Study Committee C1

Power System Development and Economics

Paper 10784_2022

# Optimising Italian Electricity and Gas Sectors Coupling in a 2030 Decarbonized Energy System


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## Motivation

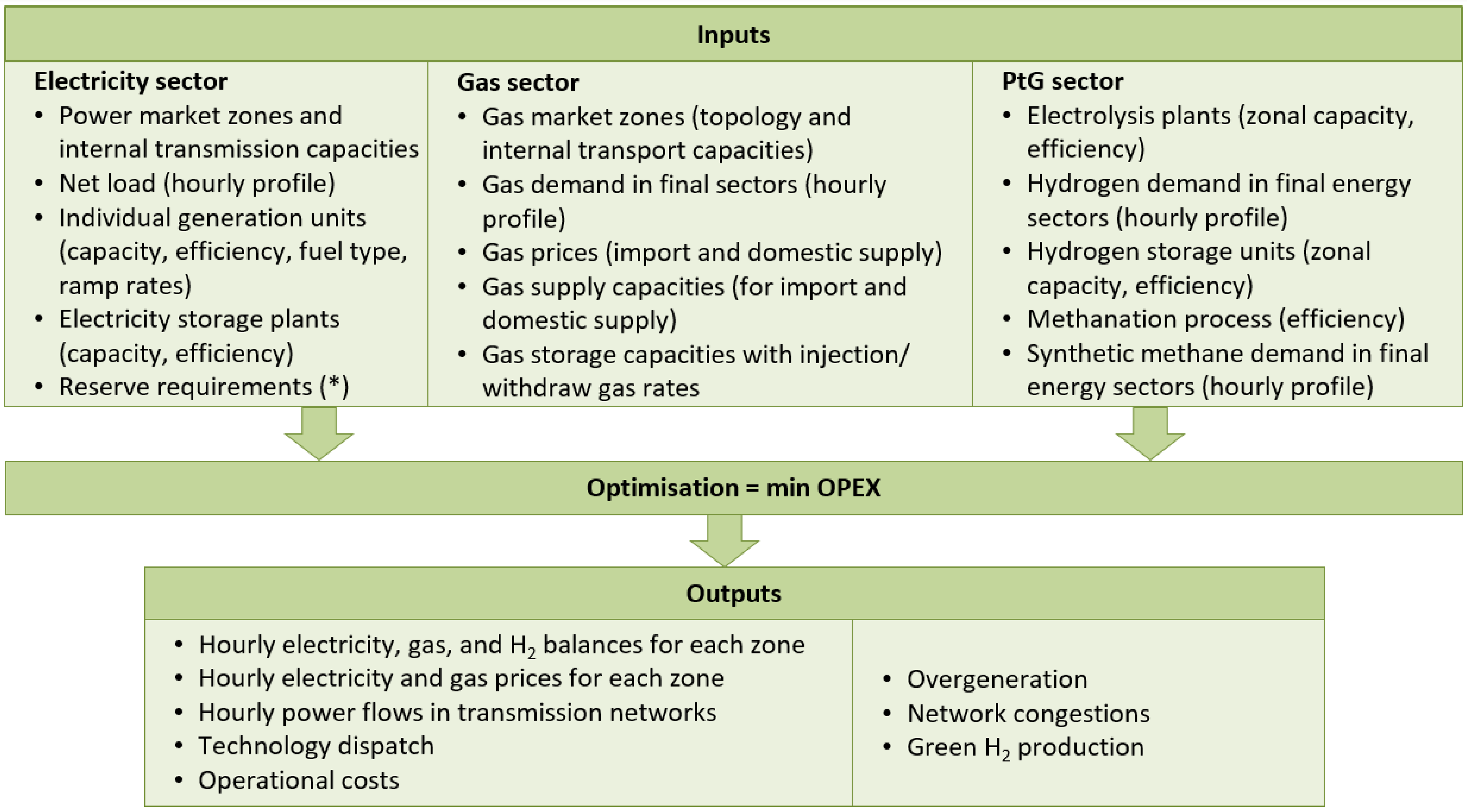
- Future low-carbon energy systems will be based on large shares of non-programmable renewable energies with frequent periods of over/under generation → it is crucial to boost power system flexibility.
- In general, power system models consider “traditional” flexibility sources: supply-side and demand-side options, grid reinforcements, e-storage systems, electrolysers for hydrogen production.
- Power-to-Gas (PtG) technologies represent a rather new flexibility option that increases the interconnection between electricity and gas systems → we developed a new simulation tool to explicitly consider a potential bidirectional energy conversion (power-to-hydrogen, hydrogen-to-gas, and gas-to-power for zero-carbon energy systems).

