Introduction to a Mid-Century Strategy (MCS) for deep decarbonisation in the EU

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Goal and main features of an MCS

Goal

A. Comply with the EU commitments for the Paris Agreement

B. Consider embedding the MCS in a 1.5 ° strategy

C. Based on a global analysis, the EU needs, relative to 1990, to reduce the sum of all GHG emissions by

- Above 80-85% in 2050 in a 2° context
- Above 95% in 2050 in a 1.5° context
- Maintain emissions reduction after 2050 and reach near zero GHG until 2070

Features

A. Transition to a low or near-zero fossil fuel energy system by 2050 and 2070, after achieving the 2030 targets, while maintaining affordability of energy costs, security of supply and market competition in the EU

B. Reduce non-CO_2 emissions significantly and reduce industrial process emissions while exploring synergies between emissions cuts and reforms in industrial materials and processing

C. Sequester CO_2 by consider land-sink, CCS/CCU and BECCS or other negative emissions enablers

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The 2030 package is not enough for the 2050 targets

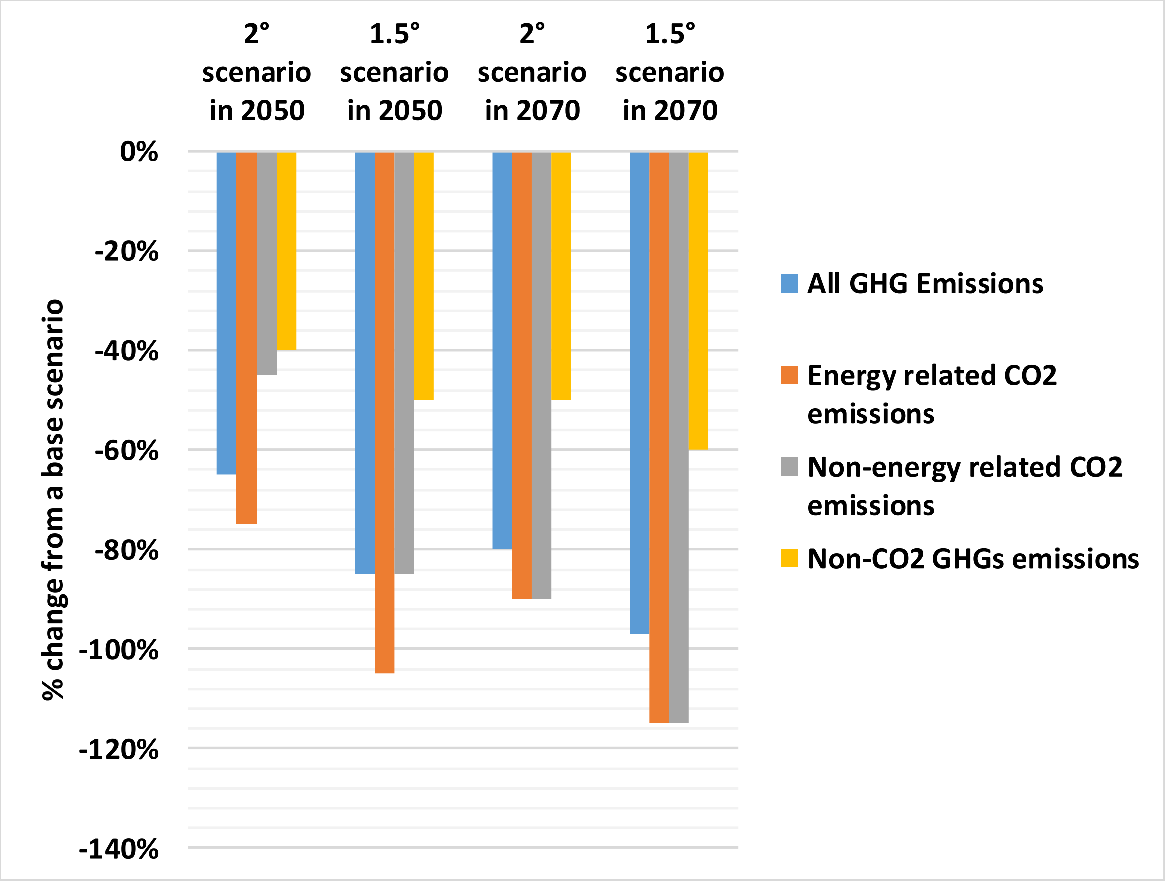
Until 2030

A. Maximize effort of energy savings
   - Buildings: high renovation rates and deep energy renovation
   - Equipment: stricter standards, as in eco-design
   - Transport: CO2 and efficiency standards for vehicles

