EU Net zero pathways: modelling challenges

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What? How? Why?

***What** has been modelled for the EU "A Clean Planet for All" exercise?*

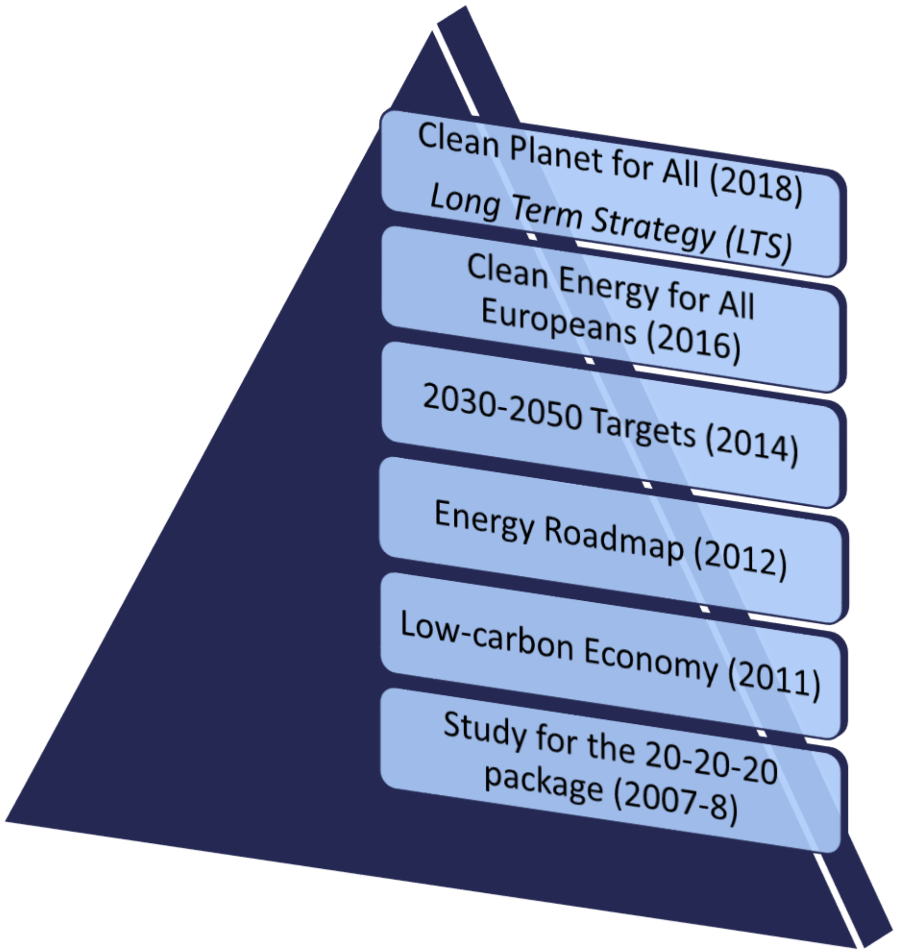
- Long term decarbonisation scenarios:
  - ✓ 2°C scenarios (-80% GHG in 2050 wrt 1990)
  - ✓ 1.5°C scenarios (climate neutral, up to -92% to -94% GHG in 2050 wrt 1990 excluding LULUCF, including LULUCF net zero GHG)
- All scenarios respect the EU 2030 energy and climate targets

***How** has the EU Long Term Strategy (LTS) been modelled?*

- Using an enhanced version of the PRIMES energy model
- Additional models used for non-CO_2 and AFOLU (GAINS, GLOBIOM, CAPRI)

***Why** enhancements were necessary?*

- Increased ambition after COP21; climate neutrality
- Unabated emissions remain using traditional approaches for decarbonisation
- New "disruptive" technologies
- Improve coverage of sectorial integration



Key questions for the model-based analysis

- Can the 2030 climate and energy framework deliver a decarbonised economy in the long term?
- Is climate-neutrality by 2050 in the EU viable and sustainable in the long run?
- Is it possible to reach carbon-neutrality solely with conventional fuels and technologies?
- If not, what additional elements to promote in addition to conventional policies and technologies?
- Is carbon-neutrality affordable?
- Which policy instruments are cost effective?