## Method

*Table 1 - Overview of the new integrated model*

| | |
|---|---|
| **Model type** | Linear optimisation (perfect foresight) |
| **Scope** | • Power system<br>• Gas system<br>• Hydrogen system |
| **Spatial resolution** | User-definable. For the Italian case:<br>• 6 power market zones<br>• 1 gas market zone |
| **Temporal resolution** | Time horizon: 1 year<br>Time step: 1 hour |
| **Developed in** | GAMS |
| **Solver** | CPLEX |

*Figure 1 - Main inputs and outputs of the new integrated model*




(*) Simplified representation of the reserve: minimum load to be provided by dispatchable generation units (gas power plants, hydro-dams, e_storages)

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## Case study set-up

- A long-term scenario analysis has been carried out with the TIMES_RSE model for the Italian energy system for the period 2018-2050.
- Results and constraints for the year 2030 were used as inputs for the new integrated model to carry out a 1-hour time step analysis. 2 scenario-variants have been assessed.

**Scenario definition**:

- *Central scenario*: developed from the National Energy and Climate Plan imposing the following changes: i) downward revision for national GDP and population projections; ii) increased climate ambition (-51% of GHG emissions by 2030 to reflect the EU Green Deal); iii) lower CAPEX projections for electrolysers (hp. large-scale manufacturing by 2030).
- *VAR 1 scenario*: 5 TWh of PV production added to replace the use of biomethane in the power sector.
- *VAR 2 scenario*: exogenous demand of 4.2 TWh of synthetic biomethane (see *Table 2*) and 5 TWh of additional PV production (vs the Central scenario).

**Hydrogen sector:**

- The national $H_2$ demand in final energy sectors (≈ 5.8 TWh) is distributed between the six power market zones based on the preliminary projects mentioned in the National Recovery and Resilience Plan (*Table 2*).
- $H_2$ is assumed to be generated where it is consumed, therefore the electrolysis capacity (7 $GW_{el}$) is allocated proportionally to the zonal $H_2$ demand (*Figure 3*).
- $H_2$ demand is assumed to have a flat hourly profile.
- $H_2$ can be stored in short-term $H_2$ storage plants.
- $H_2$ can be produced only by electrolysis, but electrolysers can use electricity from any sources → need to identify the actual green $H_2$ production. Assumptions:
  - $H_2$ is always green when overgeneration occurs
  - Electricity production from RES + e_storage discharge + net import (A) is directed to cover *first* residual load + e_storage charge + net export (B). It is t is possible to have green $H_2$ only when A > B.
  - $H_2$ is accounted as green when electrolysers consume electricity from gas-fired power plants & the reserve availability is equal to the minimum requirement (i.e. when gas power plants cannot be turned down due to the zonal reserve constraints).