B. Put the power sector on a low-carbon track
   - Market Stability Reserve and enhancement of ETS
   - Discourage subsidies to highly emitting power plants
   - Promote Renewables in addition to the ETS driver

C. Establish enabling conditions needed by the transition after 2030
   - Research, Development and Demonstration
   - Infrastructure and market arrangements for competition, electrification and integration of renewables
   - Regulate biofuels

The MCS needs to cut emissions much beyond a base scenario, which includes the 2030 policy package but no new policies after 2030



Transition of the energy system beyond 2030

No regret actions

A. Continue and enhance energy efficiency effort in the buildings and for equipment and vehicles
B. Electrify transport and heating where cost-efficient
C. Continue and enhance investment in renewables in the power sector
D. Arrange for reliable integration of renewables in the power sector (grids, market integration, storage systems, demand response)
E. Incite final energy users to become active and become clean self-producers
F. Produce advanced biofuels in a sustainable way
G. Use nuclear and geological storage of CO_2 where acceptable

Possible disruptive changes

A. Reduce demand in all sectors beyond conventional energy savings, e.g. circular economy, sharing of vehicles, materials sequestering CO_2
B. Disruptive changes in the way users get and use energy, e.g. extreme electrification in industry and transport, direct use of distributed hydrogen
C. Disruptive changes in the production and nature of energy commodities, e.g. mix hydrogen and biogas in gas distribution, replace fossil gas by renewable gas and fossil liquids by synthetic fuels (electro-fuels from hydrogen and captured or biogenic CO_2)
D. Disruptive changes to establish circuits of CO_2 capturing, use and sequestering in storage areas, materials and/or fuels, e.g. CO_2 captured in industrial processes used in ammonia or petrochemicals, replacing reforming of fossil fuels, biomass CCS and CO_2 capture from the air

Illustration: Three stylized examples of disruptive changes

	Main uncertainties	Main advantages
Distribution and Direct use of hydrogen	• Distribution and transport network specifically for H_2 • Cost of fuel cells • H_2 storage	• H_2 is an energy carrier valid for the entire system • High energy efficiency maintained • No excessive increase in power generation • Can accommodate H_2 to fuel processing if technology reached maturity in the future
Hydrogen mixed in gas networks, and clean gas and liquids	• CO_2 capture from air • Poor energy efficiency • Too high increase in demand for electricity • Costs	• Continued use of existing distribution infra for gas and liquid fuels • Convenient energy applications, equipment and processes • No major disturbance of transport system
Maximum Electrification Using RES and storage (incl. H2)	• Electric aircrafts, ships and long distance trucks • Electrification of all industrial processes • Electrification of all residential energy uses	• High efficiency of electricity in end-uses • Feasible from power system perspective • Power-to-H_2 used mainly for storage purposes can develop without major uncertainties and can achieve low costs

