Hydrogen use in EU decarbonisation scenarios

Decarbonisation kicks off new uses of hydrogen, especially in sectors where it is hard to decrease CO_2. In most scenarios, hydrogen and derived fuels add up to between 10% and 23% of the 2050 EU final energy consumption. Supplying this hydrogen would require an amount of water equal to a third of the total water consumed today in the energy sector. Depending on the way carbon-free hydrogen is produced, it also requires:

- *either* a significant amount of carbon-free electricity, equivalent to 80% of today's total electricity production, making it the sector with the largest power consumption;
- *or* a significant amount of natural gas, equivalent to 45% of today's consumption, requiring to capture annually 460 $MtCO_2$ and to store it in around 150 large-scale CO_2 storage facilities.

In the first case, up to €410 billion is needed for up to 900 GW of hydrogen producing technologies, mainly electrolysers. Significantly higher investments are required in power supply technologies: up to €1.3 trillion.

In the second case, up to €140 billion is required, mainly for steam reforming with Carbon Capture and Storage (CCS); natural gas expenditures amount up to €47 billion annually.

The Hydrogen Roadmap Europe estimates that by 2050 5.4 million jobs could be created for hydrogen, equipment and supplier industries, which is equivalent to 3 times the number of jobs in the EU chemical industry today.

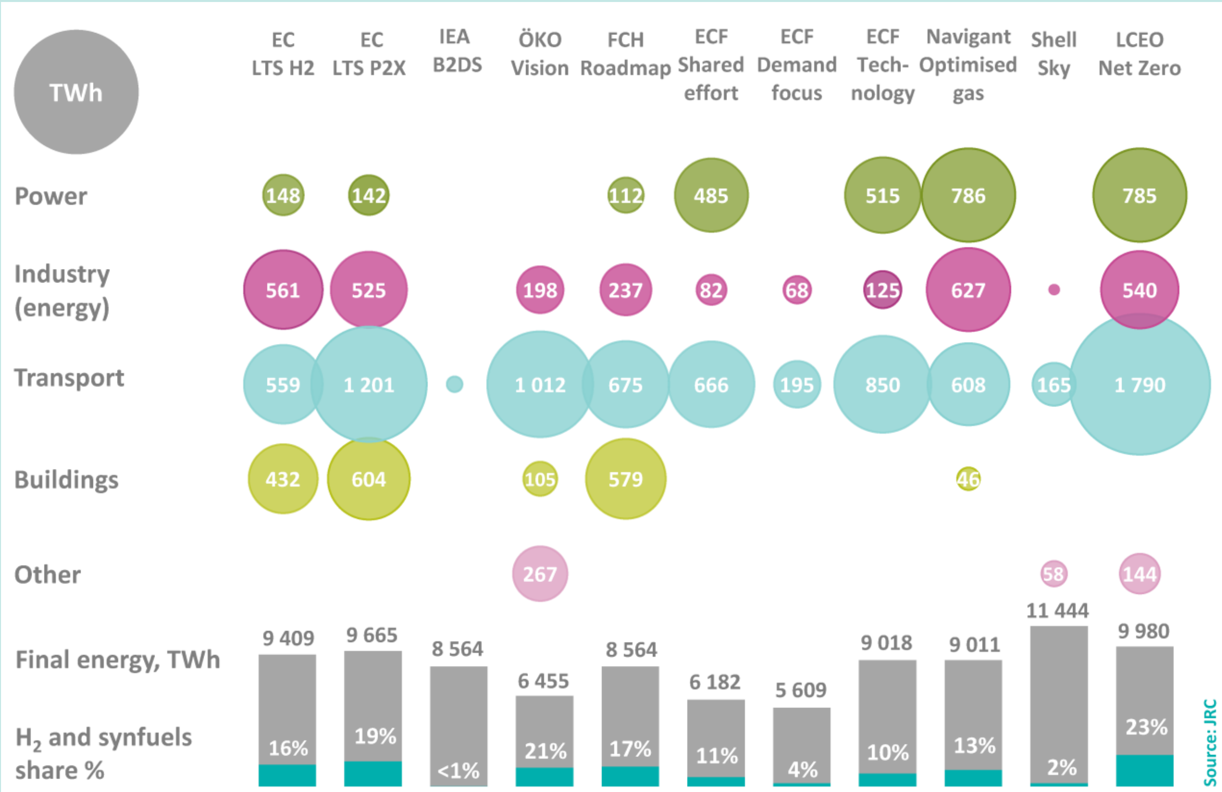

Figure 1: Consumption of hydrogen and share in final energy in EU decarbonisation scenarios in 2050

Hydrogen for non-energy uses is not included, hydrogen for synfuels is included based on 75% efficiency (for EC, ECF and Öko scenarios). Hydrogen for power generation is not consumed as final energy.

EC:	A Clean Planet for all - A European long-term strategic vision for a prosperous, modern, competitive and climate neutral economy, European Commission, 2018, November
IEA:	Energy Technology Perspectives 2017, International Energy Agency, 2017, June
ÖKO:	The Vision Scenario for the European Union, 2017 Update for the EU-28, Öko-Institute, 2017, February
FCH:	Hydrogen Roadmap Europe, Fuel Cells and Hydrogen, Joint Undertaking (FCH 2 JU), 2019, February
ECF:	Net Zero by 2050: from whether to how, European Climate Foundation (ECF), 2018, September
Navigant:	Gas for climate, Ecofys / Navigant, 2019, March
Shell:	Sky - Meeting the goals of the Paris Agreement, Shell, 2018, March (regional coverage is EU+)
LCEO:	Deployment Scenarios for Low Carbon Energy Technologies, Joint Research Centre, 2019, January

Hydrogen use in EU decarbonisation scenarios

Hydrogen uses

In ***transport***, hydrogen is a decarbonisation option for heavy-duty vehicles, large commercial vehicles and ships. In most scenarios, small passenger cars are almost entirely battery electric vehicles (BEVs). In some scenarios (like EC, FCH and LCEO), fuel-cell electric vehicles (FCEV) coexist with BEVs. By 2050, hydrogen could also be used to produce synfuels for aviation and maritime transport. In the majority of scenarios, hydrogen and synfuels add up to between 20% and 50% of energy demand in transport in 2050.

