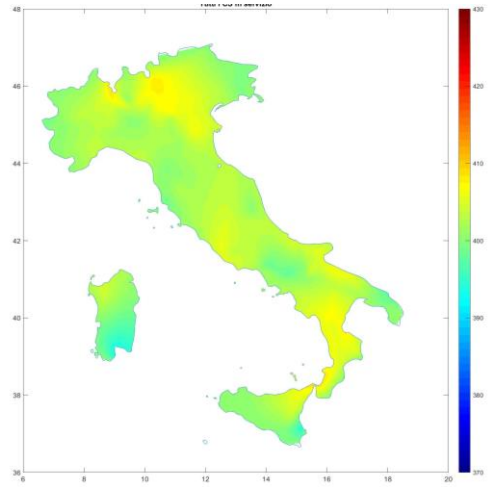
4

500 MVAr

Minimization of conventional generation used for reactive power compensation

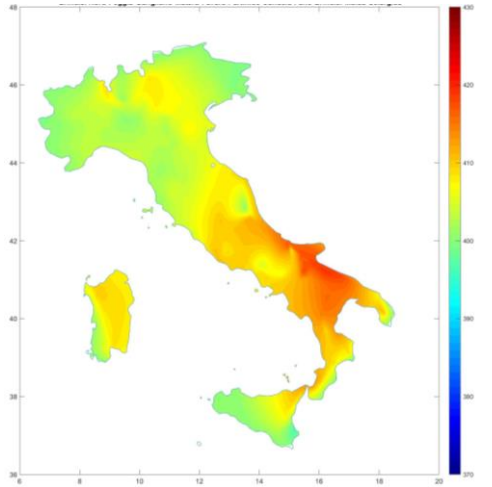
USE CASE

The availability of reactive power compensation device allows to significantly reduce the contribution required to conventional generation for this type of regulation, and to remove the violations that prevent putting expensive power plants out of service.



Recordings of 01.02.2022 between 00:00 – 03:00

- Voltage below 420 kV (all nodes)
- No dispatching orders to power pants

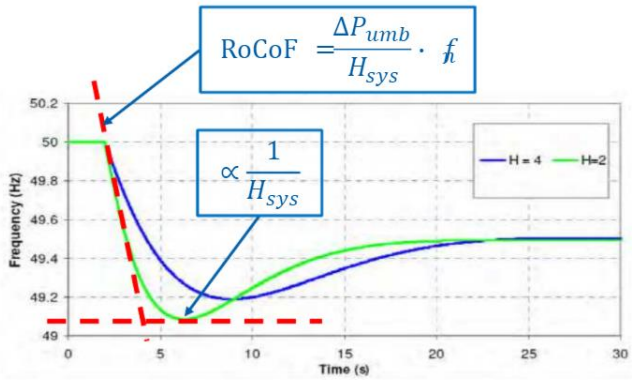


Simulation of 01.02.2022 between 00:00 – 03:00

- Widespread violations above 420 kV
- Need to start power plants

Further to voltage regulation/ reactive reserve, SCs provide the following advantages:

- Increase of **short-circuit current**, to the benefit of protection system (fault clearing time, selectivity)
- Increase of **system inertia**, to the benefit of frequency transients (reduction of amplitude and of Rate of Change of Frequency, RoCoF)
- **Oscillations damping** and increase of **transient stability**



RES integration in the Italian transmission system: action plan

2030

INFRASTRUCTURE DEVELOPMENT

- *Strengthening grids and interconnections*
- *Increasing investments in voltage regulation devices*
- *Increasing resiliency*
- *Investments in capital-light technologies and defense system*

Developing the infrastructures needed to enable RES integration

MARKET DESIGN

- *Identifying the right mix of market design to integrate future and spot markets, for both energy and services*
- *Enlarging supply of flexibility services by "new" sources*

Transforming participation in smart and sustainable markets

STORAGE

- *Developing new hydroelectric and electrochemical storage systems*
- *Dealing with overgeneration and residual load ramps*
- *Contributing to adequacy*

Sizing amount needed and technology mix

RENEWABLE INTEGRATION

- *Speeding up installations, through swift permitting process*
- *Ensuring optimal location planning of new RES installations*

Addressing technology mix and optimizing location


Terna
Driving Energy