Observations – Issues for discussion

1. Central role of electricity in the low-carbon system , acceleration of electrification in heating and road transport, but
   - ? Limited to market segments where electrification is cost-efficient, or
   - ? Count on not-yet mature technologies allowing maximum electrification (e.g. steam from electricity, high temperature heat pumps, electric furnaces, electric long-distance traveling vehicles, aircrafts, ships, etc.
2. Significant increase in power generation (mainly from RES) is necessary to replace fossil fuels by GHG-free fuels
   - ? Deploy electro-fuels (power to hydrogen, capture of CO2, and production of methane, liquid fuels and primary chemical substances via known chemical processes), which require huge amounts of electricity, or
   - ? Perform fossil fuel replacement mainly by deploying hydrogen as an energy carrier, also produced from electricity (mainly RES) but requiring much less power than the electro-fuels
3. Pursuing an ambitious energy efficiency policy is a no-regret option, but
   - ? Apply a conventional energy saving strategy, of the same nature as current policies and of course more ambitious, or
   - ? Count on extreme renovation of buildings, the circular economy, the new chemical materials and measures in transport, including sharing of vehicles and efficient logistics
4. The variable RES will dominate power generation in the long-term as both nuclear and CCS have limitations. Self-production using RES by consumers, demand response and intelligent systems are no-regret developments. But in addition the system needs high economies of scale:
   - ? Storage and in particular chemical storage, hydro and batteries are critical for reliability together with gas plants that have to remain in the system.
   - ? Economies of scale in massive production of hydrogen and electro-fuels require high concentration, optimum location with respect to grids, access to remotely located RES with diversified time profiles and back-to-back contracts with nuclear
   - ? Can the system count on geological storage of carbon dioxide? It is important in the long-term, at least for negative emissions and the use of gas for balancing and cogeneration. Carbon capture and use, including storage in materials, are important, anyway. Carbon capture from biomass and from the ambient air are critical for the electro-fuel development case.
5. The cost assessment depends on the assumptions about learning by doing and the potential of economies of scale of disruptive technologies, such as electrolysis at a large scale, power-to-X, capture of CO2 from the air, distribution of hydrogen, the extreme electrification technologies and the implementation of structural changes in demand.

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Appendix: Preliminary projections within the project ASSET using the enhanced version of PRIMES

To be shown if necessary

A combined – realistic scenario achieving zero emissions

Hydrogen uses

1. Mix up to 15% in gas distribution
2. Use fuel cells using H2 in vehicles that cannot run in batteries, such as trucks, buses, taxis, duty vehicles. Combine with large-scale H2 refueling stations, which may include electrolysis and H2 storage.
3. Use H2 directly in high temperature furnaces in industry combined with local electrolysis and storage
4. Produce clean methane in methanation plants using CO2 captured from air, integrated in power utility facilities well interconnected. H2 produced in these locations also serve electricity storage.

Rest of Options

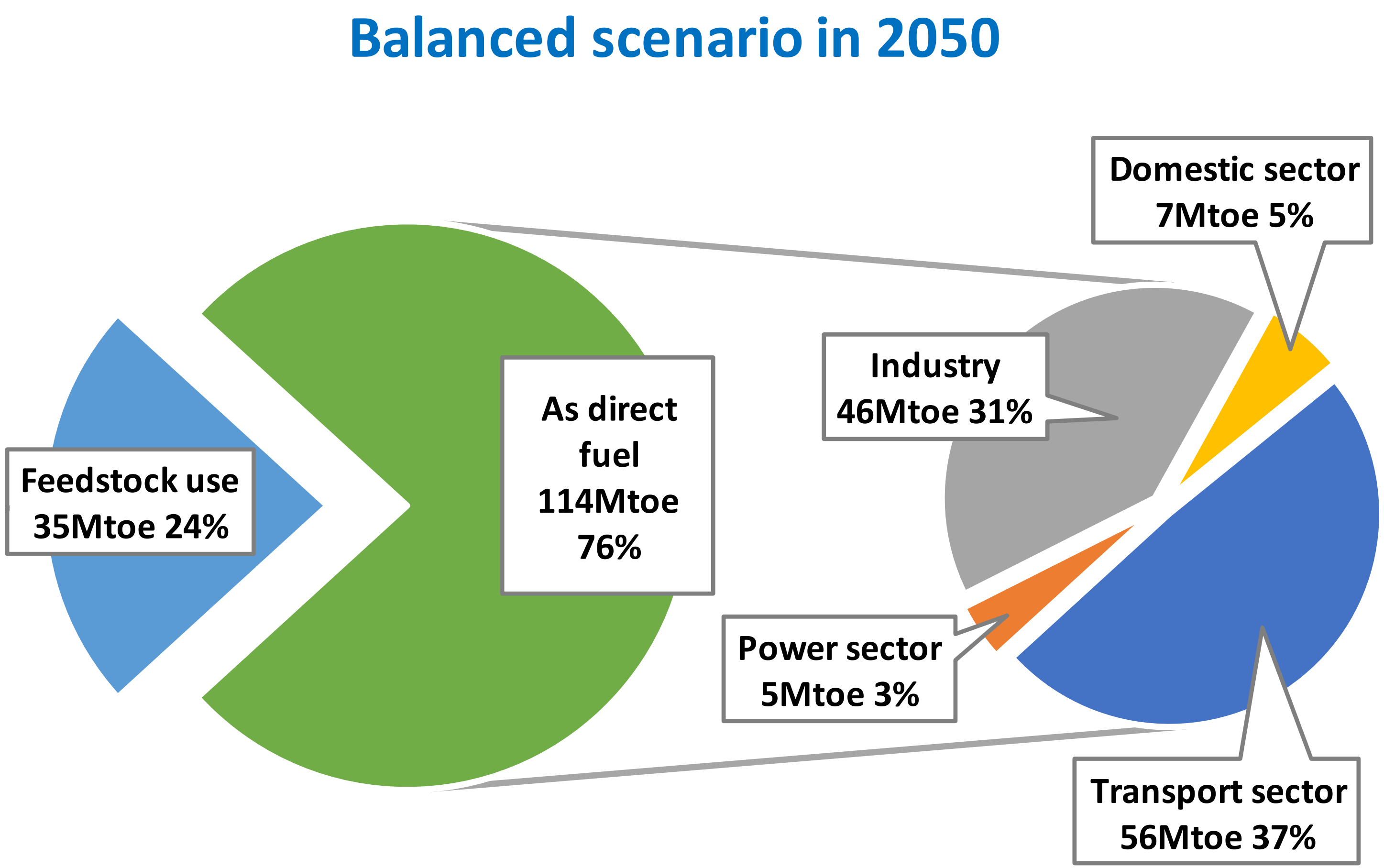
1. Full decarbonisation of the power generation using maximum contribution by RES, dispersed and centralized, complemented by nuclear and CCS where possible. Direct storage and chemical storage, as well as interconnections, succeed to balance the RES.
2. Maximum possible potential of energy efficiency in buildings and industry
3. Electrify car mobility and heating in a large segment of the markets
4. Advanced sustainable biomass feedstock to produce fungible jet fuels and ship fuel, as well as bio-methane mixed in the gas grid

