Decarbonisation roadmap's overview

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Energy Scenarios-electricity generation

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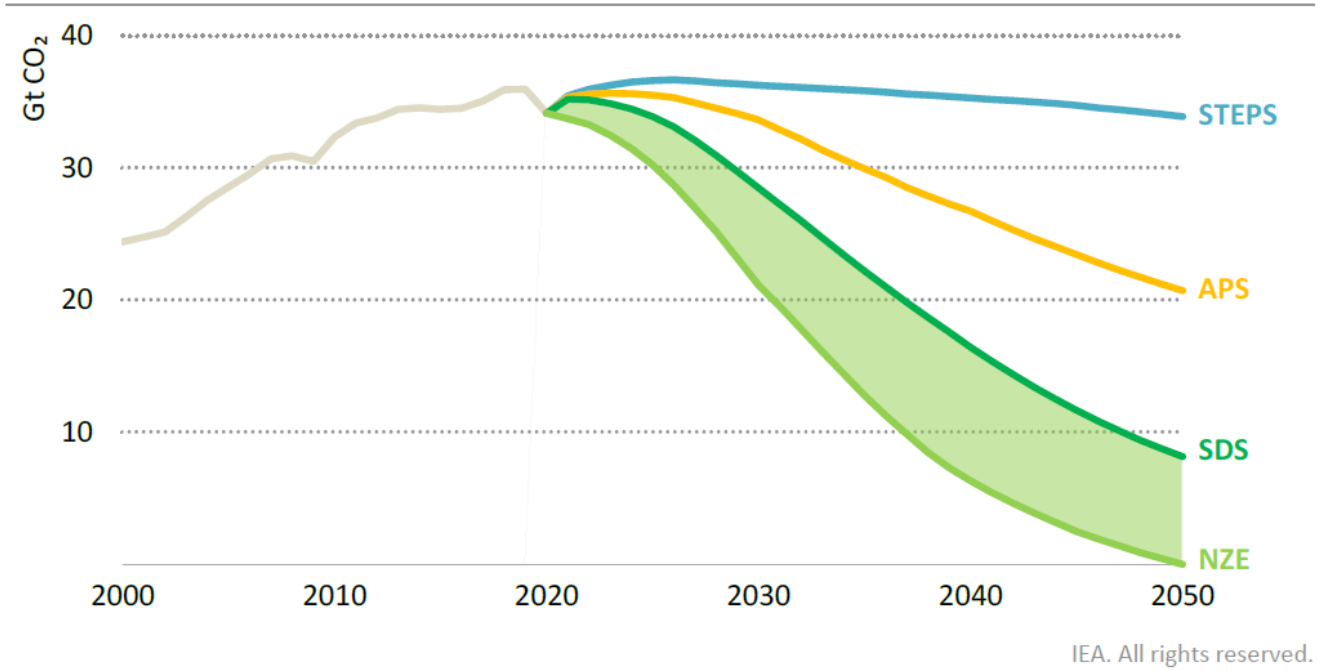
IEA scenarios

