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The hydrogen role in the Italian energy system for Net-Zero CO_2

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Abstract

Hydrogen allows a 'sector-coupled' evolution of the energy infrastructures towards a net zero-CO_2 emission target, acting as clean energy vector with multiple roles ranging from energy storage to decarbonization of hard-to-abate applications. The role of hydrogen in the national energy system can be evaluated through detailed integrated energy system models. This work shows the main results of ongoing simulation efforts, evidencing the impact of hydrogen in the different energy fields and the effect of different key assumptions on the results.

Introduction

Clean hydrogen can be produced by different sources (from renewables as well as from low-carbon pathways, like blue H_2), similarly to electricity. Hydrogen use enables the decarbonization of diverse sectors and applications (hard-to-electrify industrial processes, part of heavy-duty land transport, aviation and maritime transport, part of civil heating and power uses). In addition, hydrogen allows large-scale energy storage, coupling and interweaving of energy sectors with a resilient, multi-vector (or 'multi-fuel') energy infrastructure. Analysing the role of H_2 in long-term and low- or net-zero CO_2 emission scenarios requires the development of adequate integrated energy system modelling tools, able to perform the simulation and optimization of the national energy system [1,2].

System description, Methods, and Data

The OMNI-ES framework, used for this work, adopts a multi-vector (electricity, hydrogen, methane blends, liquid fuels), multi-node (representing multiple regions), and multi-sector (civil, industrial, mobility land/sea/air) approach (Figure 1). The analysis is time-dependent (hourly balances in each node, tracking the power and storage evolution needs) and tracks the domestic and imported sources (incl. renewables, natural gas, biogas, waste, imports of electricity, hydrogen, and liquid fuels) and the energy networks along the Italian geography. Objective of the analysis is achieving the target of net-zero CO_2 at minimum total system cost (including CAPEX for new plants and revamping and OPEX for O&M, domestic sources, energy vector import, inter-regional exchanges of energy vectors, carbon capture and storage).

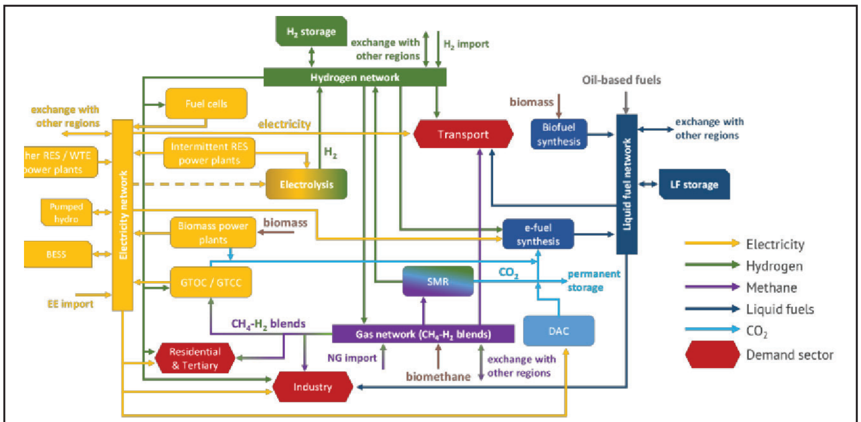

Figure 1 – Scheme of the integrated energy system, solved for each Italian region [2].

The many assumptions behind the model, of which an example is reported in literature [2], are constantly updated by the research group to improve the representation of the evolution of the Italian energy system.

Results and Discussion

An extract of results is reported in Figure 2. Hydrogen is largely adopted to decarbonize uses that currently rely on natural gas, in addition to being used in mobility. In this specific sector, electricity is largely used to decarbonize «light mobility» (passenger cars and LDV, small/short-range aviation and navigation), while hydrogen goes mostly for heavy-duty transport, part of aviation and navigation, and the remaining keeps relying on liquid fuels. As a whole, the introduction of hydrogen allows a substantial contribution to decarbonization (total Italy's 'baseline' emission of CO_2 is nearly 330 Mt/y).

Energy vector	Annual consumption (final uses + conversion)	Uses	Variation from 2020
Electricity (production RES + thermoelectric +import)	~ 800 TWh_e/y	*Direct final demand (~400 TWh_e/y)+ demand for mobility (~55 TWh_e/y) + electrolysis + CO_2 capture units*	~3x
H_2 (domestic electrolysis or SMR + import)	~ 300 TWh_{LHV}/y (~ 10 Mt_{H2}/y)	*Direct final demand for mobility (~130 TWh_{LHV}/y) + industrial feedstock demand (~15 TWh_{LHV}/y) + thermoelectric power generation, civil heating, industry (total 155 TWh_{LHV}/y)*	New vector
CH_4 $^{(1)}$ (domestic biomethane + domestic NG + import NG)	~ 100 TWh_{LHV}/y (~ 10 mld Sm^3/y)	*Civil heating, industry, thermoelectric power generation, H_2 production via SMR+CCS*	-90%
Liquid fuels $^{(2)}$	~ 160 TWh_{LHV}/y	*Mobility and industrial feedstock*	-80%

$^{(1)}$ Distributed as NG or in blend with H_2 (with H_2 share optimized by the model).
$^{(2)}$ Including grey and green options.

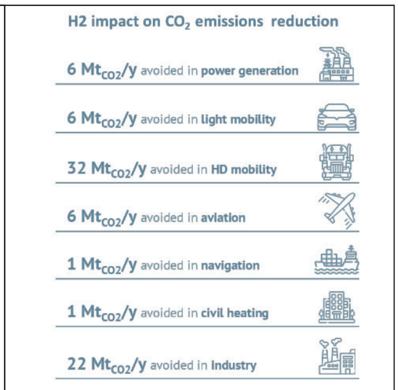

Figure 2 – Expected final consumptions (preliminary model result) for a long-term Net-Zero CO_2 target in the Italian energy system (left) and impact on CO_2 emission reduction (right).

Some interesting results are obtained through sensitivity analysis on some of the assumptions. For example, the role of import limits and of the characteristics of the imported vectors is remarkable. Results are shown in Table 2. Import prices have no impact on the energy balances, while the availability of zero-emission electricity from abroad significantly shifts towards the reliance on import. The availability of carbon-neutral liquid fuels is also critical to the net-zero CO_2 target, as a constraint on their import yields an increase in their domestic production, requiring more domestic H_2 production and renewable electricity generation for electrolysis supply. Another example of key sensitivity effects arise for the assumed capacity for CCS (not shown here for brevity), which yields a constant improvement of results when the annual assumed storage capacity is lifted e.g. from 20 $MtCO_2/y$ (lower bound assumed in existing long term strategy evaluations) to 40 $MtCO_2/y$.

Table 2 – Effect of variation in imposed limits and characteristics of imported energy vectors.

	Reduction of import prices of EE and NG (-50%)	Reduction of CO_2 intensity of imported electricity (entirely renewable-based)	Reduction of liquid fuel import limit (-33%)
PV capacity	--	-20%	+20%
Wind capacity	--	-15%	+4%
Electrolysis capacity	--	-20%	+25%
Electricity import	--	+100%	+7%
Domestic e-fuel production	--	--	+1130%

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References

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