Uses of hydrogen in the balanced scenario

A. Used directly in final consumption (3/4 of total)
   - 15% mixed in gas distribution
   - Directly in high temperature furnaces in industry
   - In transport via fuel cells

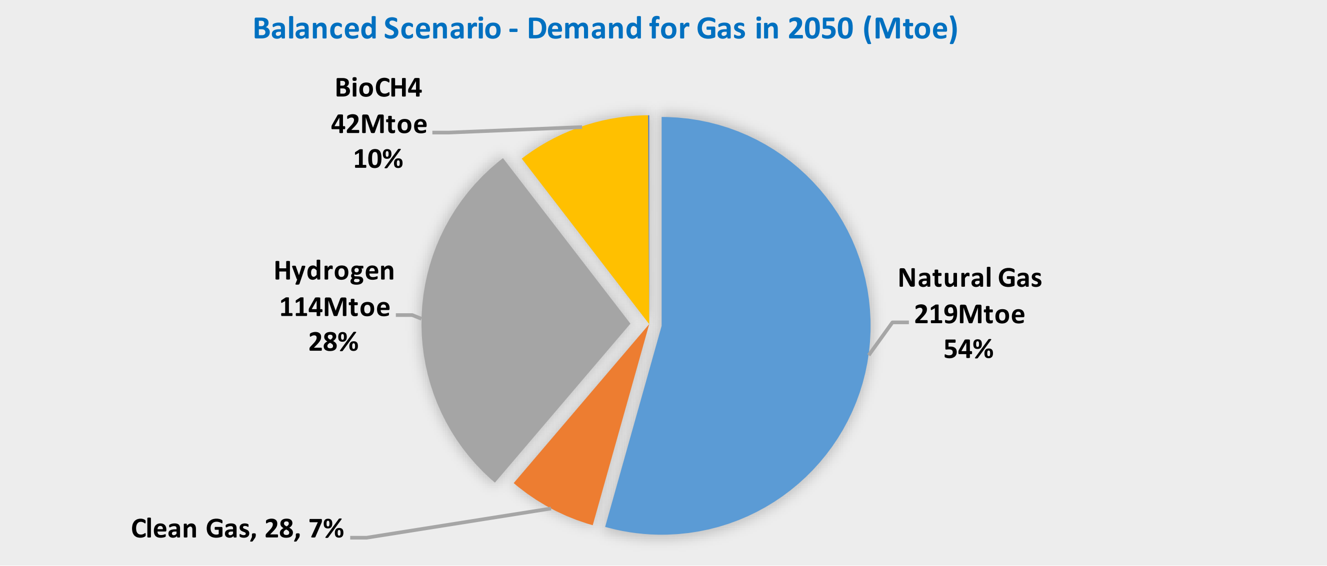
B. Used directly in power generation to perform electricity storage (chemical storage)