*Figure 2 - Electricity mix by source*

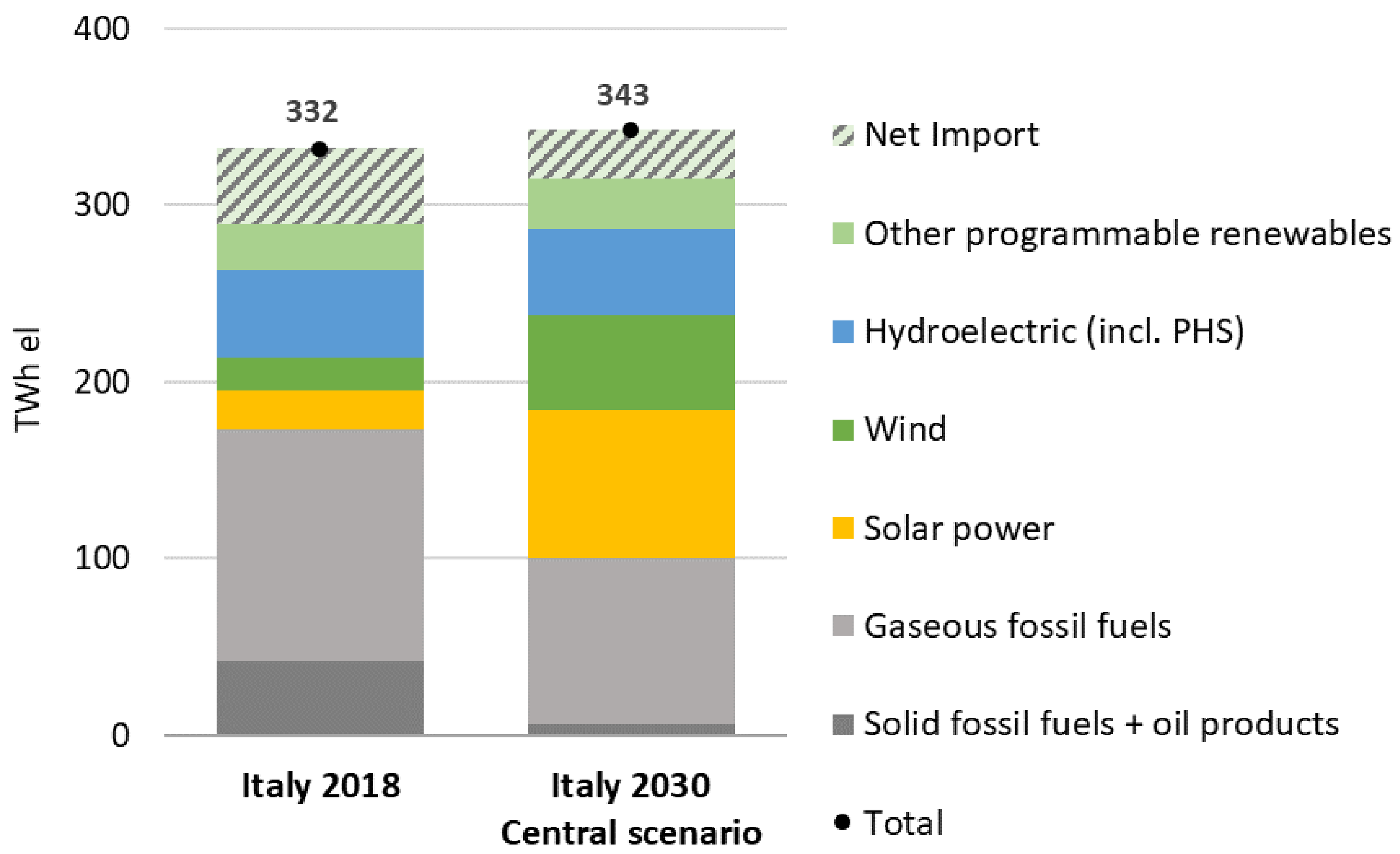
