Modeling carbon neutral pathways for EU Green Deal and climate neutrality

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EU Policy context

2016-18: Clean Energy for All Europeans package for 2030

- GHG -40%
- RES 32%
- EE 32.5%

2018-19: Clean Planet For All package

- Climate neutrality in the EU by 2050
- –> Zero net CO2 emissions
- Various pathways

National Energy and Climate Plans (NECPs) end 2019

- Compatible with the RES target
- Short in Energy Efficiency ambition

Current trends

- Coal phase-out, large RES projects
- E-mobility emerging
- Green gas and Hydrogen projects launched

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Stepping up Europe's 2030 climate ambition

(Climate Target Plan)

Key questions for the model-based analysis

- Is climate-neutrality by 2050 in the EU viable and sustainable in the long run?
- Is it possible to reach climate-neutrality solely with conventional fuels and technologies?
- If not, what additional elements to promote in addition to conventional policies and technologies?
- Is climate-neutrality affordable?
- Which policy instruments are cost effective?

Options for decarbonisation

"NO-REGRET" OPTIONS

Energy efficiency improvement in buildings, equipment and vehicles.

Enhanced **renewables** in power generation

- Large-scale investment in variable renewables
- Reliable integration of renewables (grids, market integration, storage systems, demand response)

Electrification of transport and heating where cost-efficient, e.g.:

- Private transport in urban environments
- Heat pumps in heating

Produce sustainably and use advanced (second-generation) **biofuels**.

Extension in **Long Term Operation** (LTO) of the existing nuclear fleet where possible and **geological storage of CO_2** where acceptable.

DISRUPTIVE CHANGES

Reduce energy demand in all sectors beyond conventional energy savings, e.g. circular economy, sharing of vehicles, secondary materials production via recycling.

Changes in **the way users use energy**, e.g. high electrification in industry and transport, direct use of distributed hydrogen and the way energy is distributed (grid and storage for hydrogen, liquified hydrogen or GHG-free methane) etc.

Changes in the **production and nature of energy commodities**, e.g.:

- mix hydrogen and biogas in gas distribution
- replace fossil gas by carbon-neutral methane
- replace fossil liquids by carbon-neutral fuels

Capturing CO_2 from air or biomass for re-use (**synthetic hydrocarbons**) or underground storage (**carbon sinks**).

Capturing CO_2 from fossil fuels combustion or industrial processes and use to produce materials (**sequestering carbon dioxide**).

PRIMES modelling to explore contrasted strategies

Max Efficiency & Circular Economy	Maximum Electrification	Hydrogen as an end-use carrier	GHG-neutral fuels (gaseous, liquids)
Pros • Non expensive • No pressure in the energy supply potential **Cons** • Depends on investment by individuals • Potential uncertain • Unclear appropriate policy signals • Low demand discourages investment in the supply side	**Pros** • Efficient and convenient • Modest growth of demand for electricity **Cons** • Cannot fully electrify industry and transport • Lack of competition among carriers • High seasonal and daily variability, high balancing costs	**Pros** • H2 can be a universal carrier • Chemical storage of electricity • Less electricity intensive than e-fuels **Cons** • Infrastructure changes • Uncertain future costs of H2 and fuel cells • Public acceptance	**Pros** • Existing infrastructure and way of consuming energy • Chemical storage of electricity • Competition among carriers **Cons** • Carbon neutral CO_2 feedstock (DAC, biogenic) • Uncertain future costs of e-fuels • Vast increase of total power generation

Demand side modelling challenges

Circular economy

- What is the potential for decreasing energy demand through circularity?
  - Recycling and modularity
  - Primary and secondary production of metals
  - Literature still under development

Energy efficiency

- Examine the potential of increasing the efficiency of the transport system (e.g. car sharing, improved scheduling)
  - Heat recovery capabilities in industry
  - Deep renovation strategies in buildings

Buildings

- Representation of non-market barriers, idiosyncratic behaviors: Detailed segmentation of households and dwelling types
- Long payback periods of renovation investments: Nested choice of other energy equipment, depending on the choice for heating and insulation

Industry

- Decarbonize process emissions
- Direct use of carbon-free hydrogen in industrial uses; Upper limit to the electrification of industrial uses
- 1-3 investment cycles till 2050
- High segmentation of industrial sectors, energy uses, technologies, Dynamic and intertemporal modelling of capital vintages, technology and fuel choice

Transport

- Decarbonisation of long-distance mobility
- Inclusion of novel technologies (electric aircrafts, hydrogen vessels, electric trucks)
- Inclusion of new energy carriers (hydrogen, e-fuels, advanced biofuels)
- New trends: sharing