"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

Long Term Strategy modelling challenge: circularity and energy efficiency (I)

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

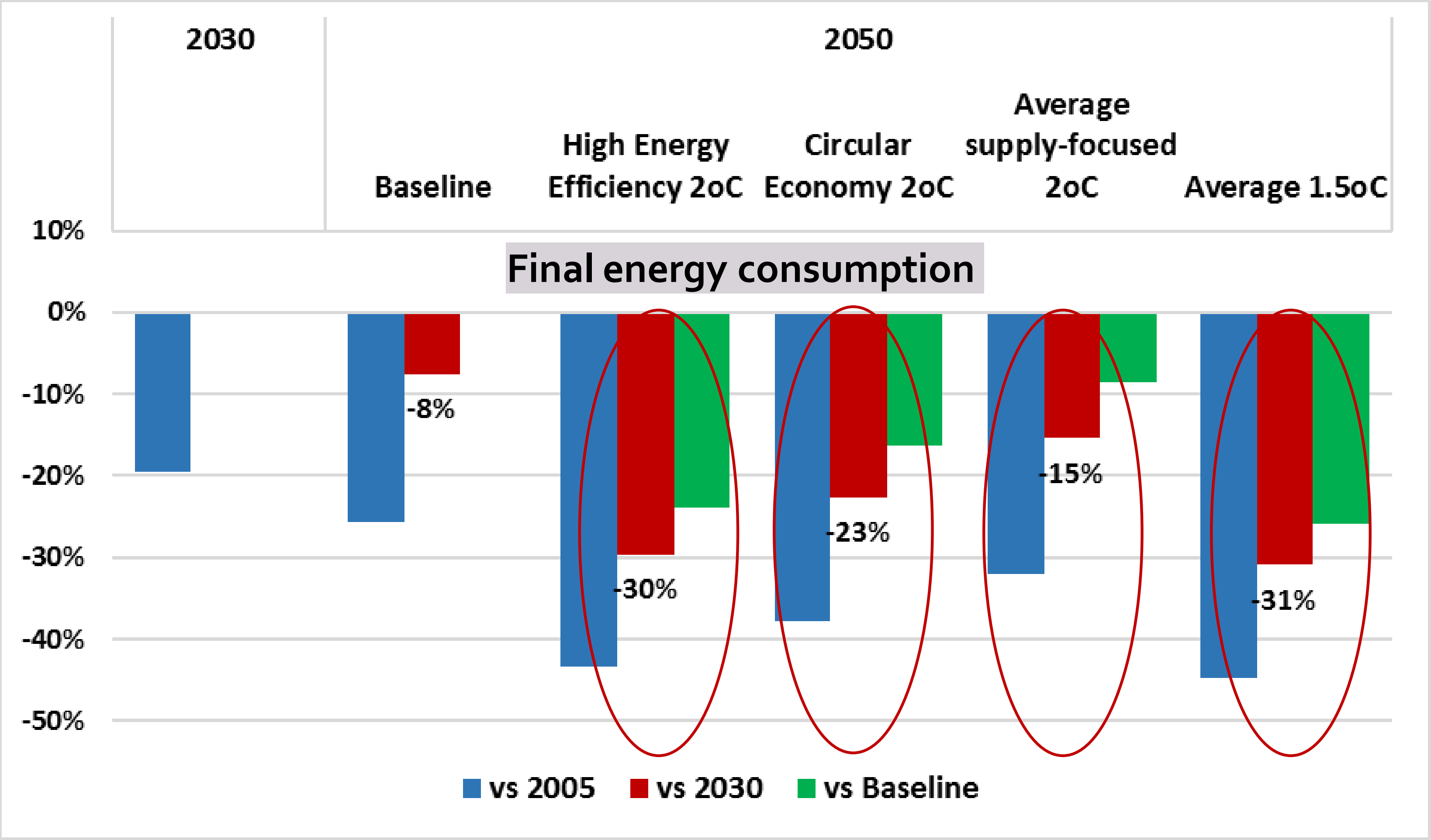
ENERGY EFFICIENCY

- 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

Long Term Strategy modelling challenge: circularity and energy efficiency (II)

CIRCULAR ECONOMY

ENERGY EFFICIENCY



Long Term Strategy modelling challenges for buildings and industry (I)

BUILDINGS

- Representation of non-market barriers, hidden costs and idiosyncratic behaviors
  - ✓ Detailed segmentation of households and dwelling types
- Long payback periods of renovation investments
  - ✓ Dynamic programming modelling of renovation strategies
  - ✓ Nested choice of other energy equipment, depending on the choice for heating and insulation