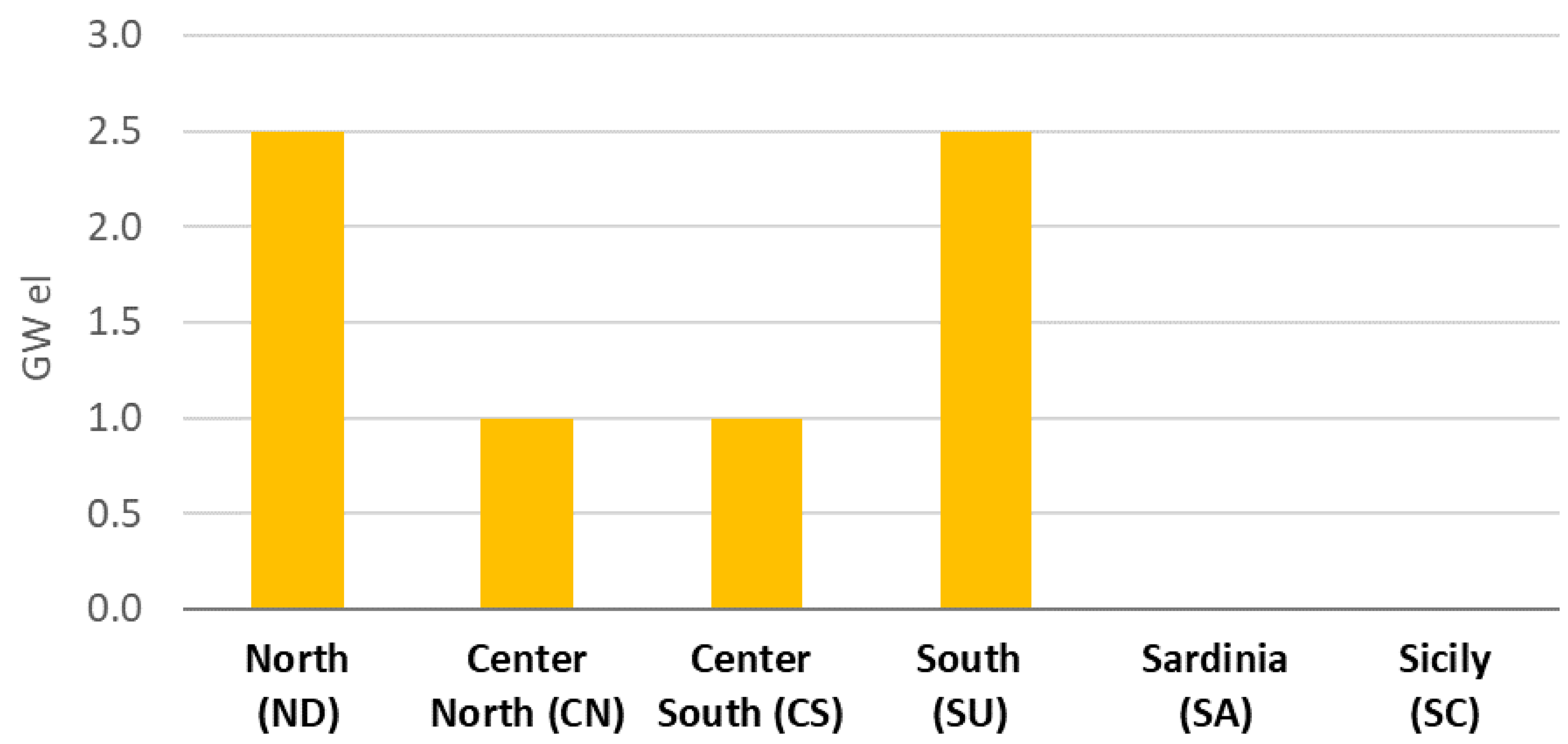



