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Energy Planning Laboratory A.Y. 23-24

Energy Planning for Italy

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Outline

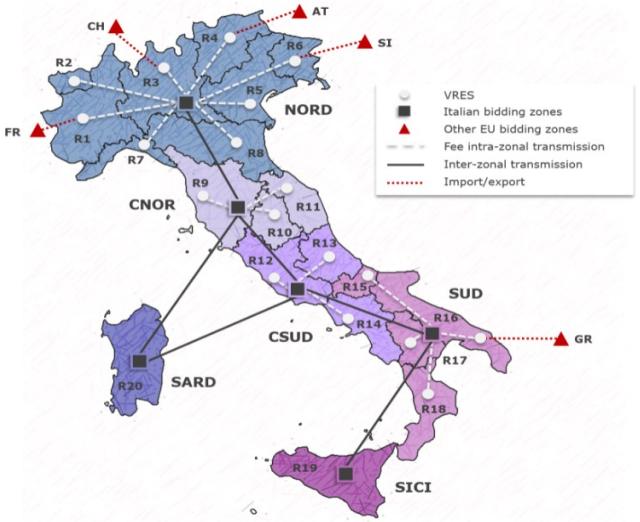
Modelling Scenarios:

- ❑ Base case, the italian situation in 2023 without any modification
- ❑ 2030 case, a suggestion on how to comply to the “fit for 55 plan”
- ❑ 2050 case, in which Italy reaches carbon neutrality in 2050
- ❑ Potential off-shore wind farms in Italy; a study on how the current energy mix would change with the hypothetical instant installation of off-shore wind farms

Modelling Approach

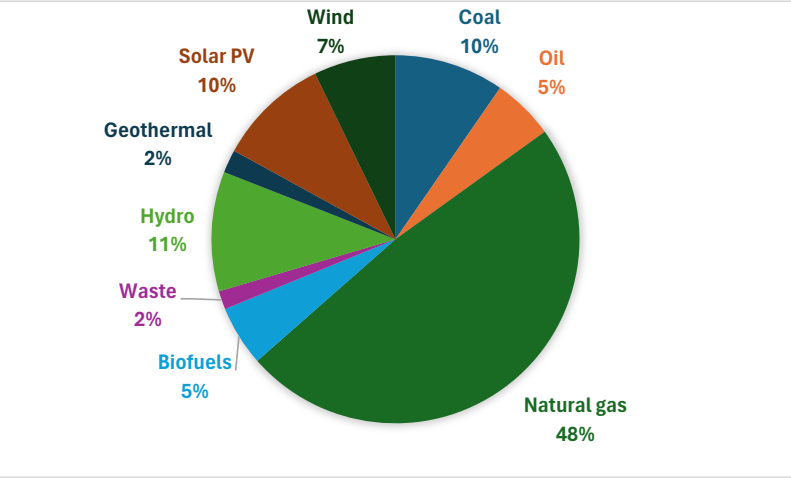
- ❑ Energy System Model: Calliope

- ❑ Operation Mode, used when analyzing current (or hypothetical current) energy mix
- ❑ Planning Mode, used when suggesting pathways to reach certain policies
- ❑ Optimization: Least costly Solution
- ❑ No unmet demand

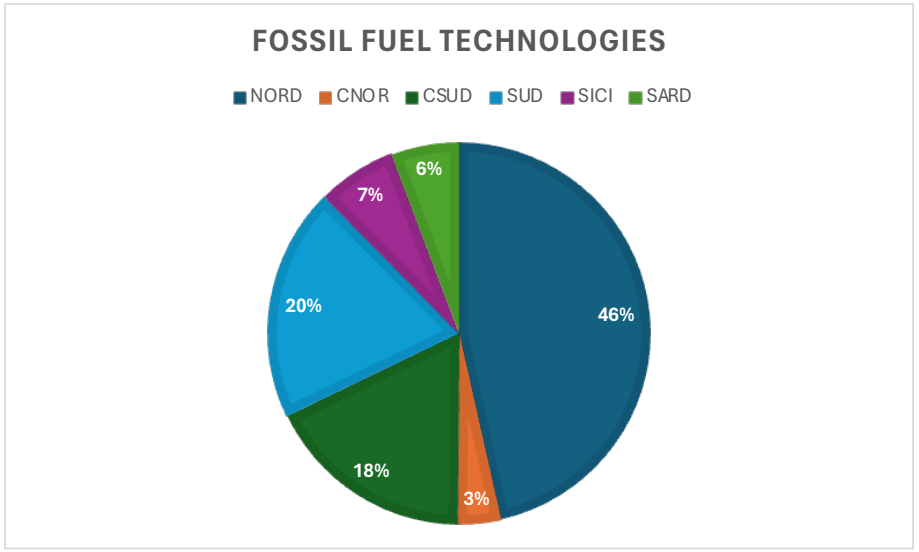


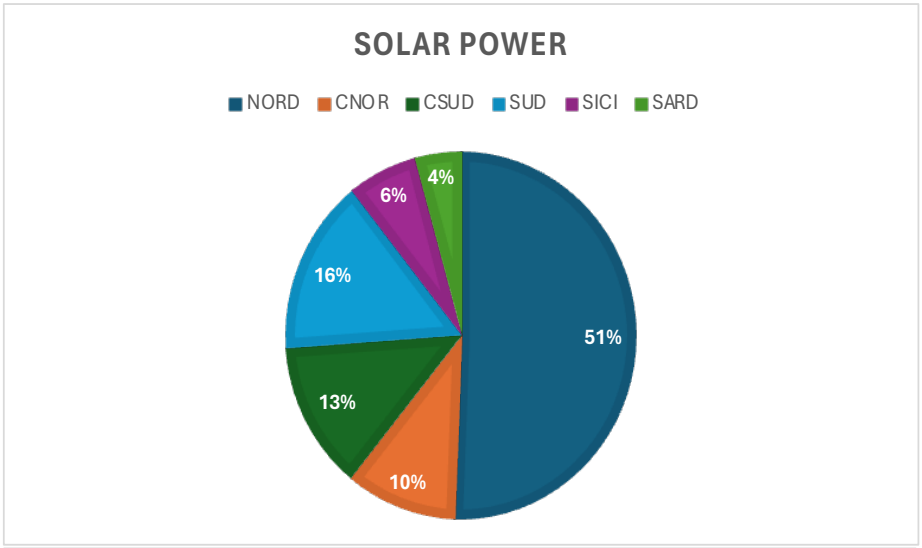
Base Case - Current Situation (2023)

