Impacts of deep decarbonization pathways on the Italian energy intensive industries

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• Work carried out in the framework of the DDPP project (led by IDDRI and the UN SDSN).

• Objective: to explore the impacts of different decarbonization pathways to 2050 for Italy. Scenarios consider 80% CO2 emissions reduction by 2050 w.r. to 1990.
  
  • Focus on the role of CCS, renewables and energy efficiency in CO2 emissions reductions, assuming different levels of penetration of CCS and Renewables and different effort in energy efficiency.
  
  • Special attention paid to energy intensive industries.

• The response strategies of the system analyzed with a linear optimization model (TIMES-Italy) under different technological hypotheses.

• Two alternative economic assumptions: exogenous energy service demand and price elastic energy service demand.

• The second case explicitly considers output reduction in energy intensive industries as a response strategy in a scenario where industrial CCS options are limited.

• The same scenarios are assessed from a macroeconomic perspective using a CGE model (GDyn-E).
Methodological approach

- **Stage 1:** Analysis of the Italian energy system to identify key uncertainties, challenges & build consistent storylines.
- **Stage 2:** Definition of reference macroeconomic drivers and CO2 emissions for the REF and DDP scenarios in both models.
- **Stage 3:** Quantification of the main energy trends for the chosen scenarios using TIMES-Italy;
- **Stage 4:** Top-down, macroeconomic evaluation of the decarbonization scenarios with GDyn-E
## Key Challenges and uncertainties

<table>
<thead>
<tr>
<th>Category</th>
<th>Challenges</th>
</tr>
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<tbody>
<tr>
<td>No Nuclear</td>
<td>- The nuclear option excluded (referendum in 2011). This could result in an increase in the generation costs for greater use of other options.</td>
</tr>
</tbody>
</table>
| RES            | - Intermittent renewables require suitable network infrastructure (smart grid, storage etc ...)  
                 -> investment and O&M costs increase. |
|                | - Resource availability (in particular for bioenergy)                      |
|                | - R&D and commercialization                                               |
| CCS            | - CO2 storage sites and social acceptability                               |
| ELECTRIFICATION| - It is promoted by low electricity prices.                                |
|                | - Lack of one or more decarbonisation factors of the electricity system reduces the role of electrification in the end-use sectors |
|                | - EV and heat pumps deployment.                                            |
| RES in end-use sectors | - Resource availability (in particular for bioenergy).                  |
|                | - Air quality (for biomass).                                              |
| TRANSPORT      | - Infrastructure costs for modal shift and attitudes towards public transport. |
|                | - R&D and costs of hydrogen and electrical storage.                       |
| Energy efficiency | - High buildings retrofitting costs and availability of financing.       |
| Industry       | - CCS R&D and commercialization                                           |
|                | - CO2 storage sites and social acceptability                               |
|                | - High energy prices could influence the shift towards a less energy intensive industry |
The three scenarios are characterized as follows:

**The CCS scenario (CCS):**

- High public acceptance of key low carbon generation technologies.
- Abundant renewable sources, capture technology and CO₂ storage sites allow to decarbonize the electricity system; high electrification of heating and transport;
- Large amount of electricity from renewables and fossil fuel technologies coupled with CCS.

**The EFF scenario (EFF):**

- Lower availability of options to decarbonize the electricity system, results in relatively higher costs and a reduction of the electricity consumed in end-use sectors.
- This is compensated by an increased reliance on advanced energy efficiency technologies and a greater renewable energy use for heat and transportation.
- A lower sectoral discount rate stimulates a higher penetration of new and advanced energy efficiency technologies.

**The DMD_RED scenario (DMD_RED):**

- Limited availability of CCS (especially in the industrial sector) and high cost of decarbonization.
- Low public acceptance of CCS, in part due to insufficient policy effort.
- Simulated using the TIMES-Italy model in the version with price elastic demand:
- the demand drivers of end-use sectors are influenced by high fuel and energy carrier prices.
### Scenario overview

<table>
<thead>
<tr>
<th></th>
<th>CCS</th>
<th>EFF</th>
<th>DMD_RED</th>
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<tbody>
<tr>
<td><strong>Generation decarbonization</strong></td>
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<tr>
<td>Nuclear</td>
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<tr>
<td>RES</td>
<td>+++</td>
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<tr>
<td>CCS</td>
<td>+++</td>
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<tr>
<td><strong>Electrification</strong></td>
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<tr>
<td>Heat pumps, EV and PHEV</td>
<td>+++</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td>Fuel switch to electricity</td>
<td>+++</td>
<td>+</td>
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<tr>
<td><strong>End-use sectors</strong></td>
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<tr>
<td>Building retrofit</td>
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<td>+++</td>
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<tr>
<td>Advanced eff. technologies</td>
<td>++</td>
<td>+++</td>
<td>+++</td>
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<tr>
<td>RES for heat and transportation</td>
<td>+++</td>
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<tr>
<td>Fuel switch in final sectors</td>
<td>++</td>
<td>+++</td>
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<tr>
<td>CCS in Industrial sector</td>
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<td><strong>Service demand in final sectors</strong></td>
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<td>Transport modal shift</td>
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<tr>
<td>Reduction in Industry production</td>
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</tbody>
</table>
Results

Energy-related and process CO$_2$ emissions in Reference Scenario and Deep Decarbonization Pathways – MtCO$_2$.