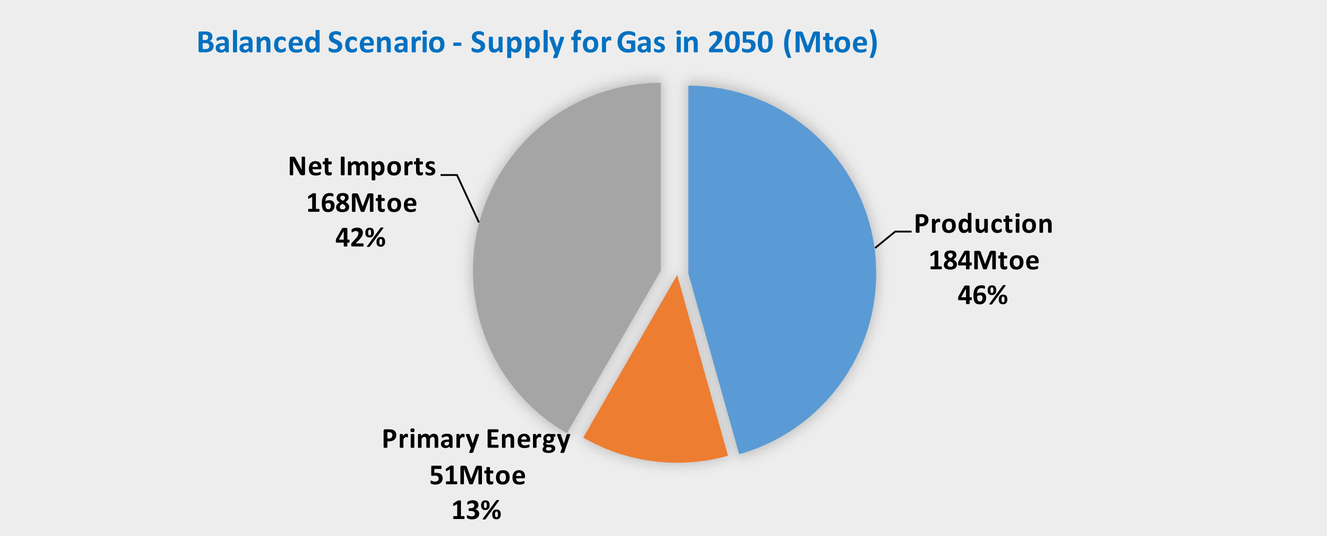
C. As a feedstock (1/4 of total) to produce clean methane (CH4), which is mixed in gas distribution and is used in the power sector for electricity storage



Gaseous fuels in the Balanced scenario

- ✓ Natural gas (fossil) covers only 54% of a total of 404Mtoe consumption of gaseous fuels in 2050
- ✓ Natural gas is roughly the only remaining fossil in the system, being used in the power balancing and mostly in CCGT-CCS plants
- ✓ Methanation and bio-energy plants produce 184Mtoe (45% of total gaseous)
- ✓ Tremendous independence from natural gas imports by 2050