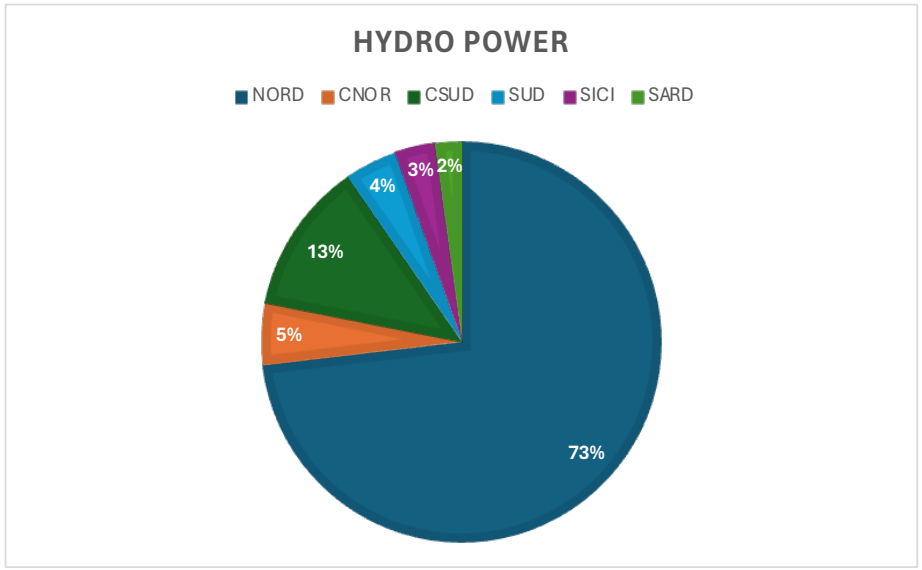
- ❑ Diversity
- ❑ Renewable Energy Growth, Notably solar and wind power
- ❑ Government Support
- ❑ Reducing Carbon Emissions
- ❑ Role of Natural Gas
- ❑ Coal Phase-Out
- ❑ Regional Disparity (In generation & consumption)
- ❑ Intensity of the Energy Mix = 0.18 $kgCO_2/kWh$
- ❑ System Total Levelized Cost of Electricity = 0.127 €/kWh

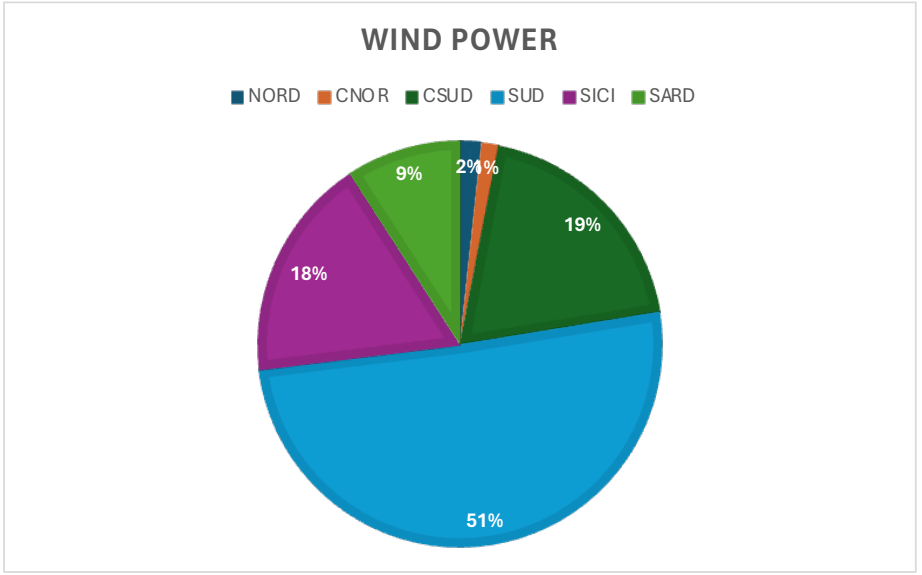


Base case – Regional Differences in Electricity Generation









Implemented Policies

❑ Fit for 55

A comprehensive energy policy package proposed by the European Commission aimed at reducing greenhouse gas emissions by at least 55% by 2030 compared to 1990 levels, through measures such as expanding renewable energy, implementing carbon pricing, and promoting energy efficiency across various sectors.

❑ Climate neutrality (Paris agreement)

An international treaty designed to combat climate change by aiming for carbon neutrality by 2050, achieved through voluntary emissions reduction commitments from participating countries and promoting global cooperation on climate action.

Implemented Policies

❑ Fit for 55

1990 equivalent CO_2 emission of the energy sector in Italy = 124 Mt CO_2

The CO_2 cap implemented to the model for 2030 = 55.8 Mt CO_2 (45% of the 1990 value)

Projected demand increase = 19.6%

❑ Climate neutrality (Paris agreement)

The CO_2 cap implemented to the model for 2050 = 0 kg CO_2 (Carbon neutrality)

Projected demand increase = 83%

Other limitations

- Italy maximum potential:

PV Farm = 90 GW (for 2030)

On-Shore Wind Farm = 60 GW (for 2030)

PHS = 10 GW (overall)

Geothermal Power Plant = 2 GW (overall)

Run-of-River Hydro Power Plant = 8 GW (overall)