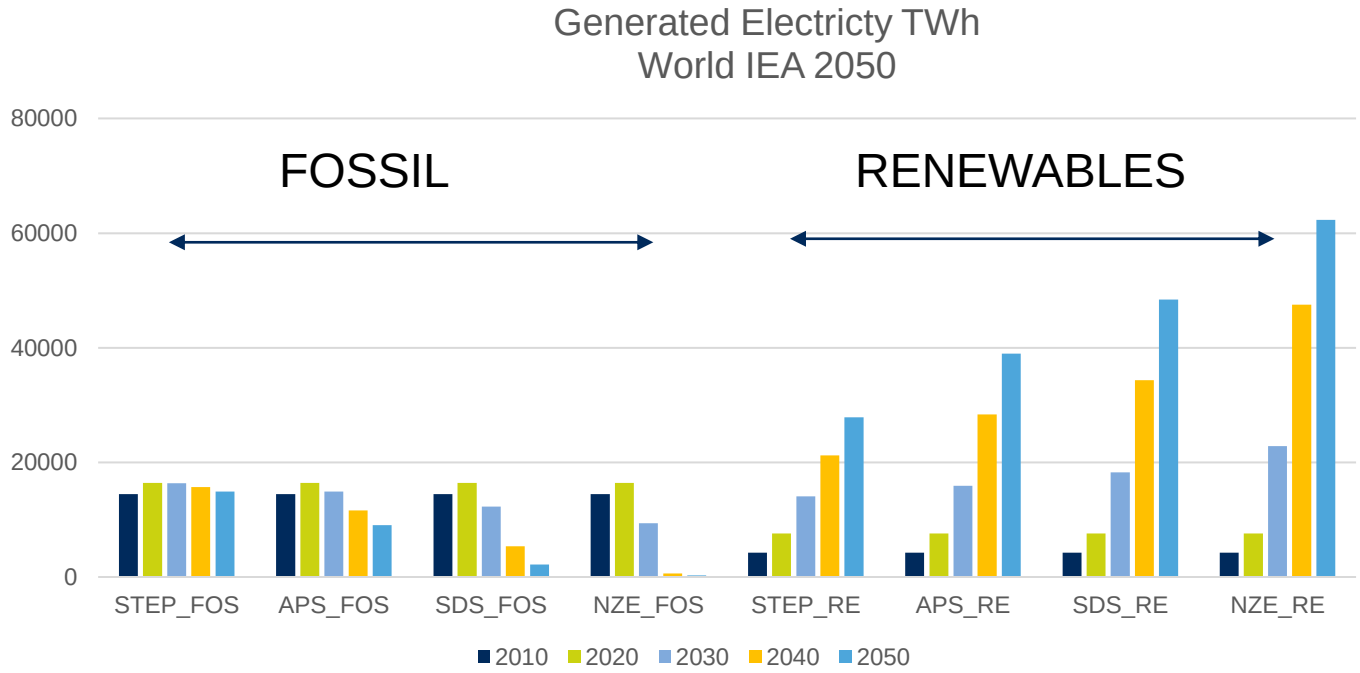
IEA scenarios



Source IEA 2050

STEPS:	Stated Policies Scenario
APS:	Announced Pledges Scenario
SDS:	Sustainable Development Scenario
NZE:	Net Zero Emission by 2050

IEA scenarios impact electricity market
Electricity generated

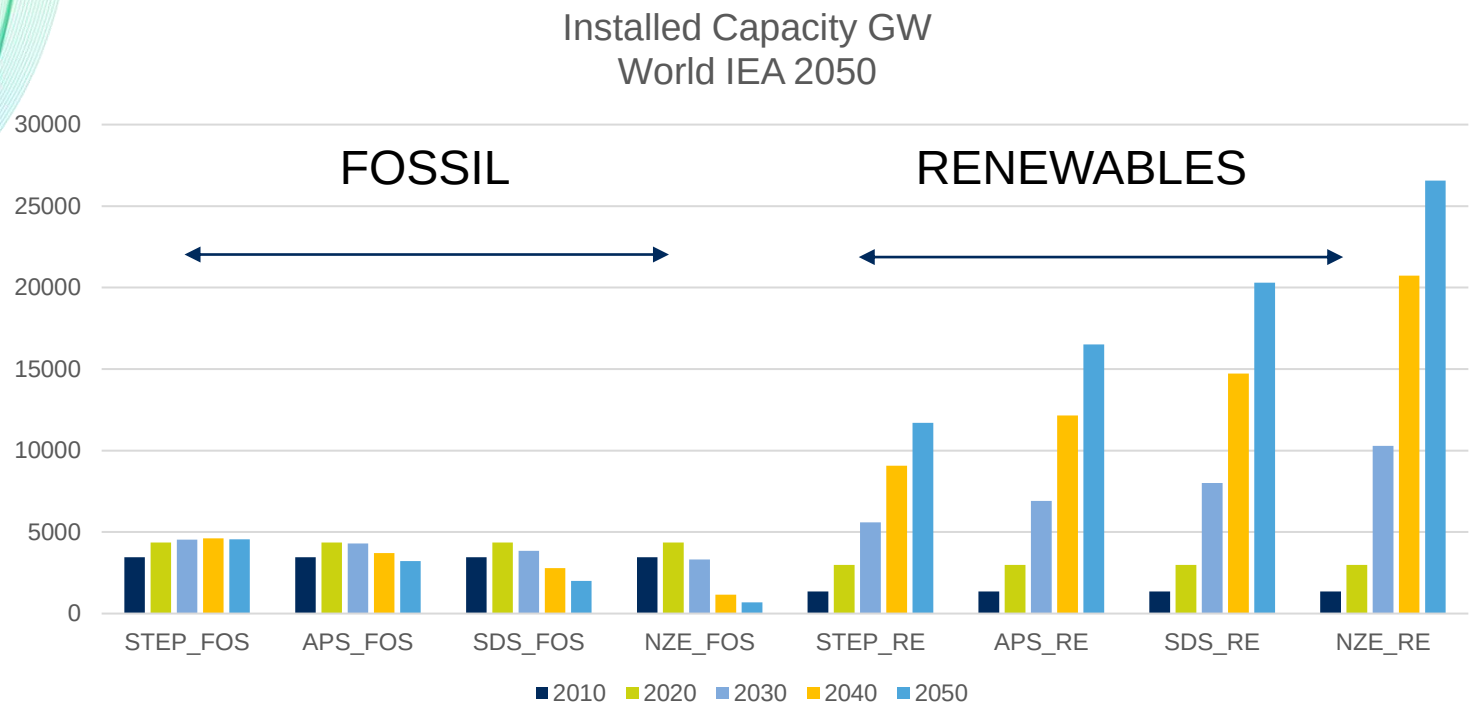


Source IEA 2050

Doubling the generated electricity (2020 to 2050).
SDS and NZE call for a significant reduction of generating fossil assets and a large increase in renewables.
Sharp decrease in fossil firing is foreseen between 2030 and 2040.
700% increase VRE based electricity generation in 2050 compared to 2020.