Emissions (combustion related + process) go down to 84-92.5 Mt CO$_2$ in DDP vs 320 in REF
### Results

#### Total Primary Energy Supply by energy source in three scenarios – Mtoe

<table>
<thead>
<tr>
<th>Year</th>
<th>Electrical net Import</th>
<th>Renewables energies</th>
<th>Hydro</th>
<th>Biomasse and waste</th>
<th>Natural gas</th>
<th>Petroleum prod.</th>
<th>Solid fuels</th>
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<tbody>
<tr>
<td>2010</td>
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<td>2050 REF</td>
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<td>2050 CCS</td>
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<td>2050 EFF</td>
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<tr>
<td>2050 DMD RED</td>
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</tbody>
</table>

**Primary energy in DDPs**  
By 2050 is 107 - 125.5 Mtoe  
vs 170 Mtoe in REF  
Energy dependence down from 70% to below 35%
Results

Energy intensity of GDP – MJ/$2005

In DDPs energy intensity is 27% to 38% lower than in REF
Results

Electricity emissions intensity, g CO2/kWh

Emissions are less than 3% of the 2010 value
Results

Power generation

Generation from fossil fuels is 10 to 15% of the REF value in DDP scenarios

![Chart showing power generation from different sources over time]
Results

Final Energy consumption goes down to 70.2-85.3 Mtoe in DDP vs 144.1 in REF
Results

Energy mix in industry sector

Source: ENEA
Results

Industry Final Energy Use by sectors

- Final energy use highest in the CCS scenario
- In DEM-RED scenario, iron and steel, non ferrous metals, chemicals and non metallic minerals reduce consumption more visibly

Energy-related CO2 emissions by sector
Output grows least in the DMD-RED scenario, especially cement, iron and steel and non ferrous metals.
GDP change relative to Reference in 2050 -%

Significant lowering of GDP trajectory vs Ref after 2030, but within the range seen in the CGE literature (Knopf et al. 2014)

Such dramatic impact due to assumptions and model characteristics:

• By construction, in this scenario Italy does -80% while rest of EU does -65% CO₂ emissions
• CGE perform poorly in long run projections;
• Renewables and zero carbon technologies not explicitly represented in this model version;
Macroeconomic analysis: Results

Output change with respect to Reference in 2050 - %

[Bar chart showing the output change for different sectors and policies: CCS, EEF, DMD-RED]
Macroeconomic analysis: Results

Change in value added with respect to Reference in 2050 - %
Macroeconomic analysis: Results

Change in employment with respect to Reference in 2050 - %
Macroeconomic analysis: Results

Trade balance with respect to Reference in 2050 - %

[Graph showing trade balance by sector with references to CCS, EFF, and DEM_RED categories.]
Conclusions 1/2

- RES, EE and CCS are key components of any Italian decarbonization scenario.
- Energy dependence in DDPs decreases significantly: to 30-35% vs 70% in the REF case.
- The power sector is about 93% decarbonized;
- Final energy use is highest in the CCS scenario;
- In DDPs electricity will be 47-49% of the final energy mix in industry by 2050.
- In DEM-RED scenario, iron and steel, non ferrous metals, chemicals and non metallic minerals contract energy consumption more visibly.
- Energy system costs structure moves away from variable (fuel) costs and towards fixed (investment) costs.
Conclusions 2

- Macroanalysis shows a significant GDP drop w.r. to Reference in all decarbonization scenarios after 2030, but within the range seen in the CGE literature.
- In decarbonization scenarios the biggest output and value added contraction occurs in extractive activities (oil&gas, other mining), oil refining, non-ferrous metals and non-metallic minerals. Employment impacts for the same sectors are also negative.
- Positive impacts in less energy intensive industries.
- Trade impacts are mostly positive (large reduction in oil and gas imports, improvement of energy dependence) except for the oil refining sector.
- If CCS is not a viable option and other enabling technologies are unable to reduce significantly energy demand and CO2 emissions in energy intensive industries, the result could be delocalization and further downsizing. This calls for immediate policy intervention especially in R&D, but may require social programs to alleviate labor displacement.
- The GDyn-E model currently used at ENEA needs to be improved to adequately represent low carbon technologies.

Thanks for the attention!