Flexibility needs from now to 2050: Study on energy storage – Contribution to the security of the electricity supply in Europe

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8 June 21

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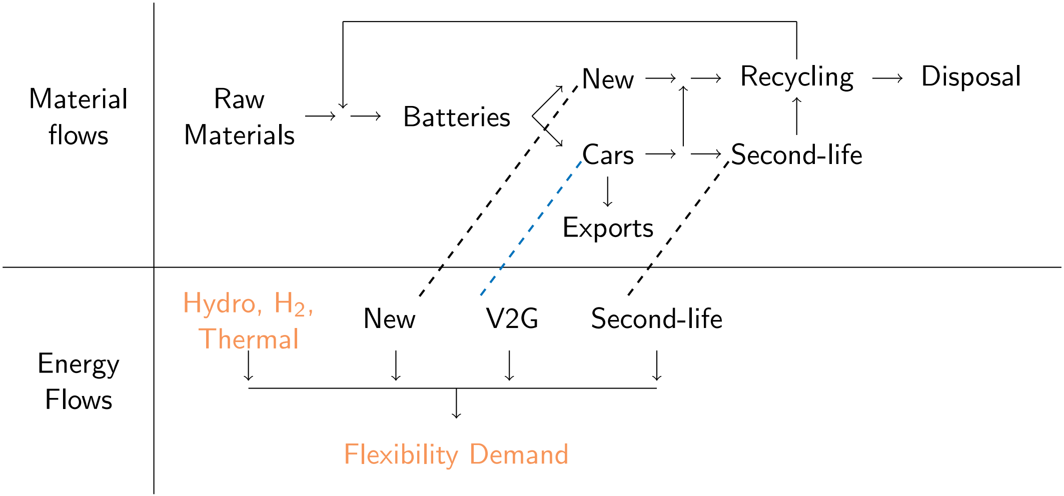
Outline

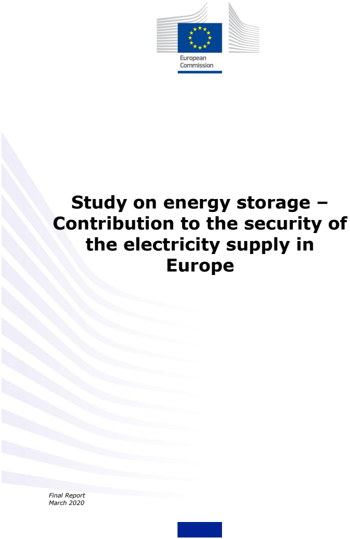
1. Introduction
2. *Study on energy storage – Contribution to the security of the electricity supply in Europe* (European Commission, 2020)
3. *A clean planet for all* (European Commission, 2018)
4. *Stepping up Europe's 2030 climate ambition* (European Commission, 2020)
5. Conclusions

Resource and energy supply security in an electrified low carbon future



Input: How many batteries / much daily storage will the EU28 need from now to 2050?

EC Study on energy storage


European Commission

Study on energy storage – Contribution to the security of the electricity supply in Europe

Final Report
March 2020

- March 2020
- Artelys
- Trinomics
- Enerdata
- Relies on scenarios from *“A clean planet for all”* (European Commission, 2018).
- Includes a V2G scenario
- Excludes COVID

Objectives

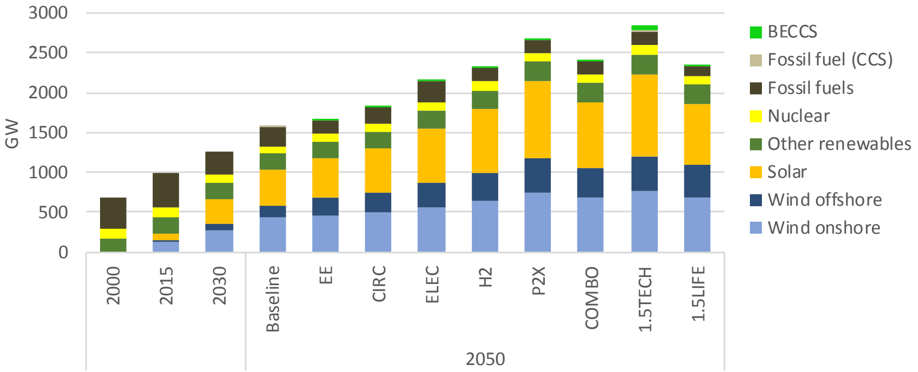
1. Existing storage facilities and projects as well as current regulation
2. Deployment potential and actual needs for energy storage by 2030 and 2050 in the EU28 + Norway + CH
3. Policy recommendations