Electricity

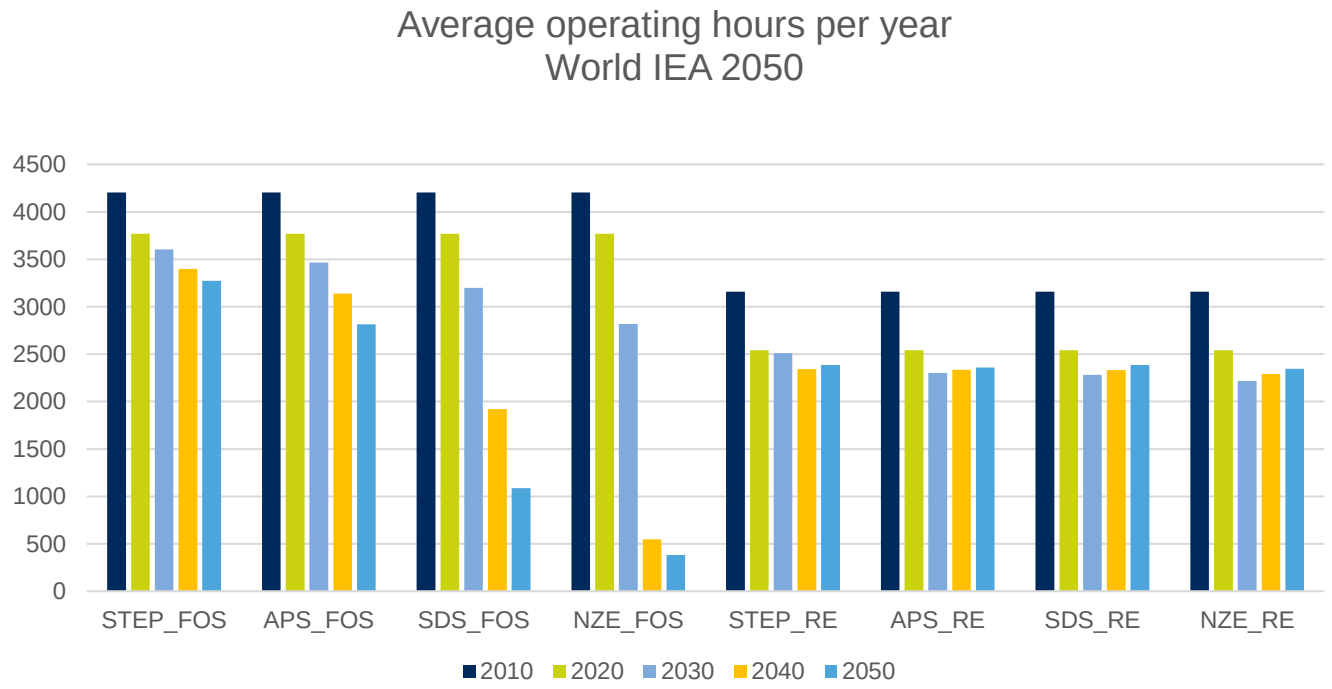
IEA scenarios impact electricity market
Capacity installed



Source IEA 2050

Reduction from 4000 GW to less than 700 GW fossil installed capacity in 2050.
Sharp capacity increase of renewables is expected between 2020 and 2030.

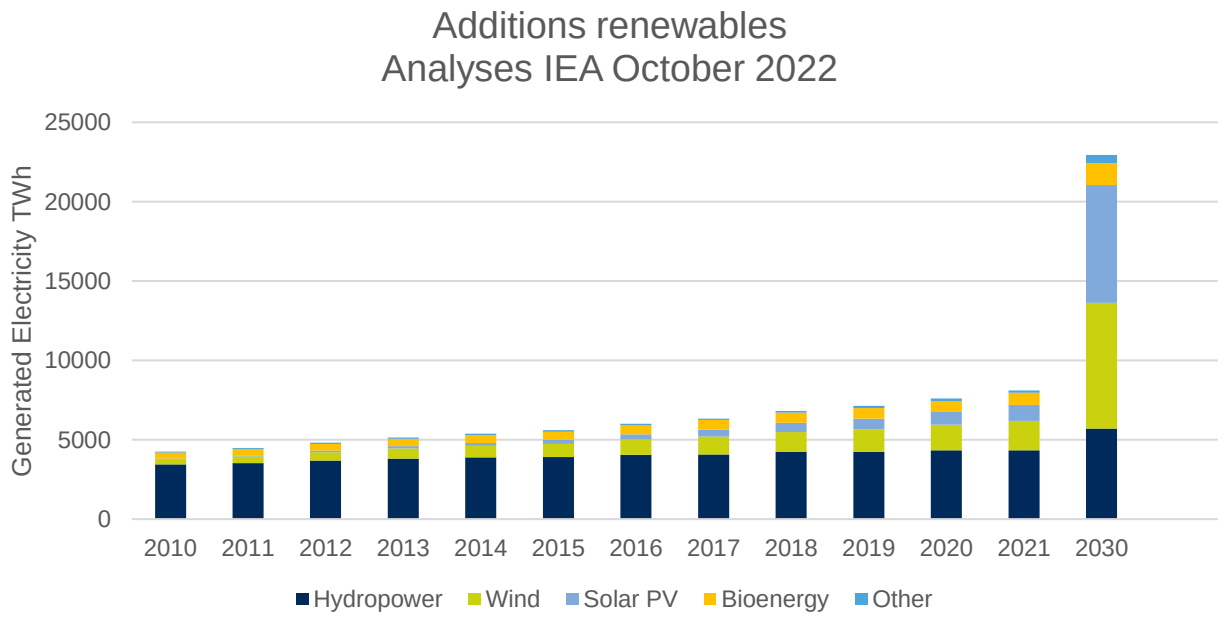
IEA scenarios impact electricity market
Average operating hours



Source IEA 2050

Operating hours fossil fired engines lower than 500 h per year.
Renewables more than 2300 h in average.