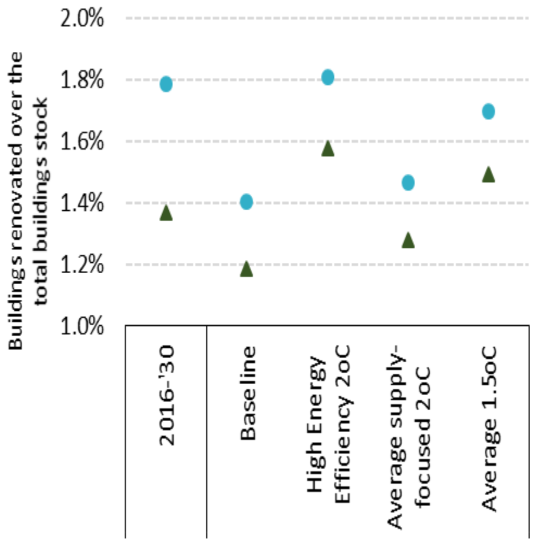
INDUSTRY

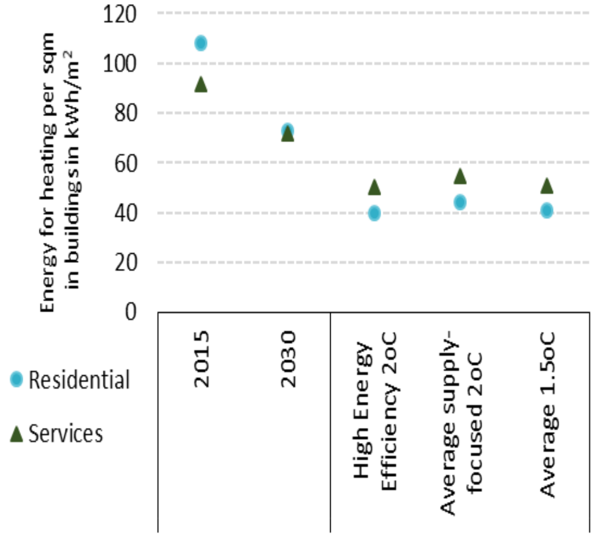
- Decarbonize process emissions
  - ✓ Direct use of carbon-free hydrogen in industrial uses
- 1-3 investment cycles till 2050
  - ✓ Dynamic and intertemporal modelling of capital vintages, technology and fuel choice
- Upper limit to the electrification of industrial uses
  - ✓ High segmentation of industrial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

Long Term Strategy modelling challenges for buildings and industry (I)

BUILDINGS

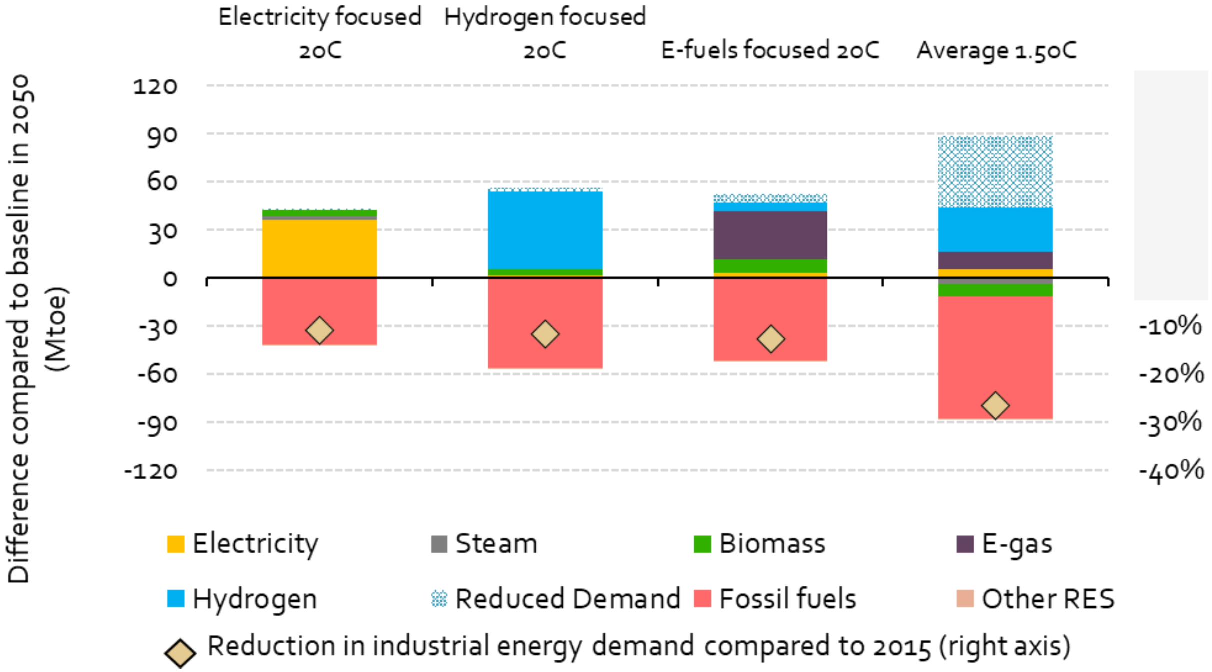
Buildings sector indicators





INDUSTRY

Industry fuel mix in 2050



Long Term Strategy modelling challenges for power & heat and transport (I)