2030 - Modelling Results

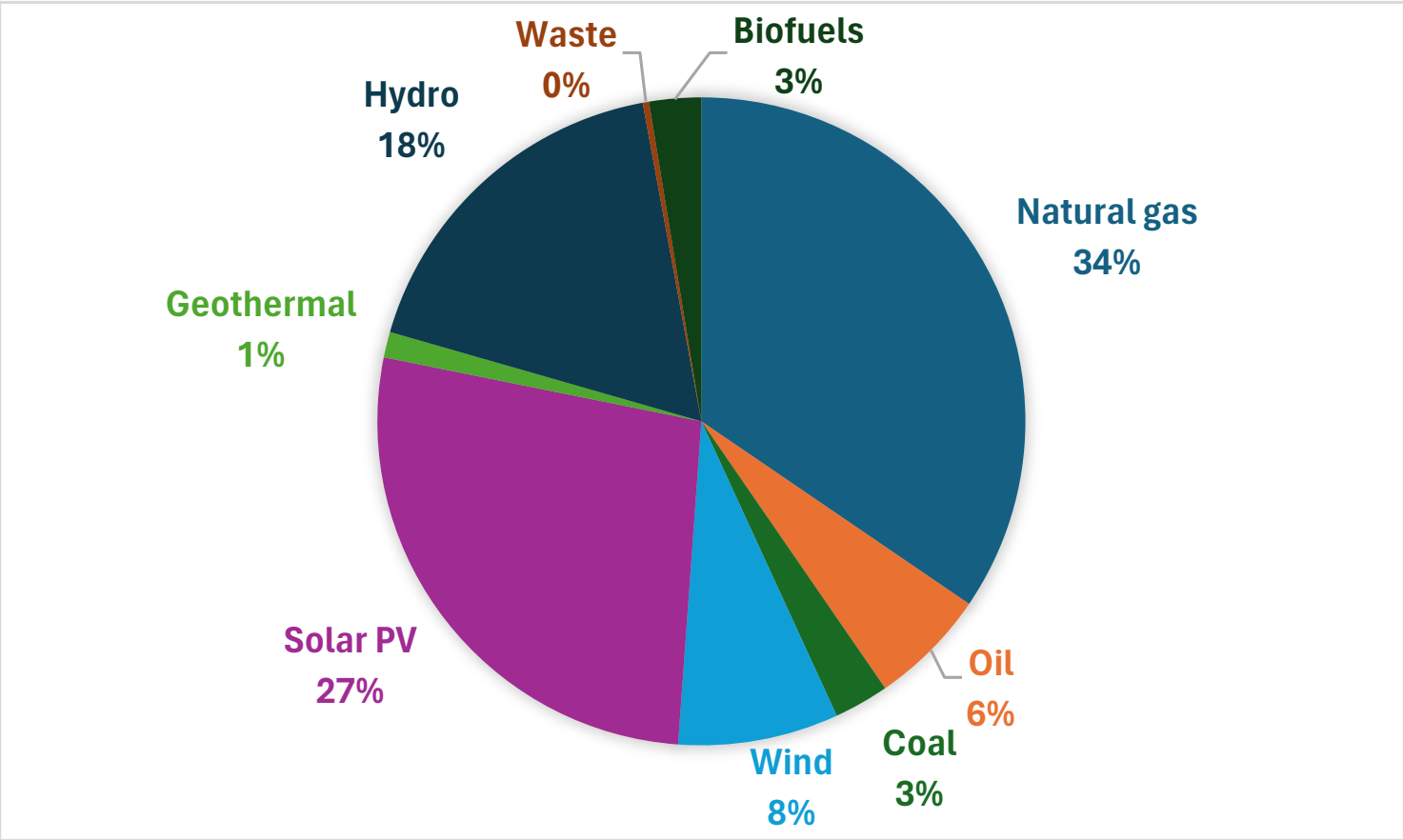
- ❑ Fading out of fossil fuel power plants
- ❑ Important installations of green power plants
- ❑ Natural Gas dispatching importance
- ❑ System Total Levelized Cost of Electricity = 0.099 €/kWh
- ❑ System CO_2 Intensity = 0.015 $kgCO_2$/kWh

	Investment Costs (milion €)
NORD	2428.95
CNOR	722.08
CSUD	598.34
SICI	225.04
SUD	55.83
SARD	51.78
Tot.	4082.03

	Geothermal	ROR Hydro	PHS	PV Farm	Off-shore Wind	On-shore Wind
NORD	0.00	2.94	1.51	8.94	0.00	0.00
CNOR	1.18	0.00	0.43	0.00	0.00	0.00
CSUD	0.00	0.00	0.50	4.04	0.00	0.00
SUD	0.00	0.00	0.00	0.00	0.00	0.28
SICI	0.00	0.00	0.00	1.87	0.00	0.02
SARD	0.00	0.00	0.00	0.00	0.00	0.26

Installed capacity between 2023-30 (GW)