Sanity check: Growth of renewables
Review IEA October 2022



Source IEA

Activities need to increase rapidly to be in step with the Net Zero Scenario.

Net Zero by 2050 IEA conclusions

- Worldwide the electricity generation will almost double in 2050 compared to 2020 level.
- Capacity of renewables is significantly growing. Additional efforts are required to realise the NZE projections.
- Fossil fired capacity is reduced (after 2030). Average operating hours of those assets is lower than 500 hours in 2050. Worldwide a capacity of 700 GW is foreseen in the NZE scenario.
- For GT-based assets, the market mechanism is changing from an energy into a capacity based.

TYNDP scenarios
Ten Year Network Development Plan

EU27 scenarios-electricity generation (Europe)

- For EU27 scenarios we selected the ENTSOE/ENTSOG TYNDP data
  - Detailed data available
  - Updated every 2 years
  - 3 different scenarios; National, Distributed Energy and Global Ambition

	Distributed Energy Higher European autonomy with renewable and decentralised focus	**Global Ambition** Global economy with centralised low carbon and RES options
Green Transition	At least a 55 % reduction in 2030, climate neutral in 2050	
Driving force of the energy transition	Transition initiated at a local/national level (prosumers)	Transition initiated at a European/international level
	Aims for EU energy autonomy through maximisation of RES and smart sector integration (P2G/L)	High EU RES development supplemented with low carbon energy and imports
Energy intensity	Reduced energy demand through circularity and better energy consumption behaviour	Energy demand also declines, but priority is given to decarbonisation of energy supply
	Digitalisation driven by prosumer and variable RES management	Digitalisation and automation reinforce competitiveness of EU business
Technologies	Focus of decentralised technologies (PV, batteries, etc.) and smart charging	Focus on large scale technologies (offshore wind, large storage)
	Focus on electric heat pumps and district heating	Focus on hybrid heating technology
	Higher share of EV, with e-liquids and biofuels supplementing for heavy transport	Wide range of technologies across mobility sectors (electricity, hydrogen and biofuels)
	Minimal CCS and nuclear	Integration of nuclear and CCS

Figure 2: Storylines for the two COP21 scenarios

Source ENTSO-E TYNDP

TYNDP 2022-electricity demand

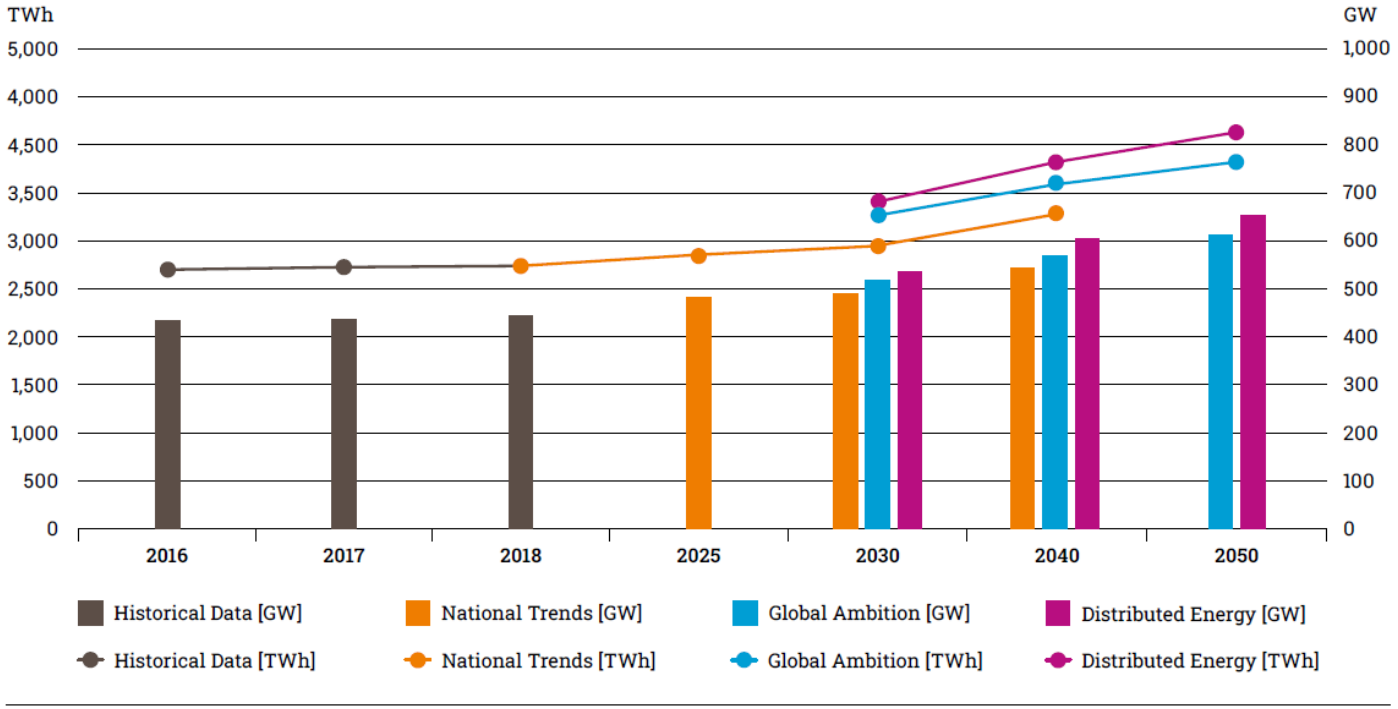


Figure 10: Evolution of average electricity demand and peak (including transmission and distribution losses)[10] for EU27