Supply side challenges

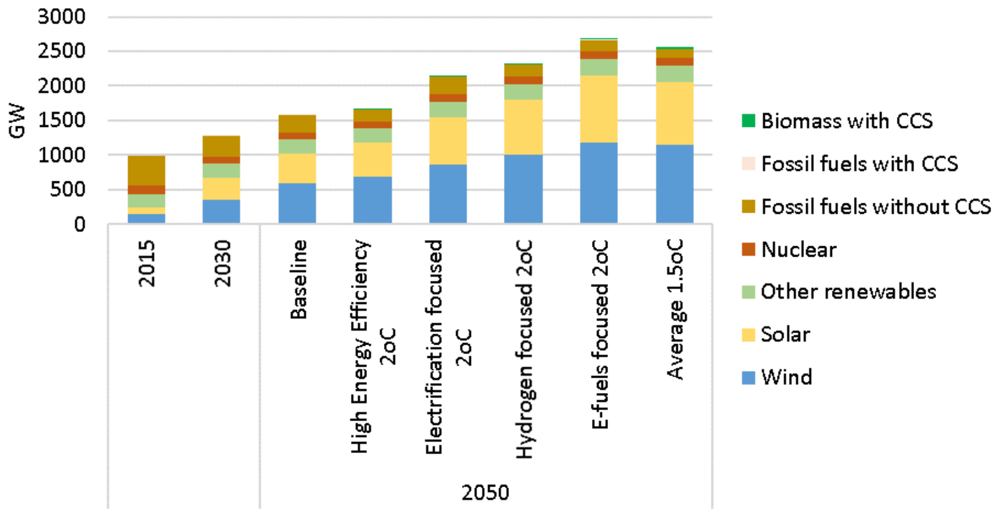
Power and Heat

- Demand for flexibility because of extreme RES (85%)
- Differentiated unit commitment from capacity expansion
- Integrated simulation over the European interconnected system using flow-based allocation
- Synergies with the industrial sector
- Simultaneous simulation of electricity, distributed heat and industrial steam (boilers, CHP, district heating)

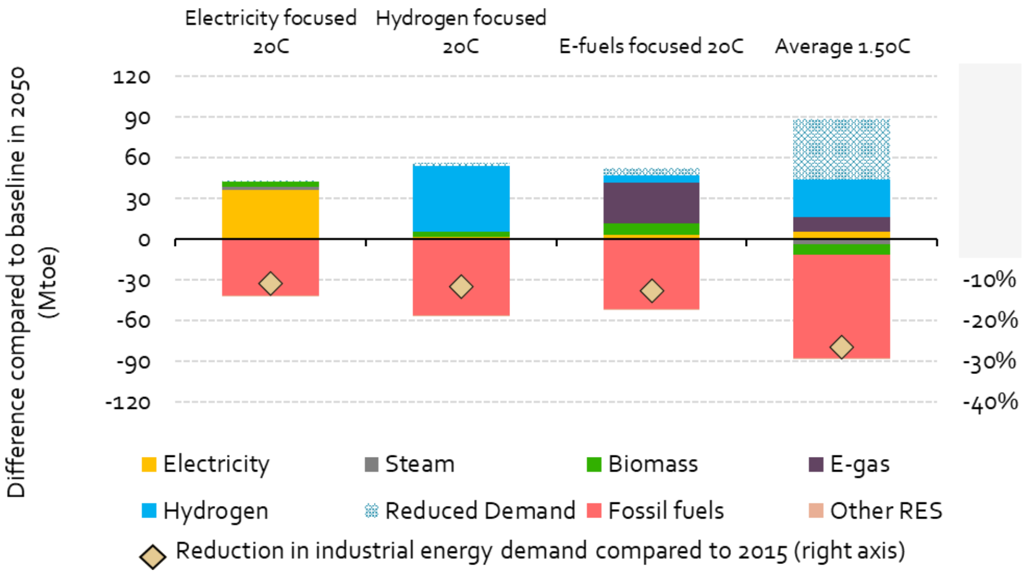
Production of new fuels and storage

- Multiple storage options (batteries, pumping, hydrogen, e-gas)
- Co-production of multiple products: location of production and consumption, infrastructure