Status quo: 51.5 GW of storage installed, 48.5 GW of which is pumped hydro. Total (nonseasonal) storage capacity: 2TWh, if nonpumped hydropower was also counted, the storage capacity would be much higher.

Comment from Antonio: important to distinguish between storage types, they may be able to provide different services.

This is done in the overview of currently existing plants, and to a lesser degree in the optimization framework (it neglects ancillary services).

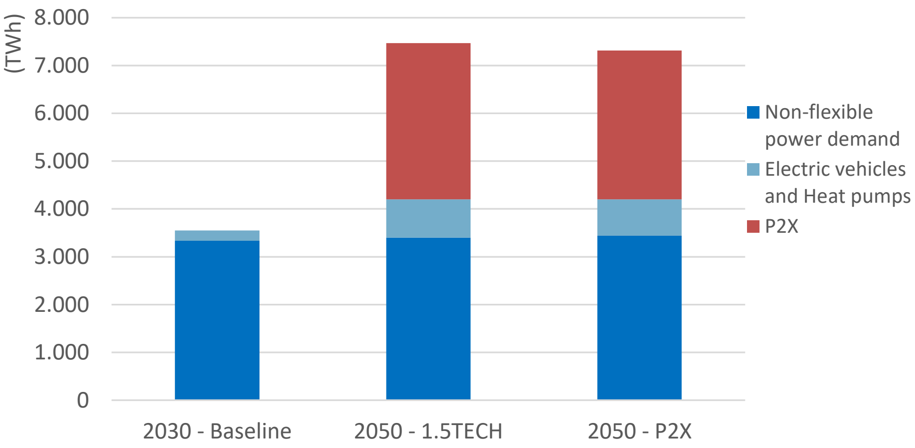
Scenarios for the future (from *"A clean planet for all"*)



In some 2050 scenarios, generation capacity *doubles*. Nuclear stays constant in all scenarios, which means that some new plants will be built to replace existing ones.

This report focuses on the 2030, the P2X and the 1.5TECH scenario. The latter two scenarios bet heavily on P2X.

Strong focus on P2X: yearly energy demand of the different scenarios



P2X doubles electricity consumption.

Min. cost capacity expansion and dispatch problem: METIS

METIS is a computer program developed by Artelys in partnership with RWTH Aachen, ConGas and Frontier Economics for DG ENER.

Here, it is used to solve a capacity expansion and dispatch problem with hourly resolution for the EU27 and 7 neighboring countries (Bosnia-Herzegovina, Montenegro, Norway, North Macedonia, Serbia, Switzerland, UK) for the years 2030 and 2050.

The problem is solved jointly for three meteorological conditions: cold, mild, and warm.

The assumptions on national electricity generation potential and demand rely on the TYNDP 2018 from ENTSOE.

Comment from Antonio: An hourly time-resolution is standard for this type of model.

Problem: This does not account for faster dynamics such as frequency regulation, where batteries may be most valuable.

Daily flexibility needs

They are calculated as follows:

1. Compute the residual load: load – variable renewables – must-run generation
2. Compute its daily average for each day of the year
3. Integrate the excess of the residual load over its average for each day of the year
4. Sum the excess energy over each day of the year. The result is in TWh per year.

Comment: residual *"load"* may be misleading because the demand could be negative. Better to call it *"net load"*?