Source ENTSO-E TYNDP

Increase in electricity demand from actual 2700 to more than 4000 TWh in 2050.
Total installed generating capacity increase from actual 500 to 600 GW in 2050

TYNDP 2022-Hydrogen and Methane demand

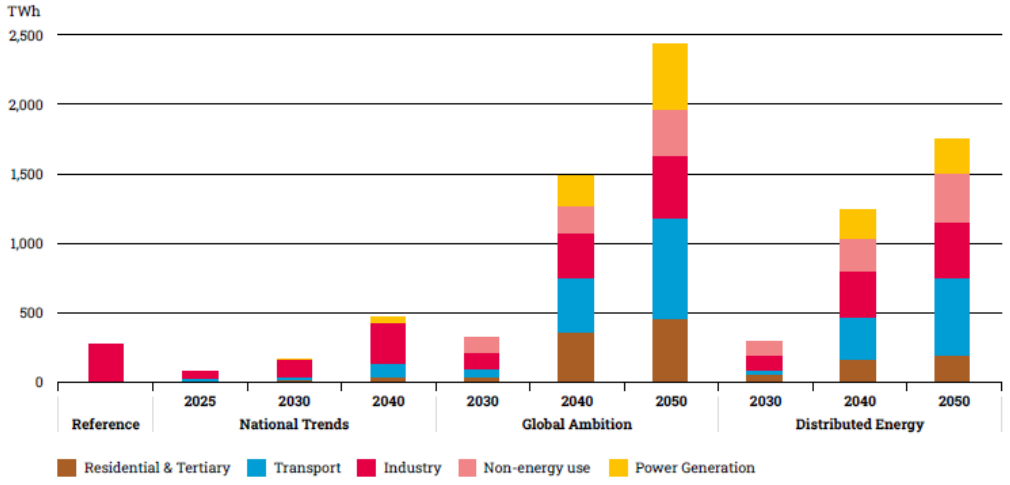


Figure 14: Hydrogen demand per sector for EU27 (excluding hydrogen from by-products and for conversion [P2M/P2L])

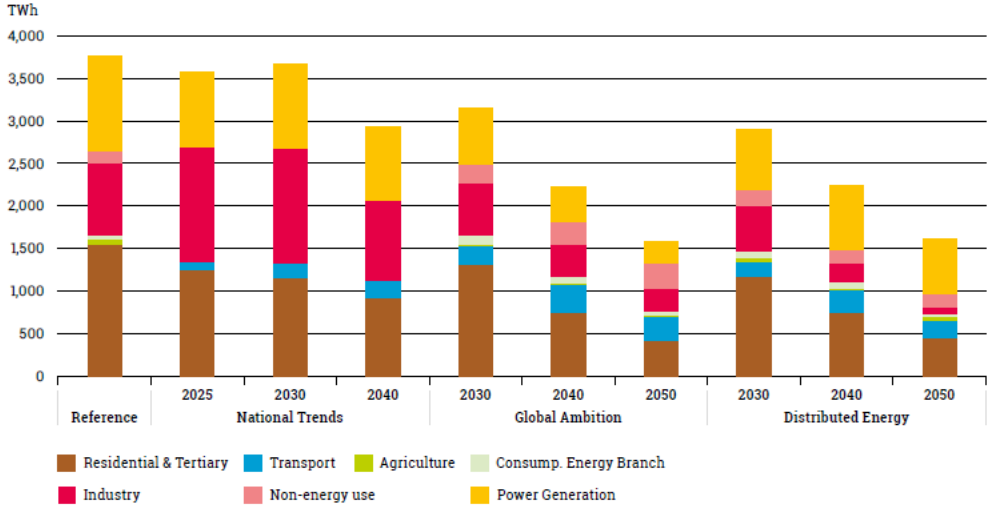


Figure 11: Methane demand per sector for EU27

Source ENTSO-E TYNDP

ENTSOG: 250-350 TWh pa hydrogen for Power generation
Remaining 500-600 TWh pa is methane