2030 - Modelling Results



Energy Mix

2050 - Modelling Results

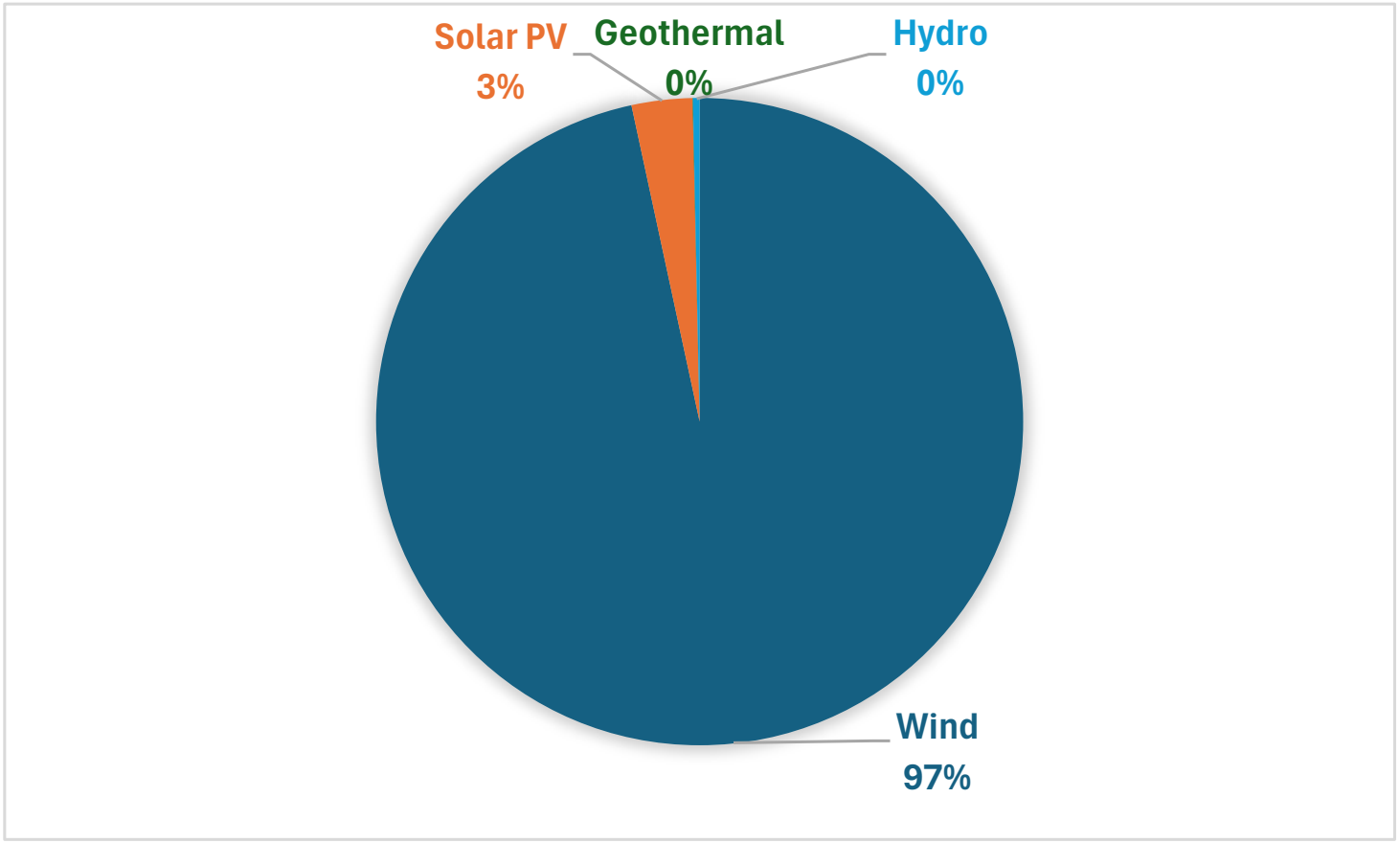
- Improvements in transmission lines were taken into account.
- Phasing out of fossil fuel power plants completely
- Unrealistic installations of green power plants & unrealistic investment cost
- System Total Levelized Cost of Electricity = 3.971 €/kWh
- CO_2 neutrality

	Investment Costs (milion €)
NORD	1787693.24
CSUD	228033.39
CNOR	97569.10
SICI	49406.59
SUD	28653.55
SARD	21501.69
Tot.	2212857.55

	Geothermal	ROR Hydro	PHS	PV Farm	Off-shore Wind	On-shore Wind
NORD	0.00	2.94	0.36	172.72	2232.06	3995.01
CNOR	1.18	0.00	0.00	38.83	42.06	375.83
CSUD	0.00	0.00	0.00	0.00	94.55	948.68
SUD	0.00	0.00	0.00	7.31	26.11	83.00
SICI	0.00	0.00	2.08	4.38	1.49	242.85
SARD	0.00	0.00	0.00	4.57	17.52	67.47

Installed capacity between 2023-50 (GW)

2050 - Modelling Results



Energy Mix

- ❑ No dispatchability
- ❑ Peak demand

Solutions:

Provide system with dispatchability

- ❑ Green Power Plants: Nuclear Power Plants & OXC CCS
- ❑ Storage: Hydrogen & Batteries

2050 - Solutions (Nuclear Power Plants)

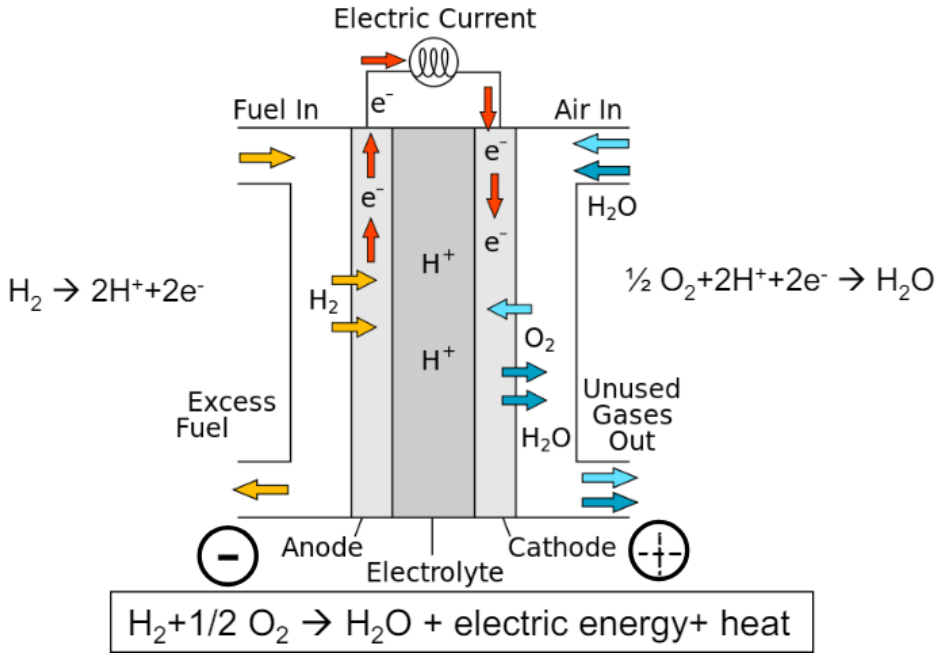
- 3rd Gen fission nuclear reactor: Neglecting possible developments in the technology
- Companies (like Terrapower) are creating 3rd generation nuclear power plants starting from old coal plants, reducing costs.
- Nuclear is a divisive topic, but the public opinion is starting to change.
- Maximum installed capacity of 2 GW for each region (Safety concerns, Public acceptance, Grid stability, Technological constraints)