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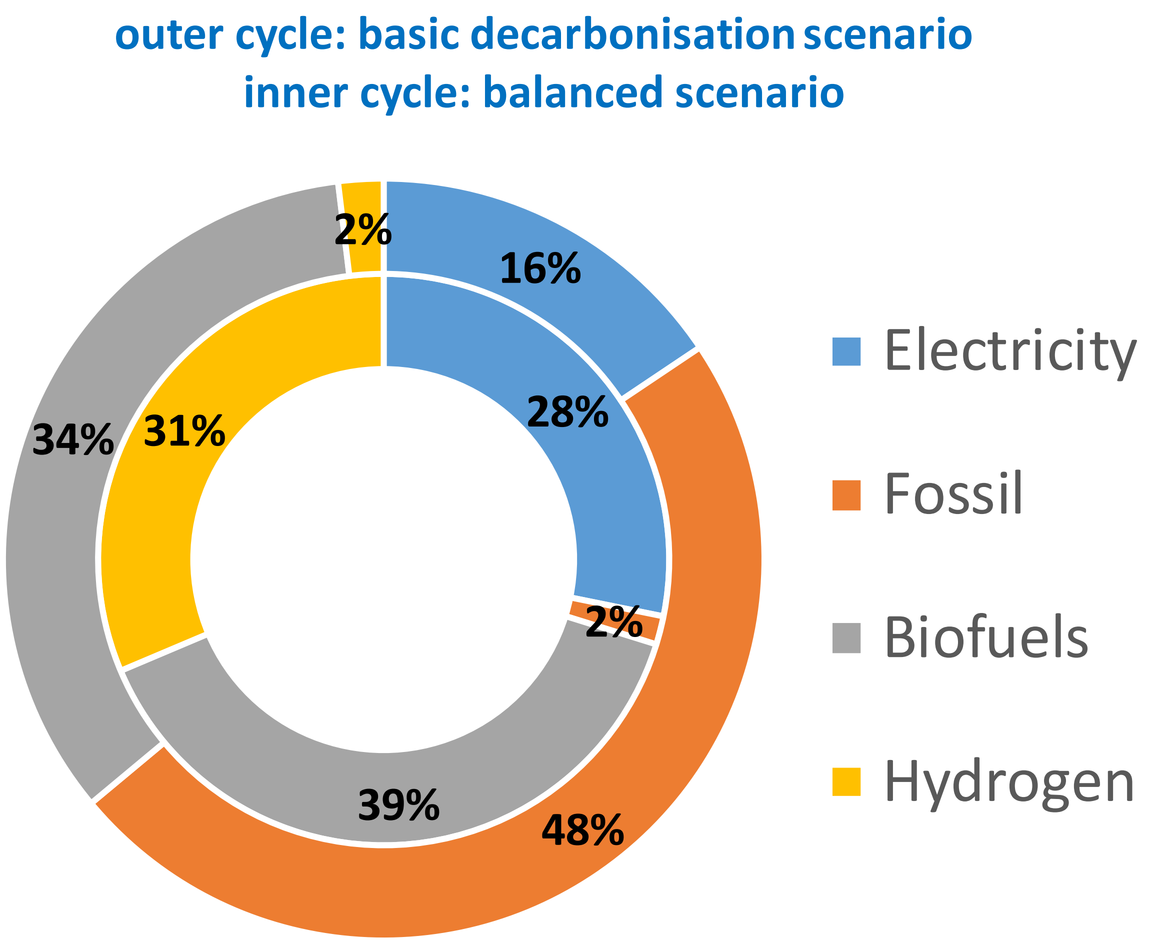
Fuel mix in Transport in 2050