TYNDP 2022-hydrogen and methane fired power capacity

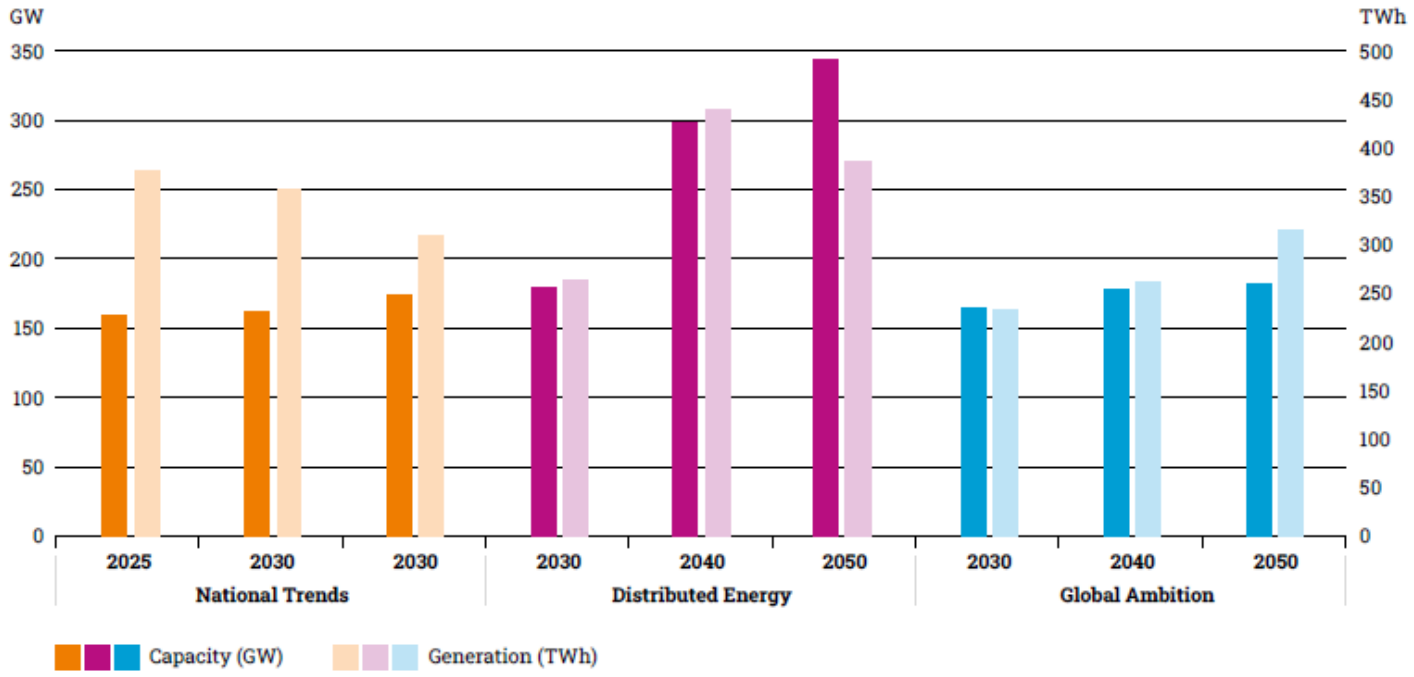


Figure 26: Evolution of the main methane and hydrogen fired power capacity and generation for EU27 (Excluding Small Thermal and CHP which operation can be driven by other factors such as heat production)

Source ENTSO-E TYNDP

150-350 GW installed base
250-450 TWh pa electricity

1000-2000 Operating hours
How do we incentivise

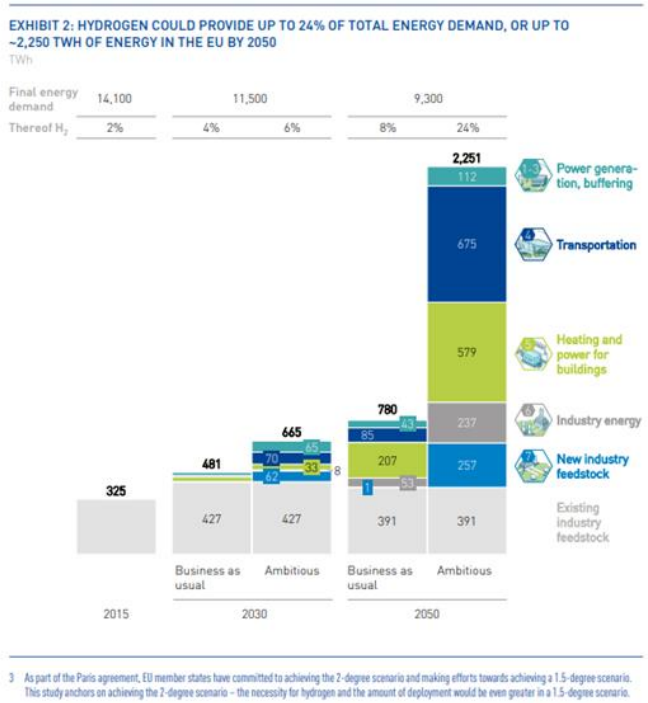
TYNDP conclusions

- Required EU27 electricity demand increases from 2700 TWh in 2020 to 4000 TWh in 2050.
- Capacity of the main hydrogen and methane fired generation assets remain stable (150-350 GW). These assets in average will run 1000 hours.
- GT based electricity market is changing to a capacity market
- In 2050 it is foreseen that 250-350 TWh electricity is generated by hydrogen fuelled assets.