2050 - Solutions (OXC CCS)

- OXC CCS: a carbon capture technology that involves burning fossil fuels in a mixture of pure oxygen and recycled flue gas, resulting in a concentrated stream of carbon dioxide
- OXC CCS can be implemented in already existing CCGT plants!
- CCGT technology can be used to burn Hydrogen instead of natural gas.
- It is possible, if needed, to add to already existent coal plants a gas turbine, creating new OXC CCS at lower investment costs.
- It is assumed that all the existing CCGT power plants, are converted to OXC CCS power plants by 2050.

2050 - Solutions (Hydrogen)

- Hydrogen: Electrolyzer/Fuel Cell pair can be considered a storage.
- Maximum storage capacity of 5 GWh for each region (Technology maturity, Grid integration, Land use, Infrastructure)



2050 - Solutions (Batteries)

- ❑ Using Lithium-ion batteries as a form of storage
- ❑ Long term feasibility of the solution as capacity costs will eventually decrease.
- ❑ 4 hours of energy capacity per storage capacity is assumed.
- ❑ Maximum storage capacity of 10 GWh for each region (Technology maturity, Costs)

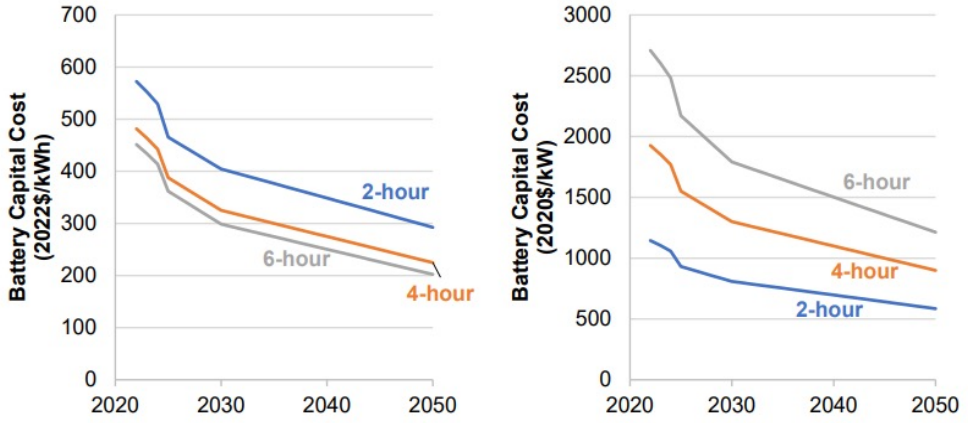


Figure 5. Cost projections for 2-, 4-, and 6-hour duration batteries using the mid cost projection.
Left shows the values in $/kWh, while right shows the costs in $/kW.

2050 - Modelling Results

- ❑ Green power plants & storage systems are helping meet the peak demand.
- ❑ Much more realistic installations & costs.
- ❑ System Total Levelized Cost of Electricity = 0.14 €/kWh
- ❑ Running the model with only one of each solutions alone, we found out that although none of the solutions are impossible to neglect, the diversity of the solutions helps the feasibility.

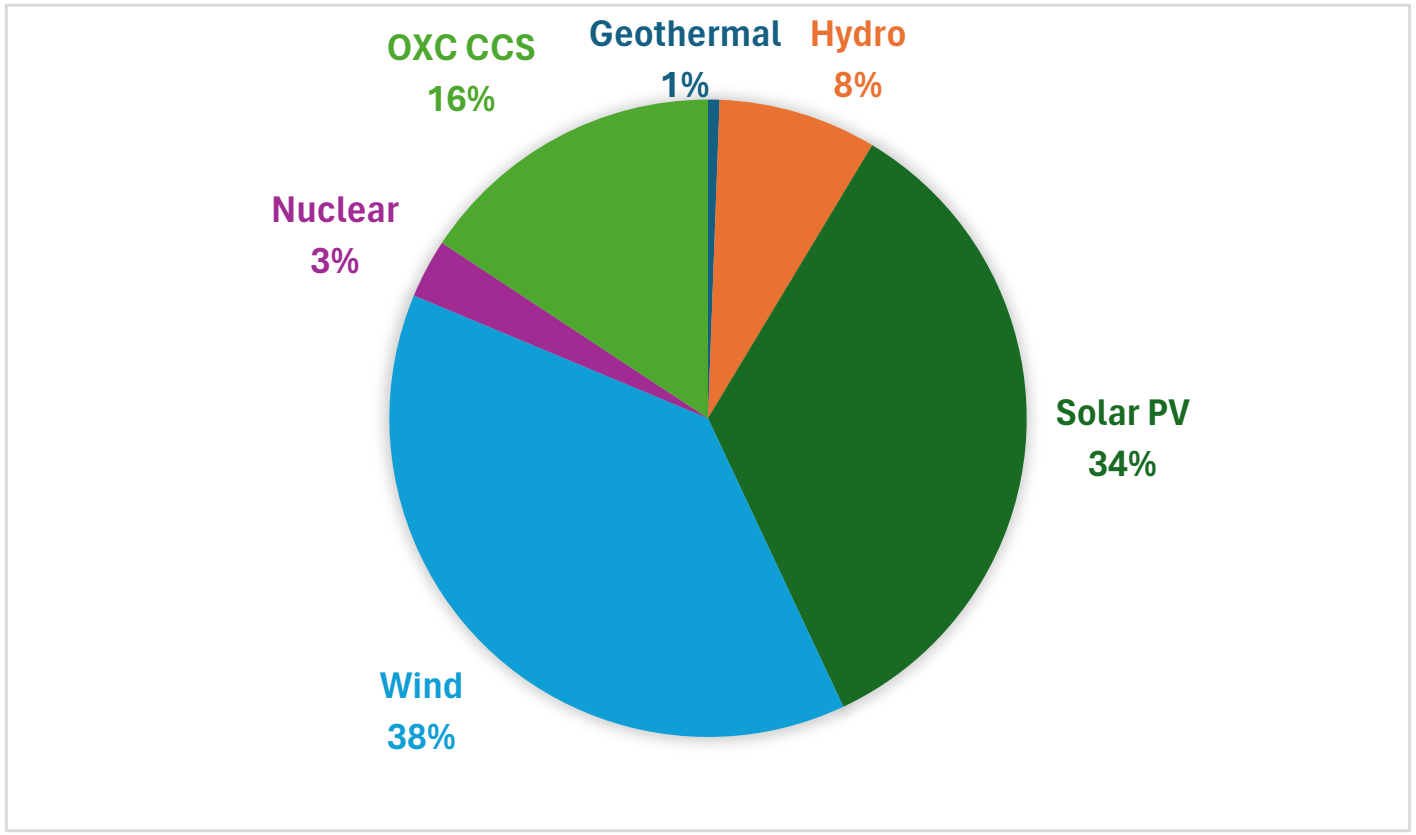
	Investment Costs (milion €)
CNOR	24050.21
CSUD	18189.12
NORD	12712.83
SUD	411.38
SICI	1273.47
SARD	4087.95
Tot.	60724.96

