Energy system model
Italy 2030

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ENERGIA CLIMA
2030

[1] Proposta di piano PNIEC, 2018
Italy - PNIEC at 2030

Target

- 40% emissions at 2030 respect to value of 1990

32% RES share

55.4% electricity sector
33% heat sector
21.6% transport sector

Figura 11 – Traiettorie di crescita dell’energia elettrica da fonti rinnovabili al 2030 [Fonte: GSE e RSE]

* Per la produzione da fonte idrica ed eolica si riporta, per gli anni 2010 -2017, sia il dato effettivo (riga continua), sia il dato normalizzato, secondo le regole fissate dalla Direttiva 2009/28/CE. Per i bioliquidi (inclusi nelle bioenergie insieme alle biomasse solide e al biogas) si riporta solo il contributo dei bioliquidi sostenibili.

[1] Proposta di piano PNIEC, 2018
Questions

• Which is the overall cost of the current Italian energy system? And the cost of the system according to the PNIEC at 2030?

• Are there any other scenarios with higher CO$_2$ emissions abatement with similar costs? How will the cost structure of the energy system change?

• Is the PNIEC or other scenarios in line with the 1.5° degrees increase of temperature?
What we are talking about

• A **dynamic model** that simulates the **hourly energy production** and **consumption**

• Starting point is the **actual energy system**

• Scenarios of **evolution** of this system considering local boundaries are calculated

• **Accuracy** of the model depends on the accuracy of the available data
What we are NOT talking about

• No prediction of the future development
• The entry of radical new technologies has not been taken into consideration
• Important variations of the costs of the natural resources and technologies have not been taken into consideration
• The model focuses on production and consumption and is not a model to simulate energy distribution
Considered sectors

Energy system modelling considering sector-coupling and hourly time-step

Electricity  Heat  Transport

Electricity sector: hourly values

Heat sector: hourly values
Transport sector: hourly values

[15] RSE, E... muoviti! Mobilità elettrica a sistema, 2013. / Photo: Alperia charging station
Electricity versus heat demand

Heat and electricity demand in Italy

[GW]

Heat demand
Electricity demand

Hourly electricity generation

Which sources cover hourly demand?

Example of a week in a summer and a week in winter

Comparison of different studies on CO₂ emissions

The graph shows the calculated overall CO₂ emissions of the Italian energy system of several studies.

It can be seen that the results of the elaborated Eurac model are in line with the results of studies of different international organizations.
Optimization model of the energy system

Model n objectives - Eurac Research

Simulation model

EnergyPLAN (Aalborg University)

Optimization model

Multi objective evolutionary algorithm MOEA

Each point on the chart shows total costs and CO₂ emissions per each combination of technologies of the energy system.

For each combination of technologies of the energy system, hourly energy production and consumption have been simulated.
Optimization model of the energy system

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Decision variables

Strategic technologies for the Italian energy system

- Residential PV
- Utility scale PV
- Wind power
- Lithium-ion batteries
- Power to gas
- Advanced Biomethane
- Heat pumps
- Energy efficiency of buildings

Values

[min, max]

in 2015 evaluated potential

[1] Proposta di piano PNIEC, 2018
Technical potential: rooftop PV

Max capacity potential for rooftop PV in Italy: **120 GW**
*(assuming 2 kW/person)*

[36] Taylor et al., [37] Vartiainen et al., [38] Solar Tyrol project / Photo: CAAB rooftop PV, Bologna, flickr, R. Serra Iguana Press
Technical potential: PV utility scale

Max capacity potential for utility scale PV in Italy: 70 GW
(assuming decommissioned industrial sites and non used agricultural surfaces)
Technical potential: wind power

Max capacity potential for on-shore wind power in Italy: **49 GW**
(assuming repowering and revamping of existing plants, plus considering additional surfaces with relevant potential)
Technical potential: storage technologies

Lithium-ion batteries max capacity: 600 GWh

(modelling result considering introduced cost – benefit ratio)
Technical potential: power to gas

Max H₂ produced from power to gas: 15% tot annual consumption of Natural gas. Electrolyser max capacity: 30 GW (modelling results considering introduced cost – benefit ratio)
Technical potential: energy efficiency

Data elaborated by Eurac Research describing the energy efficiency costs of the building stock, including different types of buildings, construction periods and location (details see annex 1).