POWER & HEAT GENERATION

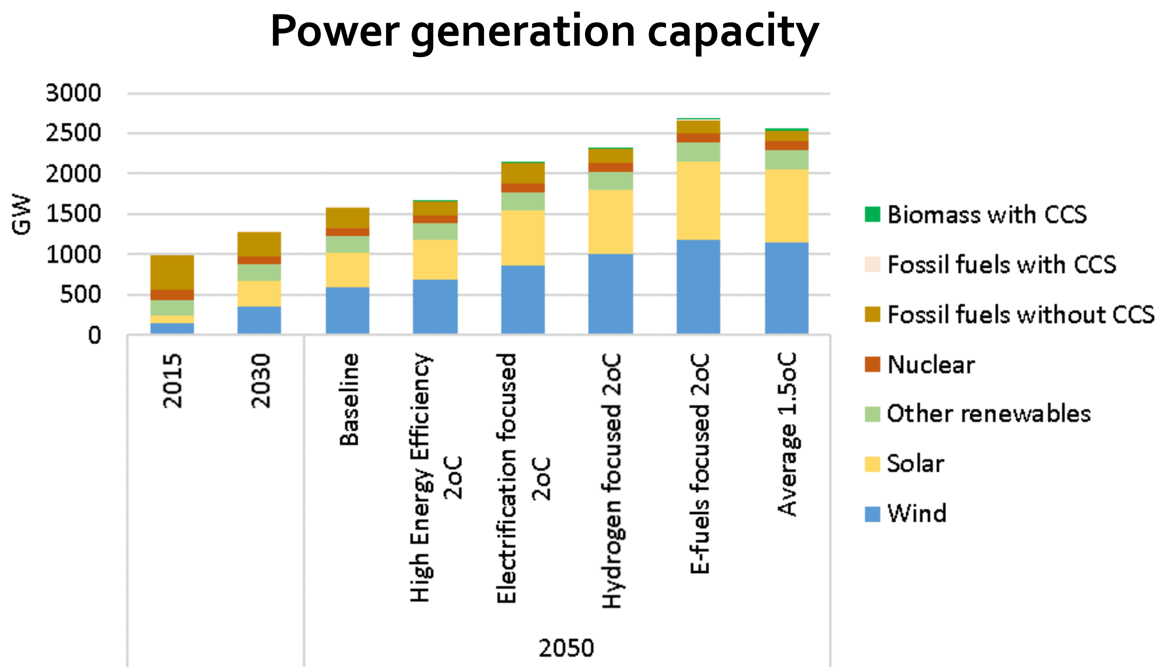
- Demand for flexibility because of extreme RES (85%)
  - ✓ Differentiated unit commitment from capacity expansion
  - ✓ Multiple storage options (batteries, pumping, hydrogen, e-gas)
  - ✓ Integrated simulation over the European interconnected system using flow-based allocation
- Synergies with the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

TRANSPORT

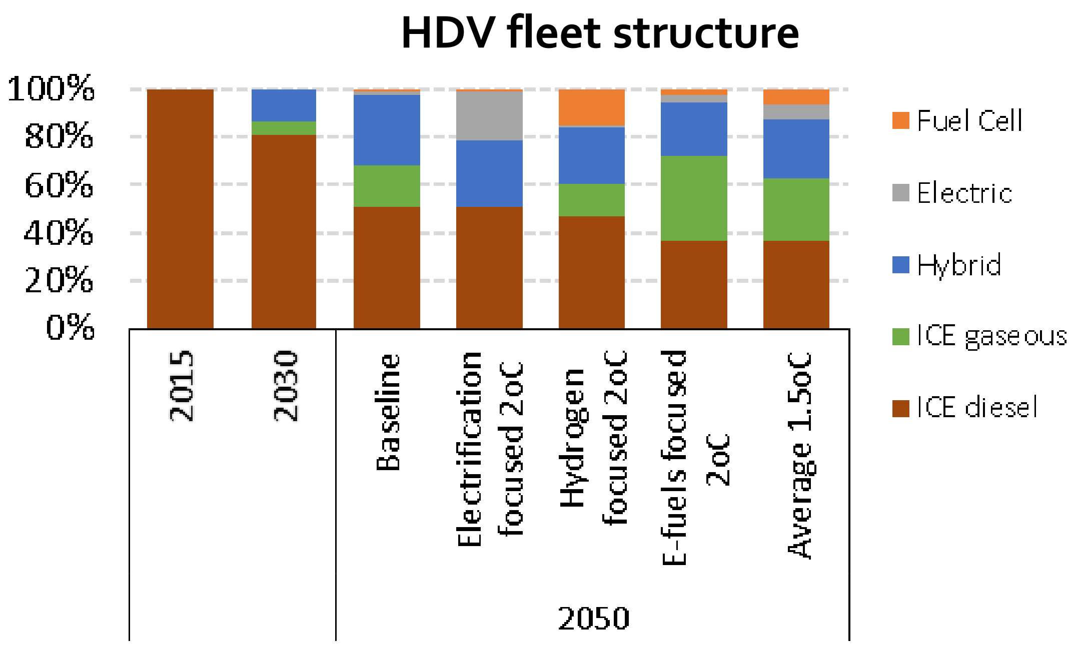
- Decarbonisation of long-distance mobility
  - ✓ Inclusion of novel technologies (electric aircrafts, hydrogen vessels, electric trucks)
  - ✓ Inclusion of new energy carriers (hydrogen, e-fuels, advanced biofuels)