Besides current uses, hydrogen in ***industry*** is expected to be used mainly in innovative production processes (e.g. steel and as feedstock for chemicals) and for high grade heat in energy intensive industry but later in the time horizon. Hydrogen use in industry could reach between 5% and 20% of total energy consumed (or about 30% if non-energy uses are included).

In the ***buildings sector***, some scenarios do not see any role for heating with hydrogen because its efficiency (65%) is lower than of competing technologies such as heat pumps (between 250% and 400%). Other scenarios see a remarkable role for heating with hydrogen, mainly because of gas infrastructure benefits. Such scenarios show that hydrogen replaces up to 50% of natural gas, reaching about 15% of the total energy used in buildings. For the existing building stock, transforming heating supply becomes possible by injecting hydrogen into the existing natural gas network (up to 10% in volume) and completely converting existing natural gas networks into hydrogen (Germany, the UK, the Netherlands and France being examples of leading countries).

Hydrogen in the ***power sector*** is mainly useful for long-term storage (days, weeks or even months). In 2050, up to 15% of the electricity produced will first be transformed into hydrogen and converted back to electricity when needed.

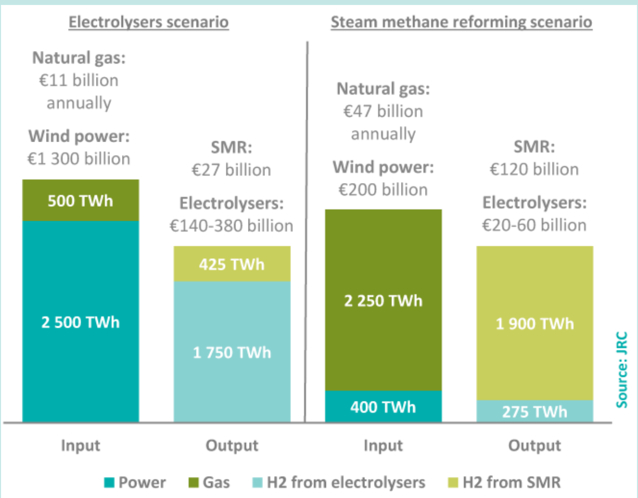

Figure 2: Energy flows, investments and expenditures for the production of hydrogen in EU decarbonisation scenarios

Hydrogen production

Based on the average hydrogen production level across most decarbonisation scenarios for the EU, we assess how it can be produced, the main investments and other expenditures that would be required. We estimate the production capacities by using two scenarios based on Hydrogen Roadmap Europe. In one scenario the main hydrogen production technology is electrolysis and in the other scenario it is steam methane reforming (SMR) of natural gas with CCS.

Producing about 2 000 TWh of hydrogen requires around 625 GW of electrolysers and 110 GW of SMR in the electrolysis scenario. In the SMR scenario it requires around 100 GW of electrolysers and 475 GW of SMR technologies[1]. Depending on the operating hours of the electrolysers, between 290 and 900 GW of total hydrogen producing technologies would need to be installed by 2050. Moreover, for natural gas-based hydrogen with CCS, between 85 and 460 MtCO_2 is captured and stored annually to assure carbon-free hydrogen production. This amount of CO_2 is orders of magnitude lower than the EU storage potential however would be the equivalent of capturing and storing CO_2 from around 150 large-scale integrated CCS facilities[2]. The annual water requirement would be about 1.2 to 1.4 billion m^3, or a third of the amount of water consumed today in the total EU energy sector[3].

Hydrogen-related investments

The total capital expenditures for hydrogen production technologies range between €140 and €400 billion by 2050[4]. However, for such volumes of hydrogen, additional power supply would be required. Investments in power supply technologies (e.g. wind turbines) or energy expenditures (i.e. natural gas) would be significantly higher. If electricity is produced only by wind turbines then investments between €200 billion (SMR scenario) and €1.3 trillion (electrolysers scenario) would be required over 30 years. Additional gas expenditures in 2050 could range between €11 billion (electrolysers scenario) and €47 billion annually (SMR scenario), assuming a gas price of 21 €/MWh.

Hydrogen-related employment

The Hydrogen Roadmap Europe estimates that by 2030 and by 2050, respectively 1 and 5.4 million direct jobs will be created. For 2050, that is equivalent to 3 times the number of jobs in the EU chemical industry today. The underlying job intensity is between 6 and 7.5 jobs per M€ revenue.

Contacts:
Jose.Moya@ec.europa.eu
Ioannis.Tsiropoulos@ec.europa.eu
Dalius.Tarvydas@ec.europa.eu
Wouter.Nijs@ec.europa.eu

[1] Assuming 4 000 hours of operation.
[2] Based on the average size of large-scale integrated CCS facilities in different stages of development as reported by the Global CCS Institute.
[3] Projected fresh water use from the European energy sector, JRC113696.
[4] Assuming 450 €/kW for electrolysers and 500 €/kW for SMR with CCS in 2050 as in "The Future Cost of Electric-Based Synthetic Fuels", Agora, 2018.