Around 5% of the previous case!

	Geothermal	ROR Hydro	PHS	PV Farm	Off-shore Wind	On-shore Wind	Nuclear	OXC CCS
NORD	0.00	2.01	2.44	85.47	0.00	0.00	2.00	28.00
CNOR	1.18	0.00	0.00	0.00	33.79	37.07	2.00	2.00
CSUD	0.00	0.93	0.00	5.28	36.32	0.00	2.00	8.80
SUD	0.00	0.00	0.00	0.00	1.37	11.17	2.00	8.80
SICI	0.00	0.00	0.00	0.00	0.00	0.00	2.00	4.00
SARD	0.00	0.00	0.00	0.00	0.00	0.00	0.25	2.40

Installed capacity between 2023-50 (GW)

2050 - Modelling Results



Energy Mix

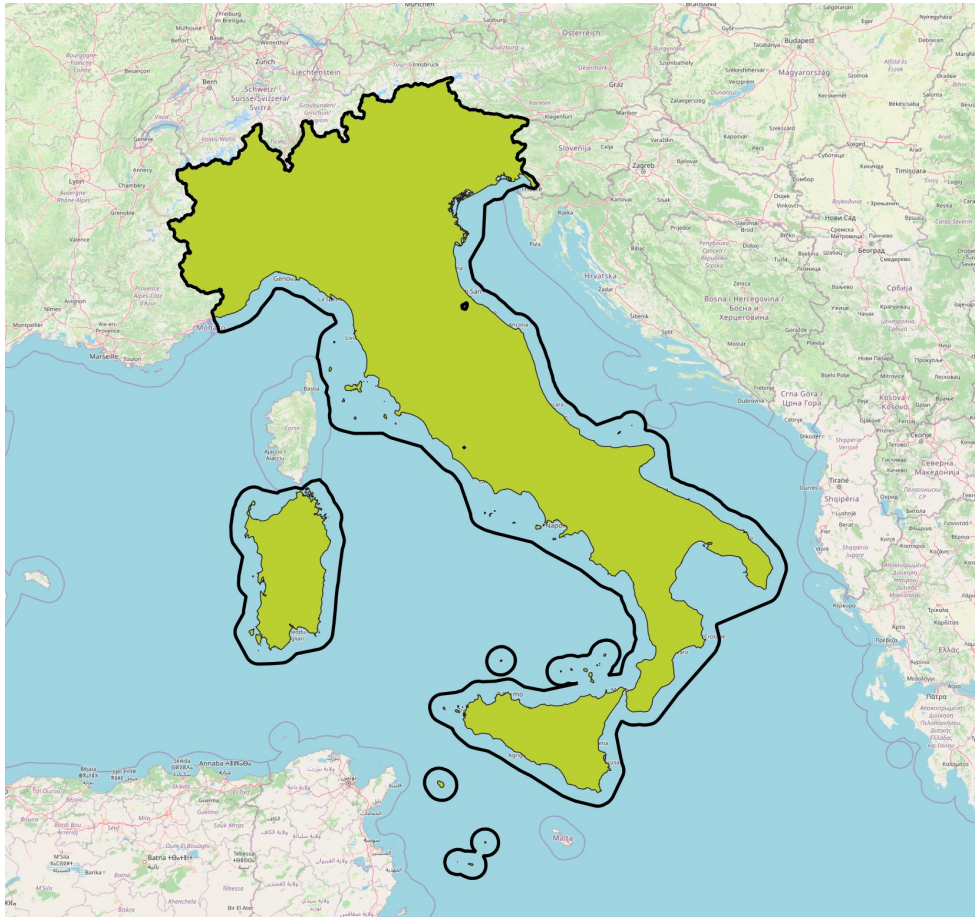
Energy Modelling Systems Limitations

- Modeler's approach may lead to forced solutions, and not unbiased ones.
- Not every important factor can be evaluated mathematically. (e.g., Public opinion, Job employment,...)
- Calliope optimizes based on the final demands and does not consider the process and the years in between.
- Optimized solution is just one point in decision space. This single solution is based on a plethora of hypothesis, and many uncertainties are involved. Generating “Near-Optimal Solutions” can help us with that.