Long Term Strategy modelling challenges for power & heat and transport (I)

POWER & HEAT GENERATION

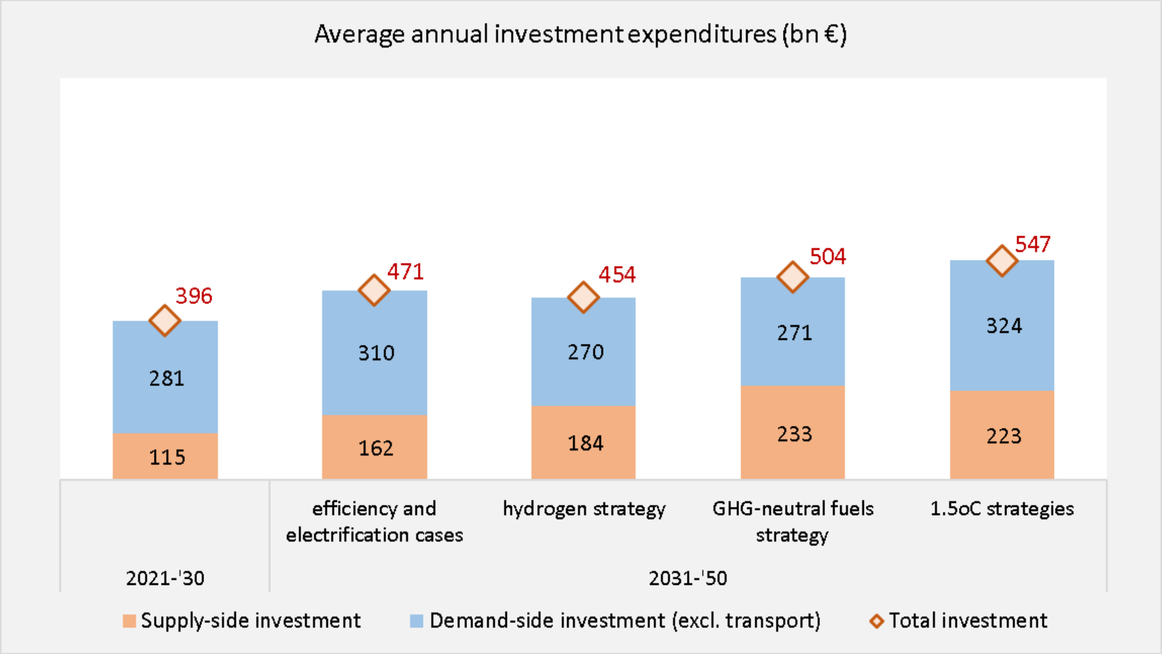


TRANSPORT



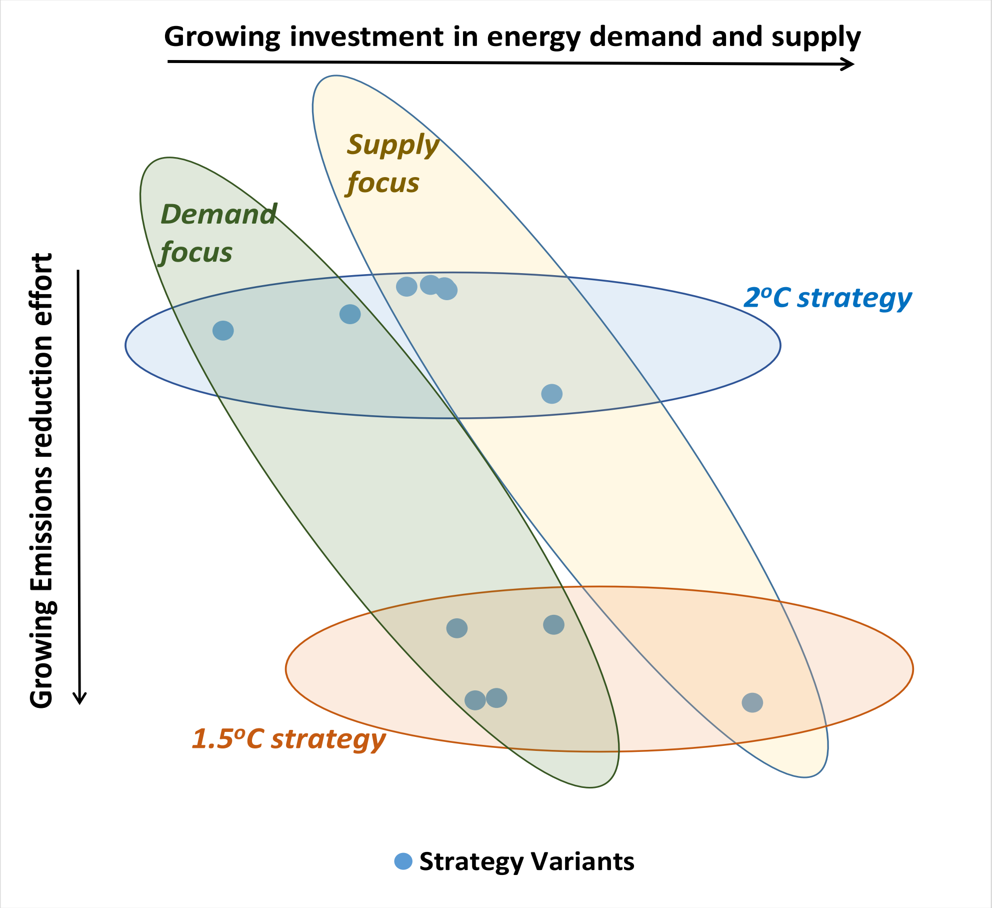
Energy system costs and investment (I)

- 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.



Energy system costs and investment (II)

- 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

- Carbon 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.

Thank you for your attention!