This does not account for:

- how much power is needed to provide this energy *in the worst case*
- sub-hourly flexibility needs such as frequency regulation
- conversion losses in electricity storage

Daily flexibility needs: illustration

The green area would be the flexibility needed for this particular day.

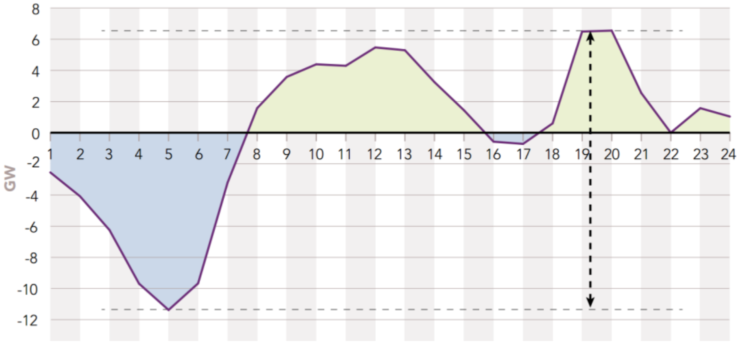


Figure 14 - Illustration of daily flexibility needs (the solid purple line measures the deviation of the residual load from its daily average for a given day). Source: RTE, Bilan prévisionnel de l'équilibre offre-demande, 2015

Daily flexibility needs: energy

With this definition of daily flexibility, the needs almost *triple* from 270TWh in 2030 to 730-780TWh in 2050.

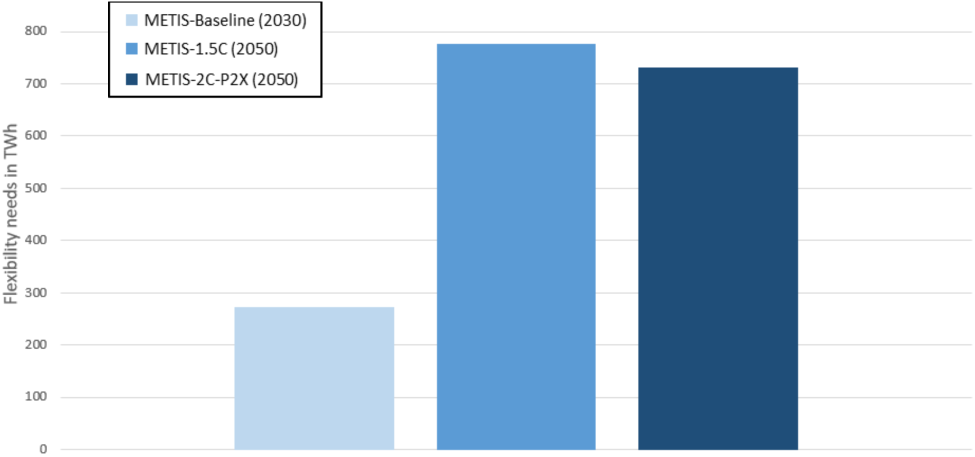


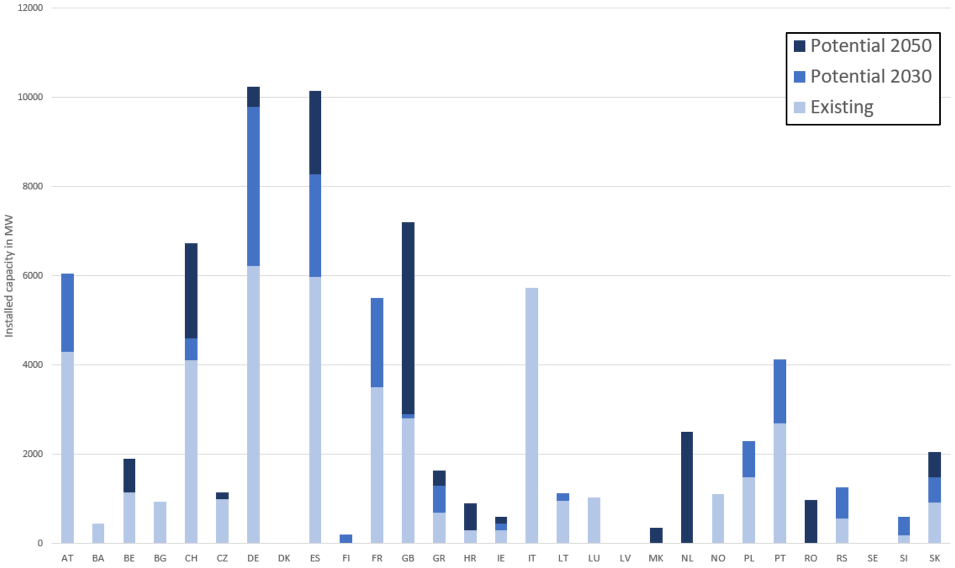
Figure 16 - Daily flexibility needs at EU28 level