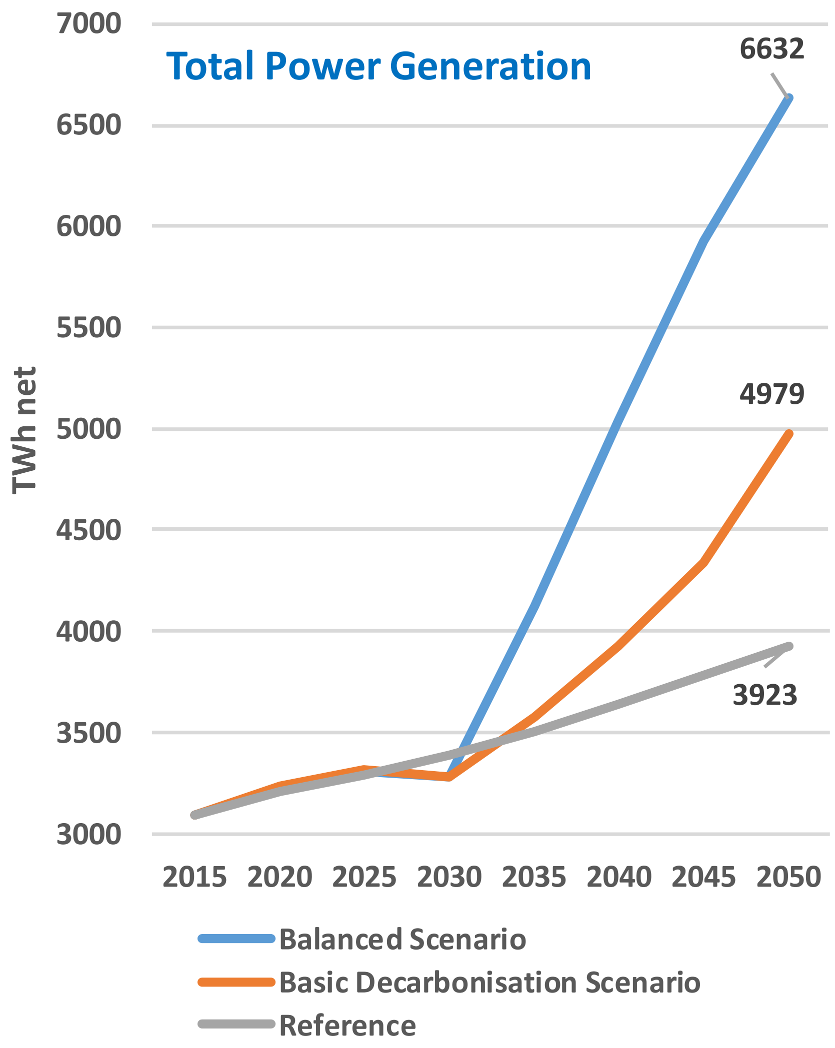
In the balanced scenario

- Almost no fossil fuels
- Complementary market segments for battery and fuel-cell vehicles
  - Battery-charged cars in cites and short-medium distance trips
  - Fuel cells heavy duty vehicles and cars with high mileage
- Lower total amounts of biofuels than in the basic decarbonisation scenario
  - The fuel cells move biofuels from trucks tc aircrafts and ships
- Optimistic learning assumptions, both for batteries and fuel cells, allow for full substitution of fossil fuels in the car market at lower total cost, compared to the basic decarbonisation scenario

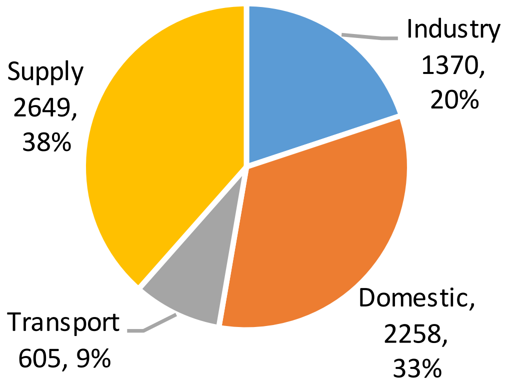


Hydrogen further enhances the role of electricity in decarbonisation

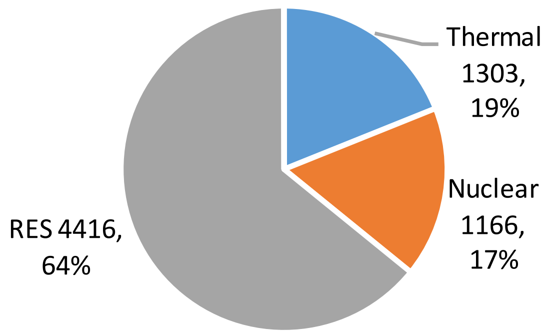
- Hydrogen and clean gas from electricity requires a large scale and a non-interrupted supply of electricity to become cost-efficient
- RES from different origins, with complementary production profiles and nuclear are an optimum input portfolio
- Large scale interconnections, full completion of the internal market and optimum location of large-scale power-to-X factories
- The power sector thus combines dispersed generation (prosumers) and a centralized generation segment over a mesh grid