[42] Prina et al. 2016 / Photo: IPES building refurbished within Sinfonia project, Bolzano, Eurac Research, Ivo Corrà
Technical potential: heat pumps

The application of heat pumps in the building stock is allowed in the model only in deeply renovated buildings. (details see annex 1).
Assumptions

Hydro, geothermal and biomass production

<table>
<thead>
<tr>
<th>Dammed hydro</th>
<th>River hydro</th>
<th>Geothermal</th>
<th>Biomass power plants</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Dammed hydro" /></td>
<td><img src="image2" alt="River hydro" /></td>
<td><img src="image3" alt="Geothermal" /></td>
<td><img src="image4" alt="Biomass power plants" /></td>
</tr>
<tr>
<td>2015 = 24.5 TWh</td>
<td>2015 = 23.1 TWh</td>
<td>2015 = 6.0 TWh</td>
<td>2015 = 19.4 TWh</td>
</tr>
<tr>
<td>2030 = 24.5 TWh</td>
<td>2030 = 24.8 TWh</td>
<td>2030 = 7.1 TWh</td>
<td>2030 = 15.7 TWh</td>
</tr>
</tbody>
</table>

[1] Proposta di piano PNIEC, 2018 / Photos: pixabay, wikimedia
Assumptions

Electric mobility costs

\[ y = 65,851x + 46,025 \]

\[ R^2 = 0.9976 \]

[20] Enel, APRIAMO LA STRADA AL TRASPORTO ELETTRICO NAZIONALE (2017) / Photo: pixabay
Industry sector efficiency

Assumptions

[21] Odyssee-Mure database (H2020) / Photo: pixabay

eurac research
For single key technologies very clear learning curves could be observed in the past years. Based on different publications on the development of this learning curves in the years to come average data have been calculated for 2030.
Results of the simulations

Each single dot shows total annual costs and CO₂ emissions of a specific energy scenario. It can be seen that the PNIEC scenario is close to a cost optimum for the given CO₂ emission target. Still keeping the cost constant other scenarios can be identified further reducing CO2 emission in a relevant way.

Values of the main technologies in the different scenarios

<table>
<thead>
<tr>
<th></th>
<th>PV</th>
<th>Wind power</th>
<th>Stationary Batteries</th>
<th>Batteries of EV*</th>
<th>Advanced Biomethane</th>
<th>Energy efficiency of buildings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline 2015</td>
<td>19 GW</td>
<td>9 GW</td>
<td>0 GWh</td>
<td>0 GWh</td>
<td>3 TWh</td>
<td>0 %</td>
</tr>
<tr>
<td>PNIEC 2030</td>
<td>59 GW</td>
<td>23 GW</td>
<td>40 GWh</td>
<td>200 GWh</td>
<td>15 TWh</td>
<td>15 %</td>
</tr>
<tr>
<td>Advanced 2030</td>
<td>86 GW</td>
<td>48 GW</td>
<td>0 GWh</td>
<td>400 GWh</td>
<td>3 TWh</td>
<td>30 %</td>
</tr>
</tbody>
</table>

*Vehicle to grid is not considered in the simulations
**PNIEC 2030 scenario considers energy production from RES as given in PNIEC, but historical energy equivalent hours leading to differences in installed capacity

[1] Proposta di piano PNIEC, 2018
Hourly electricity demand
Electricity generation mix

Baseline 2015, in summer
Baseline 2015, in winter
PNIEC 2030, in summer
PNIEC 2030, in winter
Advanced 2030, in summer
Advanced 2030, in winter

- Demand Baseline 2015
- Demand
- Charging PHS
- Charging batteries
- Gas power plants
- Discharging PHS
- Discharging batteries
- Hydro
- River hydro
- Wind
- PV utility scale
- PV
- Geothermal
- Biomass power plants
- CHP: cogeneration
- Coal power plants
- Import
Annual electricity generation

The overall structure of the electricity generation is shown in the three scenarios.

It can be seen that the overall electricity consumption rises based on additional needs from e-mobility and the heating sector (heat pumps).

At the same time the renewable share is increasing with coal phasing out and imports reduced.
Final energy consumption

The **overall final energy consumption is reducing** over the scenarios.

This is based on the energy **efficiency measures** in the building sector, industry sector and electrification of transport.

The **renewable share is increasing** in all sectors but mainly in the electricity sectors.
Final energy consumption

Electricity demand from electric transport

<table>
<thead>
<tr>
<th>Scenario</th>
<th>TWh</th>
<th>% of the total electricity demand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline 2015</td>
<td>0.9</td>
<td>0.3</td>
</tr>
<tr>
<td>PNIEC 2030</td>
<td>12.5</td>
<td>3.6</td>
</tr>
<tr>
<td>Advanced 2030</td>
<td>24.1</td>
<td>7.0</td>
</tr>
</tbody>
</table>

Electricity demand from heat pumps

<table>
<thead>
<tr>
<th>Scenario</th>
<th>TWh</th>
<th>% of the total electricity demand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline 2015</td>
<td>0.1</td>
<td>0.02</td>
</tr>
<tr>
<td>PNIEC 2030</td>
<td>4.3</td>
<td>1.2</td>
</tr>
<tr>
<td>Advanced 2030</td>
<td>8.5</td>
<td>2.5</td>
</tr>
</tbody>
</table>
The results

The overall CO$_2$ emissions are reducing by 39% and 47% respectively.