Potential off-shore wind farms in Italy

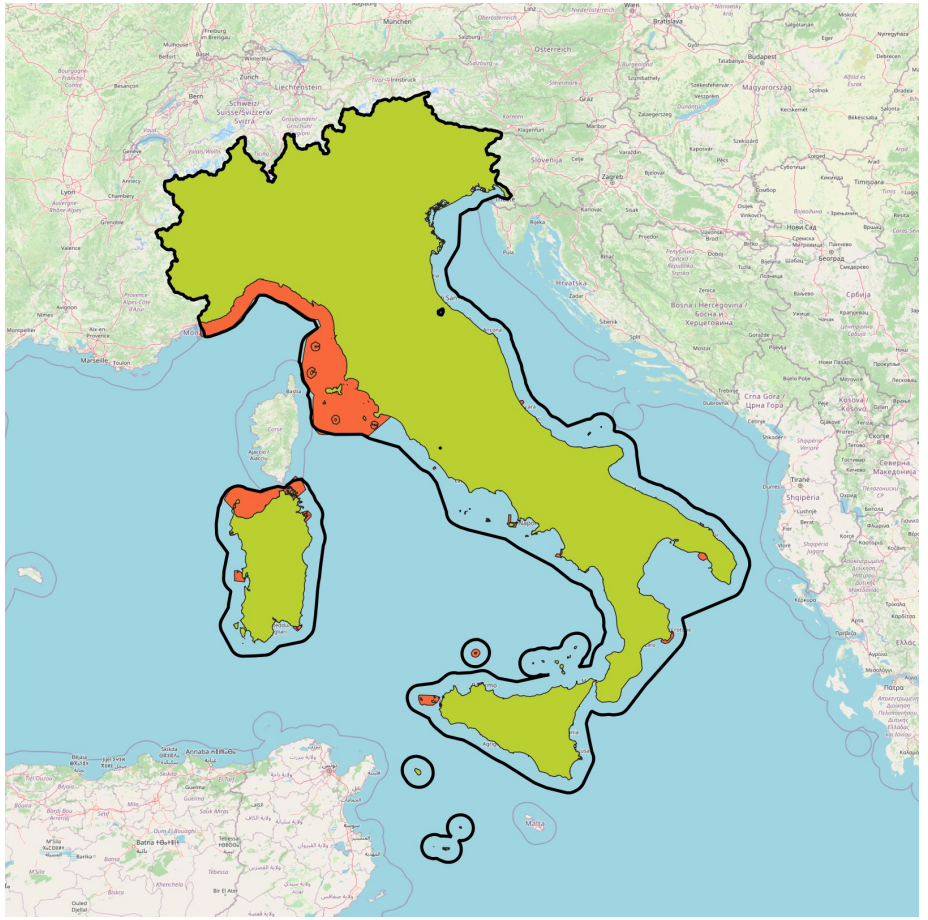
- Geographic Information System: QGIS

1. Areas inside Italian territory, but not in the land



Potential off-shore wind farms in Italy

2. Excluding the protected areas

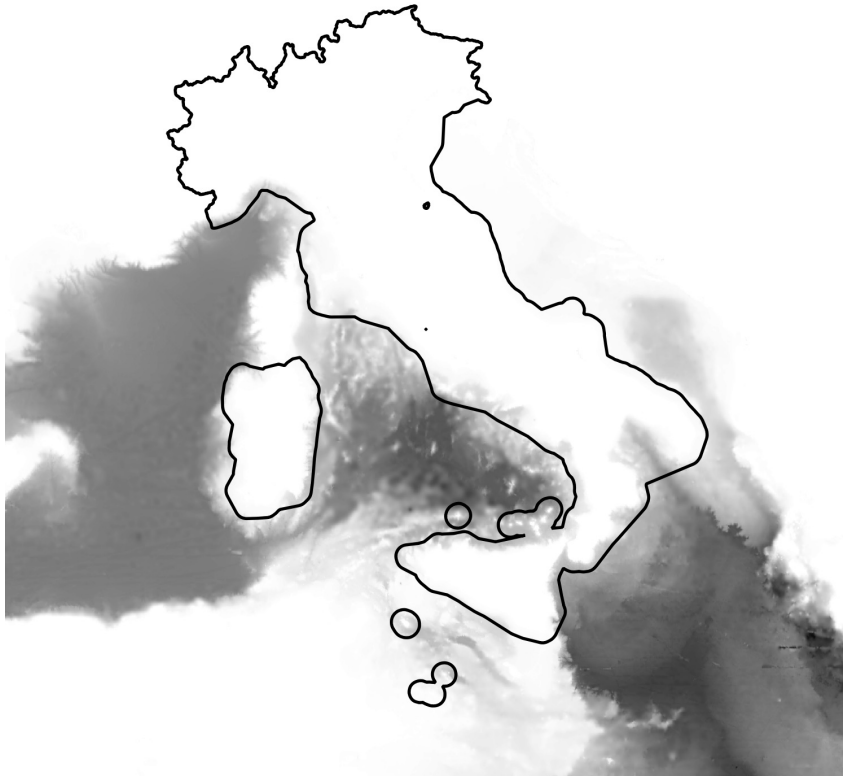


Potential off-shore wind farms in Italy

3. Using an elevation raster to assign each grid point with a depth

To use monopile foundation, the depth of the water should be between 50-150m.

(due to the higher costs of installation, floating off-shore wind was excluded in the Off-shore integration)



Potential off-shore wind farms in Italy

4. Using a raster of mean wind speed to assign each grid point with an average value of the wind speed

An average wind speed of at least 7.5 m/s for each grid point is desirable.