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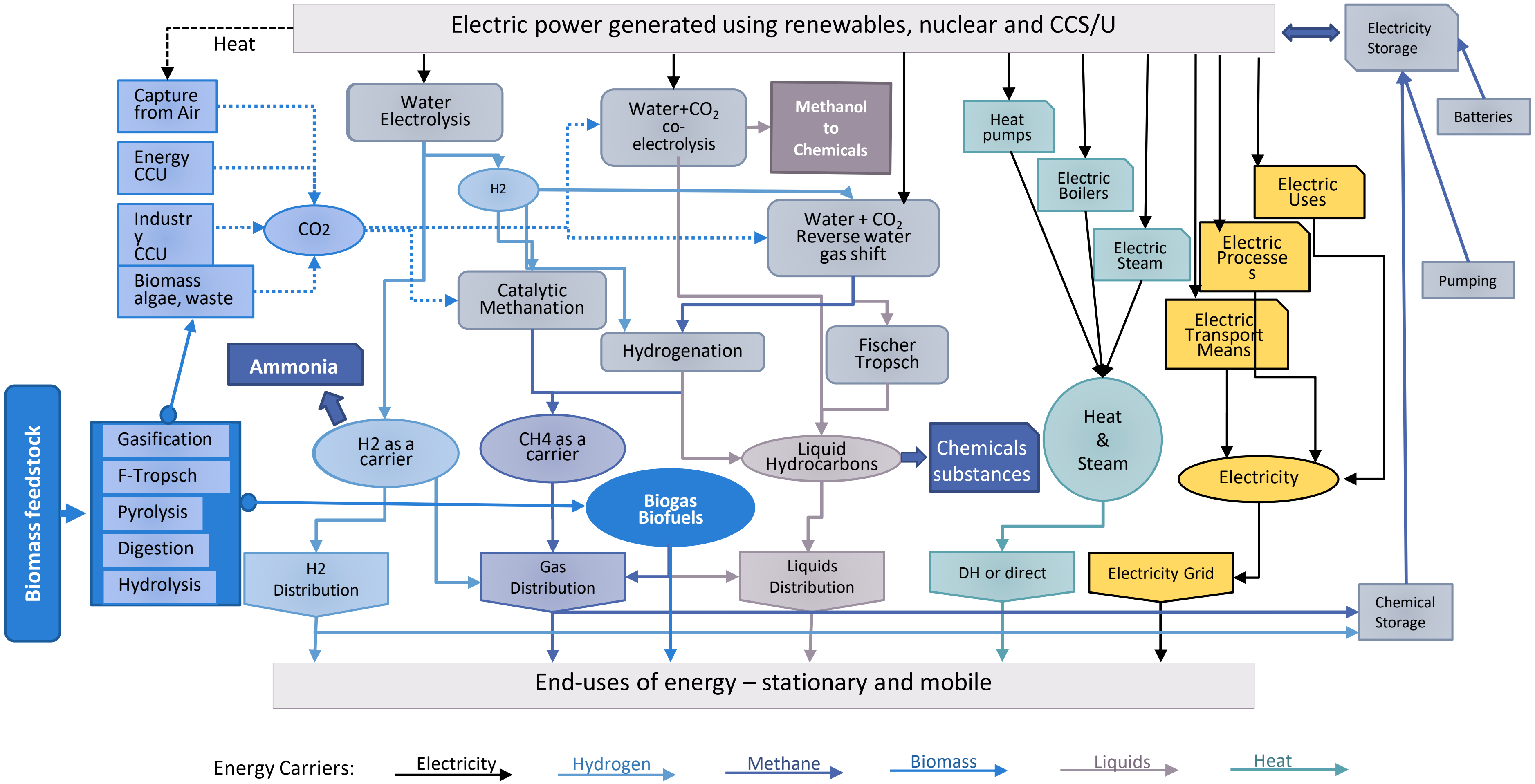
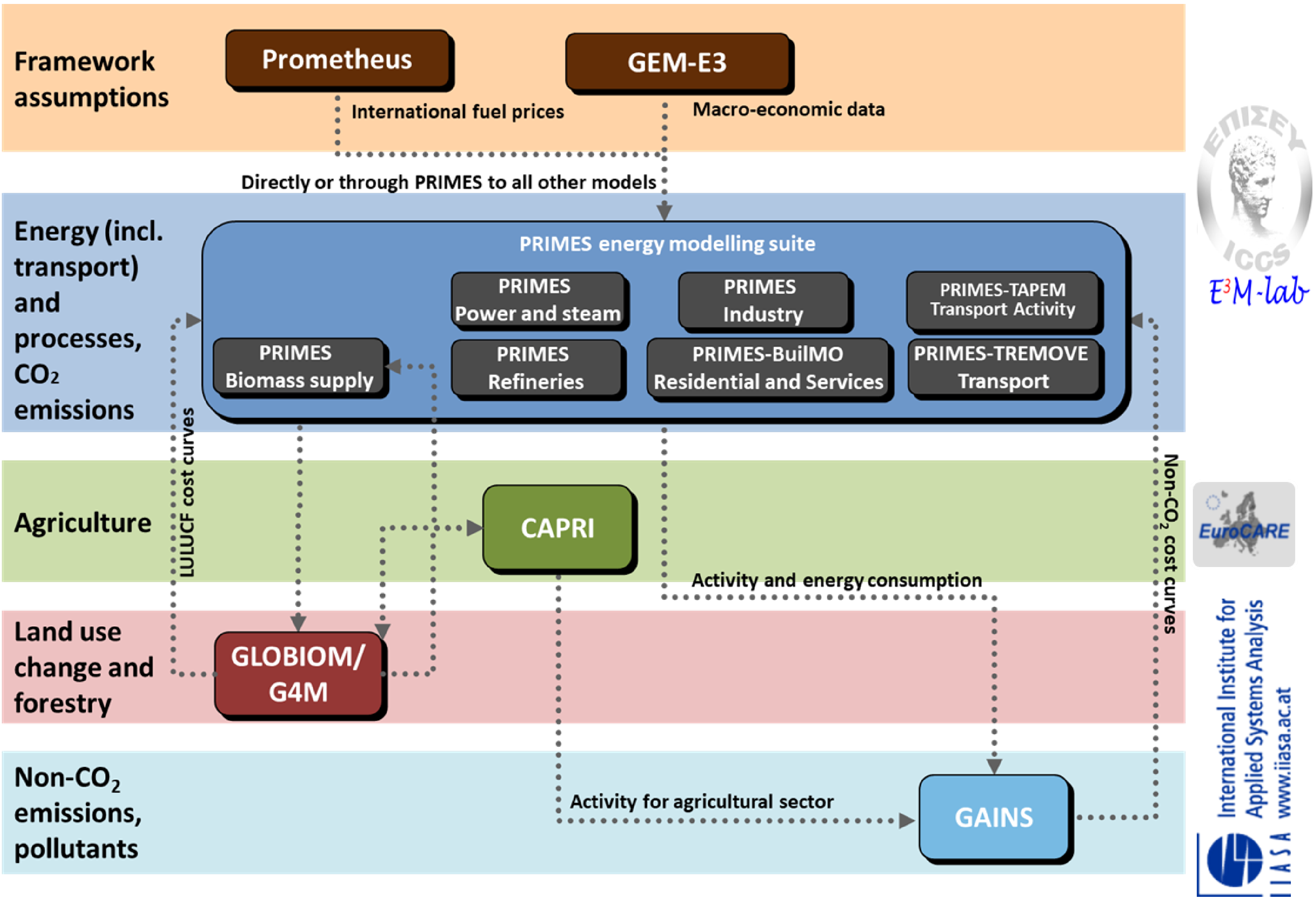
APPENDIX