Other topics

Hydrogen

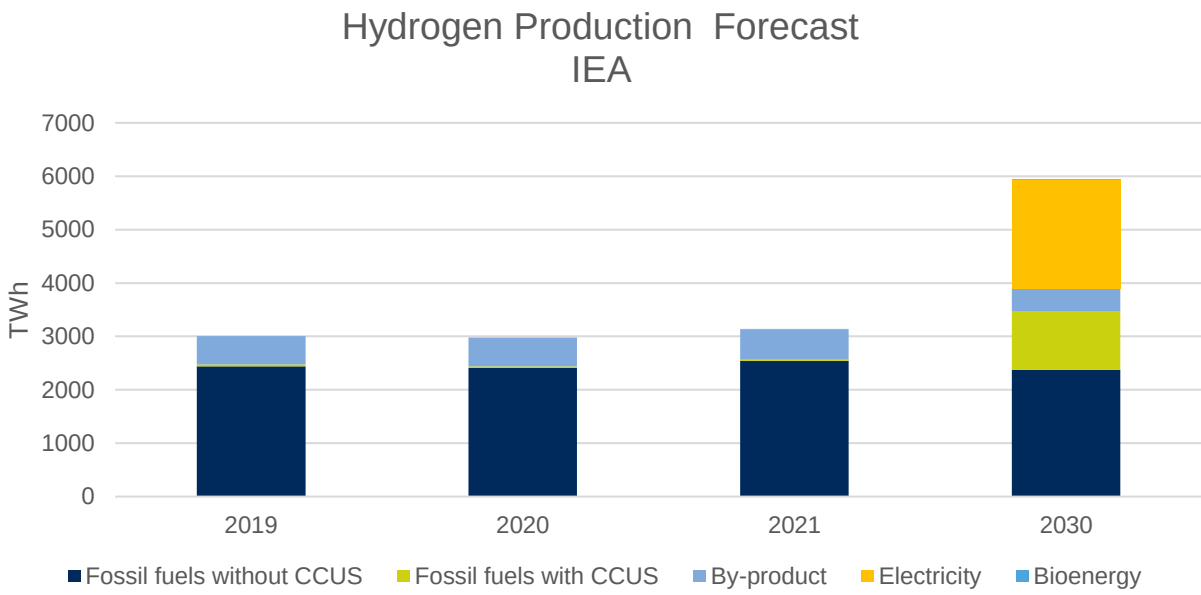
EU27



Source Hydrogen Europe

0-65 TWh Hydrogen for the power sector in 2030
43-112 TWh Hydrogen for the power sector in 2050
Need for 250-350 TWh hydrogen in 2050!

WORLD



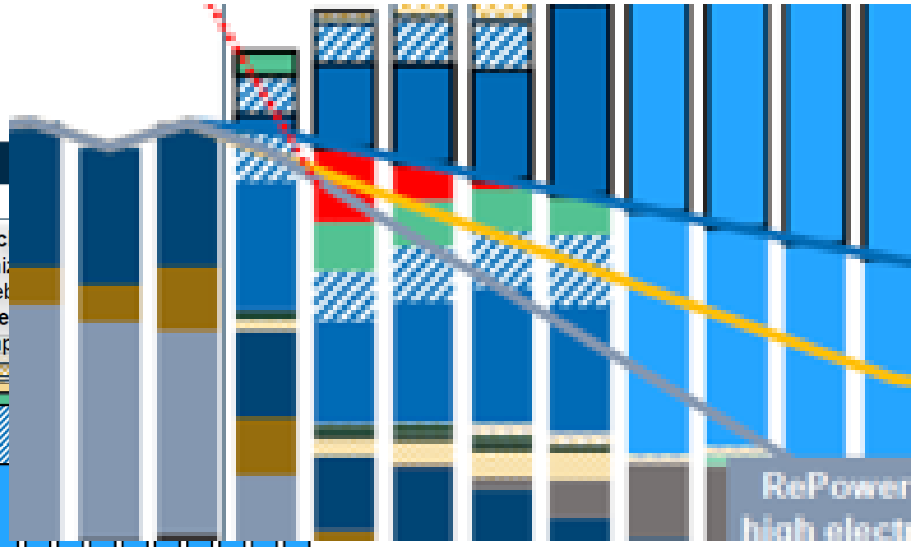
Source IEA

Lot of projects have started to generate Hydrogen. IEA NZE requires approx. 1600 TWh fuel for hydrogen fuelled assets in 2030

Gas supply

No Russian supplies as of 2023 creates supply gap in 2023 - 2025

Gas source	Increment group	Timing
Domestic	Base	Both
	Increment contingent	Long term
	Increment exploration	
Special domestic increment	Troll max	Short term
	Higher GCV	
	Groningen	
	Barents pipe	Long term
	European shale	
Russia	Russian piped gas	Short term
Piped gas	Europe piped gas imports	Both
	Algeria increase	Short term
	Turkey pass-through	
	TR/Azerbaijan expansion	Long term
LNG	LT Contracted	Both
	Spot/FOB LNG	Short term
	Available for LT contracts	Long term