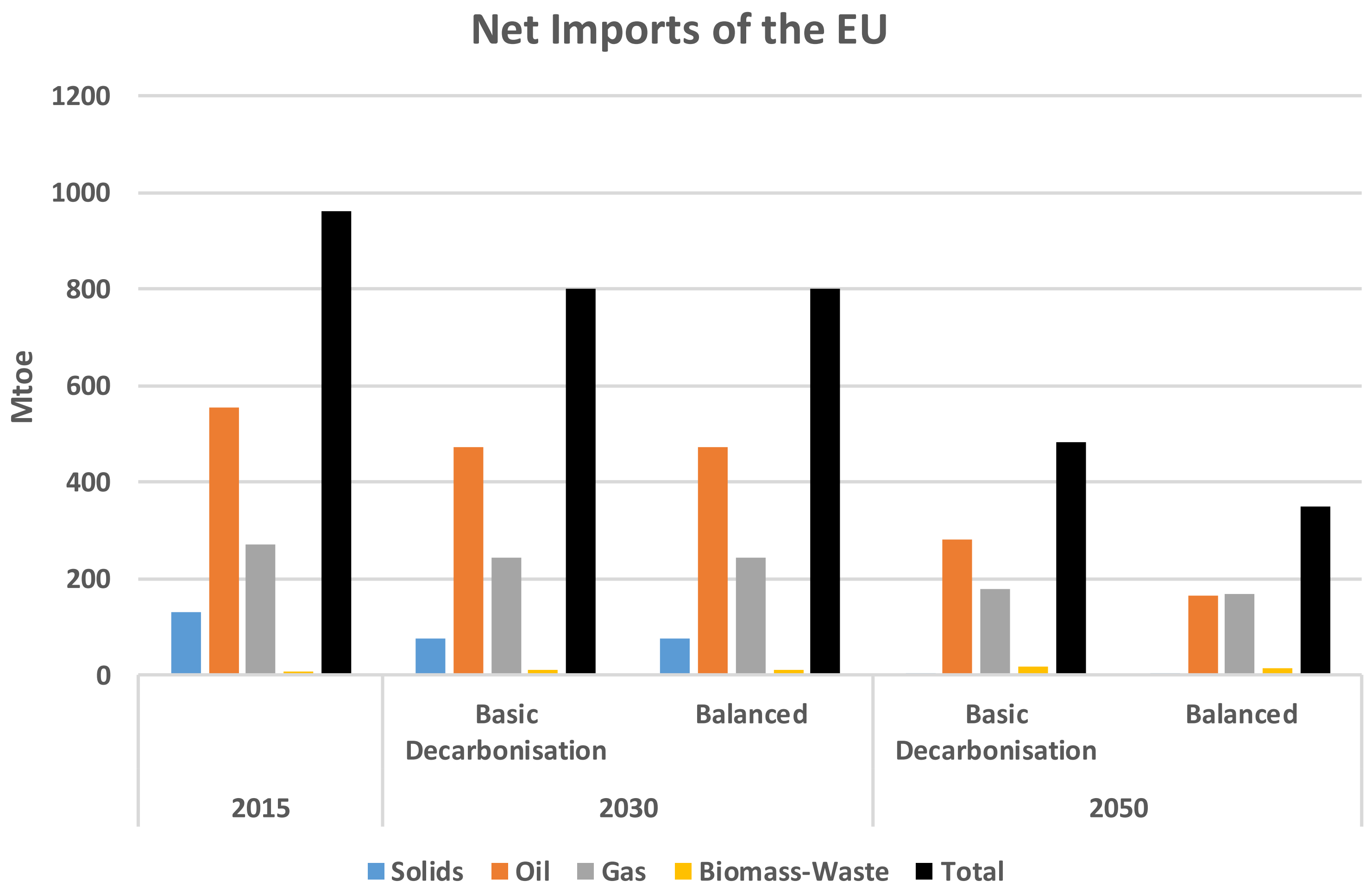
Electricity Consumption in the Balanced Scenario in 2050 (GWh)



Electricity Production in the Balanced Scenario in 2050 (GWh)



Tremendous benefits for import independence



- Oil imports are limited to petrochemicals, and they are fully substituted in transport
- Natural gas imports continue but at a much lower extent
- Biomass imports do not increase unreasonably, as biofuels are used in 2050 mainly in aircrafts and ships