*Table 2 - Power, $H_2$ and syngas demand in 2030*

| | Residual load [TWh] | $H_2$ demand [GWh] | Synt. $CH_4$ demand [GWh] | |
|---|---|---|---|---|
| | All scenarios | All scenarios | Central, VAR1 | VAR2 |
| North (ND) | 75 | 2035 | 0 | 3023 |
| Center North (CN) | 11 | 1018 | 0 | 368 |
| Center South (CS) | 22 | 1018 | 0 | 516 |
| South (SU) | -18 | 1745 | 0 | 251 |
| Sardinia (SA) | -3 | 0 | 0 | 0 |
| Sicily (SC) | 4 | 0 | 0 | 0 |
| **Italy** | **90** | **5815** | **0** | **4158** |

*Figure 3 - Electrolysers capacity in 2030*



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## Case study results

*Table 3 - Main results for the power and hydrogen sectors*

| Scenario | Over-generation [TWh el] | Electricity from gas power plants [TWh el] | Electrolysers' capacity factor |
|---|---|---|---|
| Central | 1.9 | 75.4 | 14% |
| VAR 1 | 2.0 | 71.0 | 14% |
| VAR 2 | 1.9 | 77.6 | 25% |

*Figure 4 - Share of green hydrogen production*

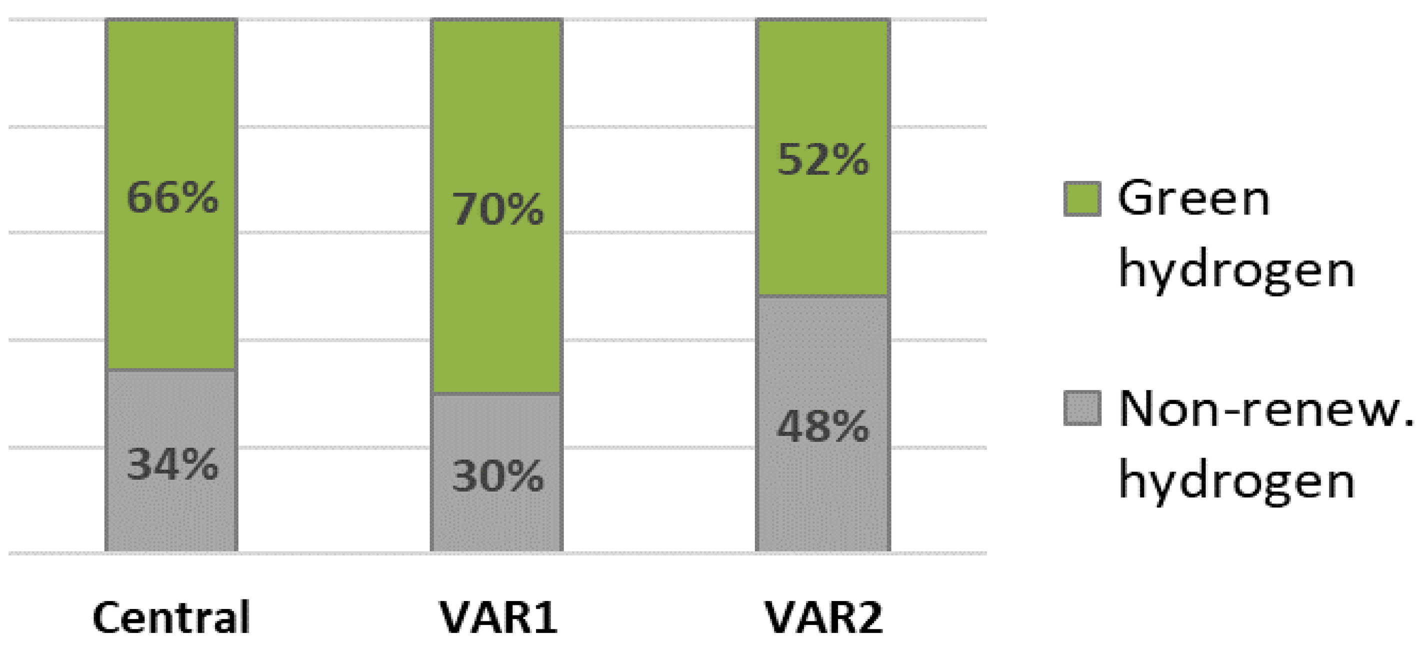


*Table 4 - Congestions on the transmission grid in 2030: % of hours with delta electricity price between linked zones (*)*

| Scenario | CN-ND | CN-CS | CS-SU | SU-SC | SA-CN | SA-CS | SA-SC | SC-CS |
|---|---|---|---|---|---|---|---|---|
| Central | 25% | 24% | 8% | 5% | 28% | 7% | 2% | 6% |
| VAR 1 | 20% | 24% | 8% | 5% | 28% | 7% | 2% | 6% |
| VAR 2 | 24% | 27% | 8% | 5% | 31% | 7% | 2% | 6% |

*(*) ND = North; CN = Center-North; CS = Center-South; SU = South; SA = Sardinia; SC = Sicily.*

## Discussion

- Electrolysers have higher capacity factors in the VAR2 case (extra $H_2$ demand for the methanation, but identical $PtH_2$ capacity). In VAR 1 and VAR 2 scenarios, power generation from gas power plants is higher than expected because of additional overgenerations and e_storage losses (the share of PV and wind is already high, and it is difficult to integrate additional PV).
- In VAR1, we assumed 5 TWh of extra PV supply in the North, so there are less congestions on the line flows CN → ND. In VAR2, most of the synthetic methane demand is in the North, therefore congestions on the line CN → ND rise again.
- The quota of green $H_2$ is 52%-70%. Higher shares could be obtained by increasing the $H_2$ storage capacity and assuming more flexible $H_2$ demand profiles.

## Conclusion

- We developed a new simulation tool to jointly optimize the dispatch of electricity and gas sectors with a potentially bidirectional energy conversion, with an explicit modelling of both electricity and gas storage systems, and an hourly definition of both electricity and gas prices.
- The new model was tested by assessing a 2030 scenario for the Italian energy system that shows a strong development of PV and wind and the first $H_2$ applications in end-use sectors. Two scenario variants were assessed to evaluate a higher PV penetration (VAR 1), and an exogenous demand of synthetic biomethane (VAR 2).
- Sensitivity analysis is necessary to minimize the share of non-renewable $H_2$ (made with electricity coming from thermal power plants). Crucial parameters are electrolysis capacities, $H_2$ storage capacities, and hourly $H_2$ demand profiles.
- Possible model developments to address the limitation of the tool are:
  - additional technical constraints in the power sector, e.g. explicit representation of 1st, 2nd, 3rd reserve power;
  - additional sector coupling options, such as $H_2$ blending, Power-to-Heat and Power-to-Liquids;
  - description of the full $H_2$ supply chain with different transport technologies.