POWER GENERATION

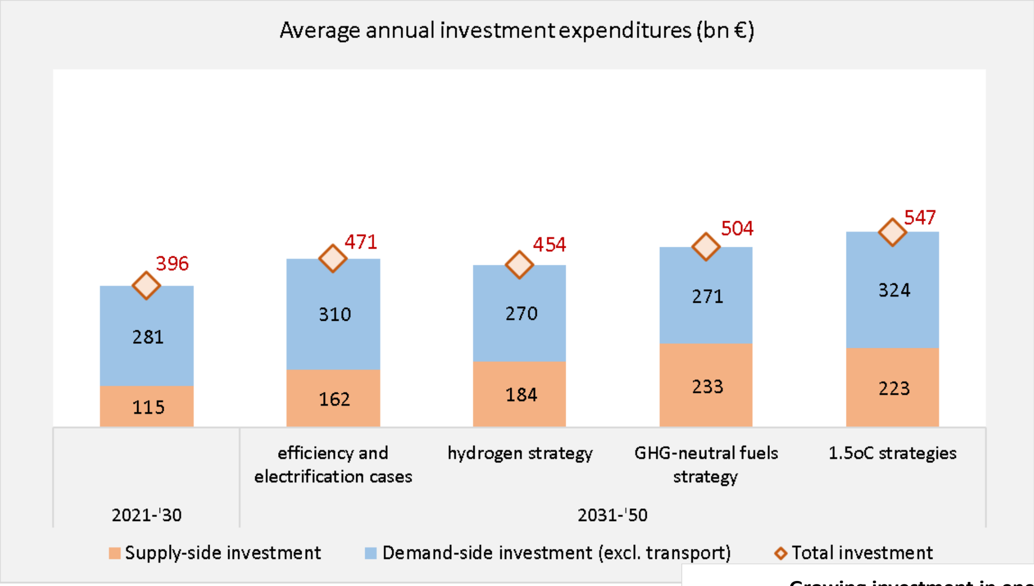


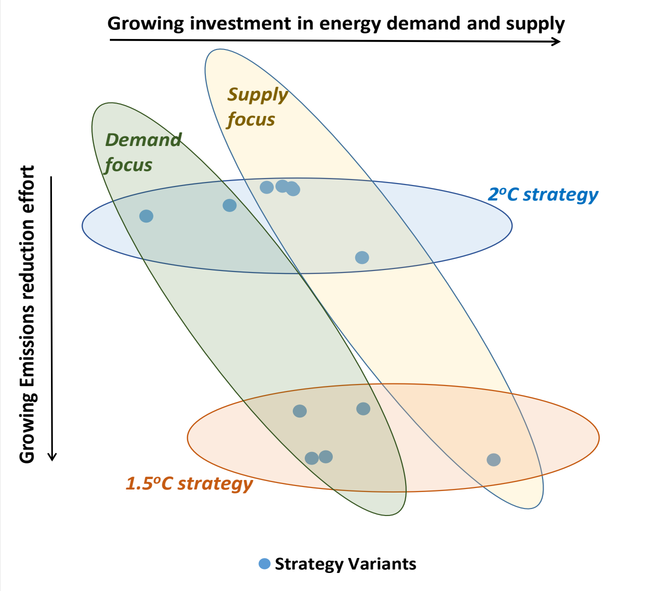
INDUSTRY



Energy system costs and investment

- The long-term strategy needs increasing investment (in both energy demand and supply sectors) but reduces energy purchasing expenditures
- The fastest growing part of investment concerns individuals and firms as end-users of energy.
- Investment in infrastructure is the fastest growing part of investment in energy supply sectors
- Average costs of electricity are similar in all strategy variants, as the decreasing capital costs of RES and chemical storage offset diseconomies of scale.
- The learning-by-doing dynamics of today's low TRL technologies are of crucial importance for the costs of the supply focused scenarios.
- The transition is particularly capital-intensive, both in demand and energy supply sectors.
- The scenarios focusing on reducing the demand for energy services require lower total investment expenditures compared to the supply-focusing scenarios.
- As expected, the 1.5°C variants are more costly than the 2°C ones.





Concluding remarks

- Climate neutrality in the EU by 2050 is feasible without excessive cost burden.
- However, cost estimations are uncertain as depending on the potential of learning and massive industrial production of new technologies.
- There should be no doubt about the no-regret options of the strategy, namely energy efficiency, renewables, electrification and advanced biofuels where cost-effective. The 2030 EU climate and energy is consistent with the LTS.
- Disruptive changes are necessary to reach climate neutrality. They may imply changes in the energy production, distribution and consumption paradigm.
- The choice of a single strategy for disruptive changes is not yet mature. Actions are necessary to resolve the technology, as investment requires long-term visibility.
- The next decade is of utmost importance for infrastructure, industrial development of immature technologies and the power sector restructuring.
- Addressing concerns related to investment by individuals and firms with poor fund raising capabilities constitutes a new policy priority.