The overall cost is slightly growing from Base 2015 to the PNIEC scenario and remaining constant for the Advanced 2030.

The share of expenditures for renewables and efficiency increases the one for fossil fuels decreases.
Fossil fuel costs

By limiting CO$_2$ emissions as well the imports of fossil fuels are being reduced by 10% and 23% respectively.

Here through the energy dependence of Italy form other countries is reduced while the internal added value through renewables and efficiency in Italy can be increased.
The imports of fossil fuels reduces by **over 7 billion € per year**. Expenditures available for investments in the Italian energy systems.
Expenditure for different energy scenarios

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Fossil fuels</th>
<th>Possible domestic value creation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline 2015</td>
<td>32.1</td>
<td>28.4</td>
</tr>
<tr>
<td>PNIEC 2030</td>
<td>29</td>
<td>34.8</td>
</tr>
<tr>
<td>Advanced 2030</td>
<td>24.8</td>
<td>39</td>
</tr>
</tbody>
</table>

Costs in billion €
Consideration on the overall Italian territory from a multi-node point of view

Division of the Italian territory into the different main areas of the electric system, identified by the transmission constraints of the grid [MW] in 2015.

Connection between zone CNORTH-CORSICA-SARDINIA is not considered because it would have needed to include also another node for Corsica with several difficulties in data collection.

Consideration on the overall Italian territory from a multi-node point of view

Division of the Italian territory into the different main areas of the electric system, identified by the transmission constraints of the grid [MW] at 2030. As defined by Terna in “Piano di sviluppo 2019” [52].

Considerations from a multi-node point of view

The multi-node energy system model Oemof has been used to estimate the over-generation due to the transmission constraints of the grid.

- The development of the transmission grid foreseen by Terna allows to contain the over-generation in the order of 1% (for the PNIEC 2030 scenario) of the overall electricity generation from renewable energy sources.
- This number enhances by several % in the Advanced 2030 scenario. But ...
- In order to assess more realistically the order of magnitude of over-generations it would be important to consider:
  - Different profiles for electric vehicles charging, an “active” charging and / or vehicle to grid possibilities
  - Demand-side management in different sectors (particularly in industry)
  - The impact of future energy communities
Remaining carbon budget: definition

“Finite total amount of CO₂ that can be emitted into the atmosphere by human activities while still holding global warming to a desired temperature limit”
The number shows the overall amount of CO$_2$ emissions that can be emitted in order to limit global warming following the estimations from Rogelj et al. Assuming that each person on earth has the same carbon budget, the overall carbon budget for Italy results in 3,8 Gt.

Carbon Budget: constant emissions

Italian carbon budget to limit warming to 1.5°C

CO₂ emissions [Mt.]

CO₂ emissions 1990-2018
12.4 Gt

Remaining carbon budget
3.8 Gt

Carbon Budget: Italy

Italian carbon budget to limit warming to 1.5°C

Co2 emissions
1990-2018
12.4 Gt

Remaining carbon budget
3.8 Gt

[34] Nature article
[35] JRC 2019
[10] European commission, 2018
Carbon Budget: Italy

Italian carbon budget to limit warming to 1.5°C

CO₂ emissions [Mt]


Remaining carbon budget
3.8 Gt

CO₂ emissions 1990-2018
12.4 Gt

PNIEC 2030
Advanced 2030

Key messages (1/2)

- A dynamic simulation model has been developed evaluating thousands of different energy scenarios considering production and consumption of the electricity, the thermal and the transport sector on an hourly base.

- The model shows that the PNIEC scenario is close to a cost optimum but that other scenarios allow a further CO₂ emission reduction with the same annual cost.

- Actions in all sectors are needed. In the considered time frame (2030) as key sectors emerge renewable electricity (especially PV and wind), e-mobility and energy efficiency in buildings (including heat pumps).
Key messages (2/2)

- The energy transitions needs a deep change of our existing energy system including relevant investments.

- The presented scenarios reduce CO₂ emissions strongly, thus limiting the need of fossil fuel imports in an order of magnitude of over 7 billion € a year in the Advanced 2030 scenario. Expenditures which are available for the investment in the Italian energy system enhancing national economy.

- The Advanced 2030 scenario is very ambitious, but considering the Italian Carbon Budget available, it shows that after 2030 an even stronger reduction of CO₂ emissions would be needed.
Thank you for your attention

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http://www.eurac.edu/it/research/technologies/renewableenergy/references/Pages/Simulazioni-energetiche.aspx