Potential off-shore wind farms in Italy

5. Filtering the grids, to find suitable sites

The 5 proposed locations have the following characteristics:

1. Inside Italian territory
2. Off shore
3. Outside protected areas
4. Water depth between 50-140m
5. Average wind speed higher than 7.5 m/s

Potential off-shore wind farms in Italy

Ait / Regione Sardegna

Nuova protesta a Cagliari contro mega impianti rinnovabili

SARDINIA

WIND POWER

16 settembre 2023 alle 07:13

The Sardinians don't want the lords of the wind but Rome continues

However, the Undersecretary for the Environment and Energy Security, Claudio Barbaro, yesterday in Olbia underlined the importance of involving the population

CRONACA SARDEGNA

INCHIESTA

23 aprile 2024 alle 15:01

Assalto eolico, in porto le navi cariche di pale

Nella banchina industriale di Oristano un carico imponente di aerogeneratori da 200 metri d'altezza

Potential off-shore wind farms in Italy

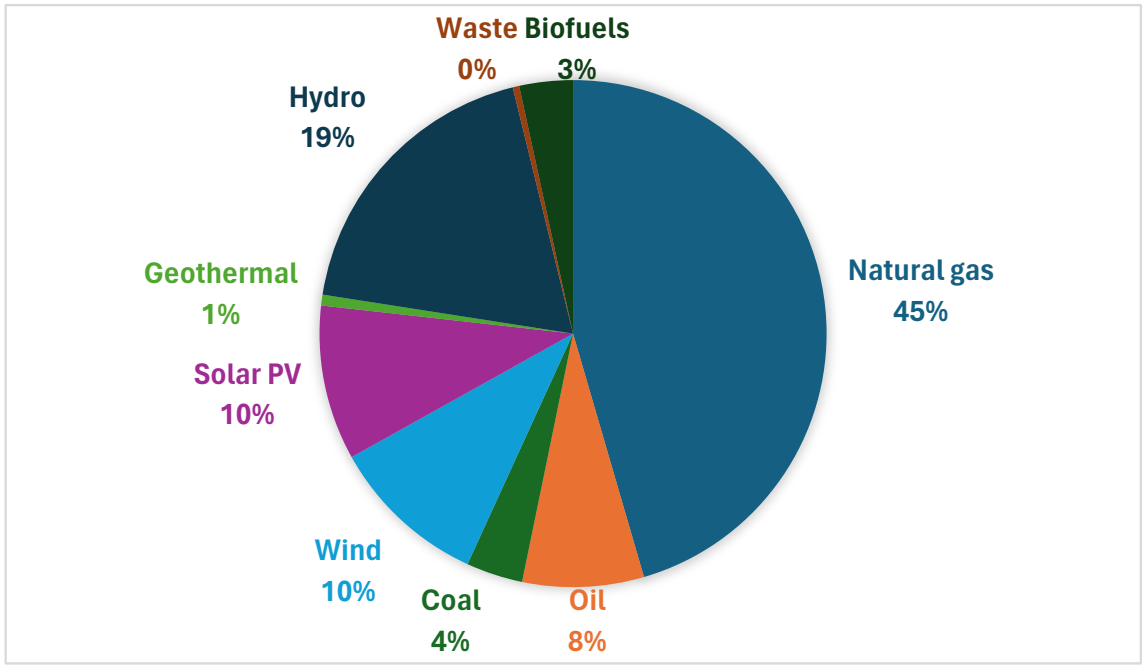
- Proposed locations, with specifications:

Location	Investment Costs [€/kW]	O&M Fixed Costs [€/kW/y]	Total Capacity [MW]	Distance from coast
Sardinia_NE	3117	97.41	728	7.5km
Sardinia_SE	3117	97.41	728	7.5km
Vieste	3124	97.63	728	12km
Mazara del vallo	3111	97.22	728	4.1km
Santa Maria di Leuca	3122	97.56	728	10.5km

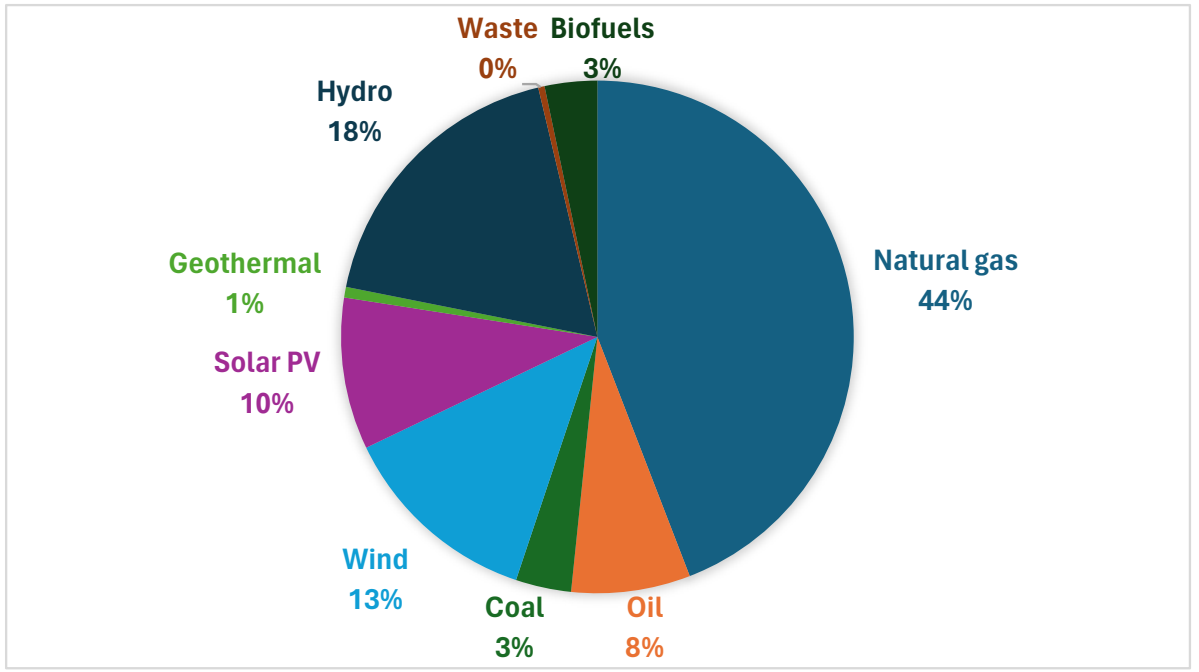
- Capacity factors for each location have been calculated. Each proposed location has been introduced to Calliope as a separate technology, with specific costs and capacity factors.

Potential off-shore wind farms in Italy - Results

- Adding the 5 proposed off-shore wind farms to the current energy mix of Italy (2023)



Current Energy Mix



Current Energy Mix, with 5 proposed off-shore wind farms

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Thanks for your attention!