Alternative pathways for LTS - illustration




Framework assumptions
Prometheus
GEM-E3
International fuel prices
Macro-economic data
Directly or through PRIMES to all other models
Energy (incl. transport) and processes, CO_2 emissions
PRIMES energy modelling suite
PRIMES Power and steam
PRIMES Industry
PRIMES-TAPEM Transport Activity
PRIMES Biomass supply
PRIMES Refineries
PRIMES-BuilMO Residential and Services
PRIMES-TREMOVE Transport
LULUCF cost curves
Non-CO_2 cost curves
Agriculture
CAPRI
Activity and energy consumption
Land use change and forestry
GLOBIOM/ G4M
Non-CO_2 emissions, pollutants
Activity for agricultural sector
GAINS
E3M-lab
EuroCARE
International Institute for Applied Systems Analysis www.iiasa.ac.at
IIASA

PRIMES model overview

AIM:

- **Simulate structural changes and long-term transitions**

Model structure:

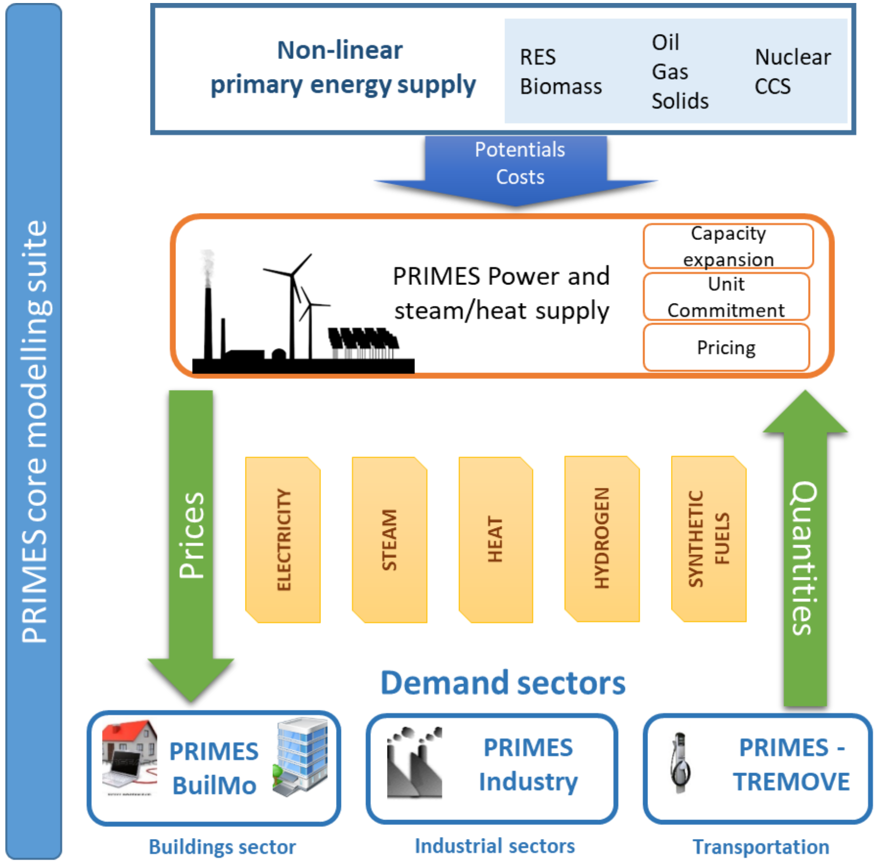
- **Modular system:** one module per sector
- **Microeconomic foundation with engineering representations**

Focus:

- **Market-related mechanisms**
- Representation of **policy instruments for market, energy and emissions**, for policy impact assessment

Technology database:

- Energy technology database has a standard format and is open access



Temporal resolution: to 2070, in 5-year time steps
Geographic resolution: 28 EU MS + 10 European non-EU countries
Mathematically: concatenation of mixed-complementarity problems with equilibrium conditions and overall constraints (e.g. carbon constraint with associated shadow carbon value) - EPEC