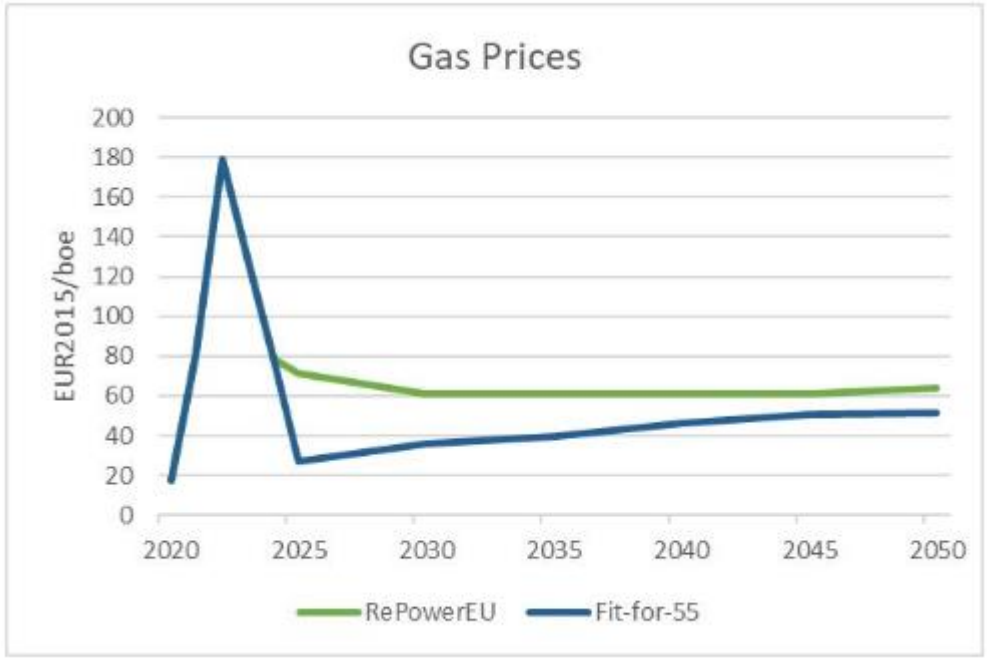


Source Rystad Energy

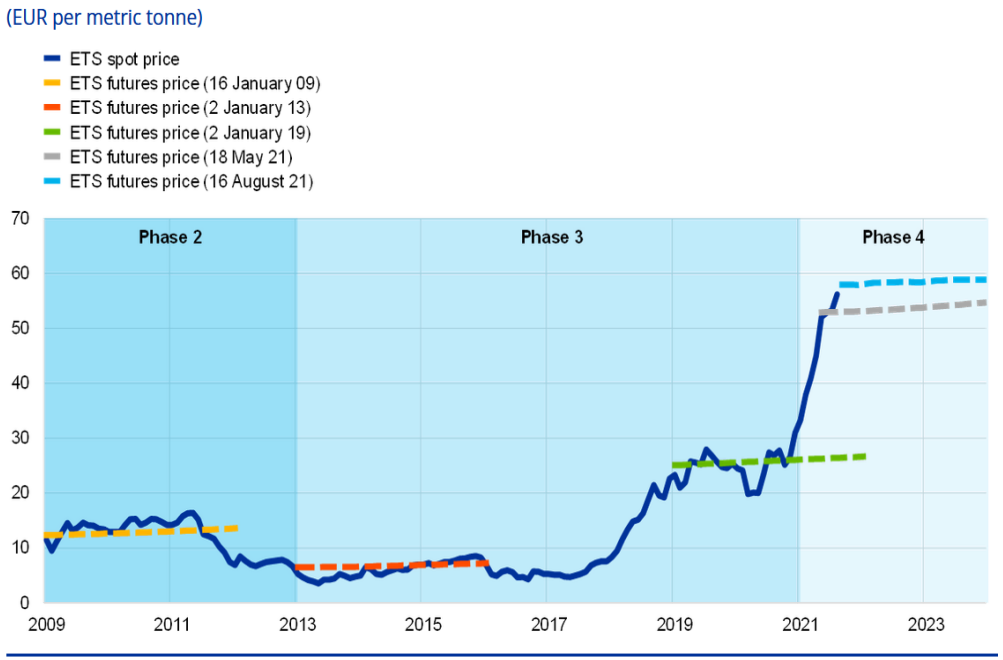
Gas supply is critical in year 2023 and 2024. Current price level lead to suspension of industrial activities and fuel saving.

ETS/gas Prices

Volatile market conditions



Gas price trajectories used in EU analyses Source: EU



Sources: Refinitiv, Bloomberg and ECB calculations.

Development of the Natural Gas price and ETS/CO2 tax are important parameters to influence the technology merit order.

Conclusions

- VRE capacity is growing significantly, however need to increase rapidly to be in step with the Net Zero Scenario.
- Gas turbines support the development of VRE capacity and storage development through providing electricity security and grid stability.
- The supply of sufficient hydrogen to the power sector is questionable. This situation is hindering the hydrogen readiness of our fleet.
- Volatile fuel prices and unknown ETS/CO2 penalties will not favour industry to invest in high investments such as hydrogen and CCS
- Sufficient infrastructure is needed to operate hydrogen and CCUS run gas turbines. National initiatives lift off and will be operational soon.

VRE requires dispatchable gas turbines to provide electricity adequacy and security. This role has to be understood by all stakeholders. Appropriate incentives shall convince energy companies to invest in new dispatchable technologies such as GT-hydrogen firing and GT-CCS.