Where should the flexibility come from?

List of resources:

- Pumped hydro storage: +15GW potential by 2030, +30GW potential by 2050, storage for 24hours, potentials based on TYNDP 2018
- No new hydro for seasonal storage!
- Batteries: four storage duration types (1h, 2h, 4h, 8h), unlimited potential
- Gas power plants: open-cycle (OC) and combined-cycle (CC) with or without CCS (90% efficient). OC is faster but less efficient than CC. By 2050, there is enough biogas (450-560TWh) to power the gas turbines when needed.
- Electrolysis and Methanation: unlimited potential, only alkaline electrolysers (cheapest option)
- Interconnections: +74GW potential by 2030, +170GW potential by 2050
- EVs and Heat Pumps: by 2030, 30% of them are flexible; by 2050, 70%. Heat pumps are combined with 2h thermal storage.

PHS potential: why is there none for Italy and Norway?



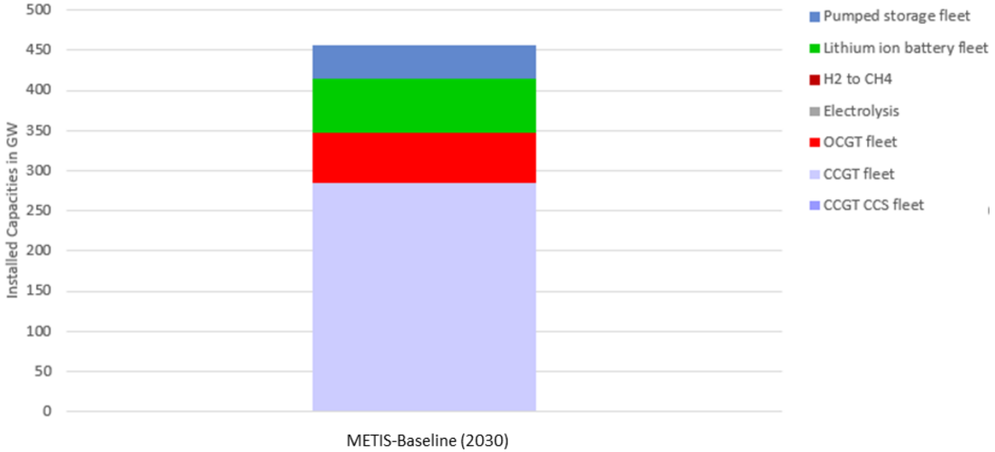
Flexibility resources by 2030

		Potential	Optimised capacity	Investment cost (€/kW)	Fixed O&M costs (% CAPEX)	Efficiency	Lifetime
Interconnectors	Additional capacities	+ 74 GW	✓	Based on line-by-line projects		-	50
Back-up power plants	OCGT	-	✓	700	3%	40%	25
	CCGT	-	✓	770	2%	63%	30
	CCGT with CCS	-	✓	1625	2%	49%	30
Storage capacities	Pumped Hydro	+ 15 GW	✓	1212	1,20%	81%	60
	Batteries	-	✓	120€/kW + 120€/kWh	4,30%	90%	10
Power-to-X technologies	Electrolysis	-	✓	300	6,50%	82%	20
	Methanation	-	✓	633	3,50%	79%	25

Flexibility resources by 2050

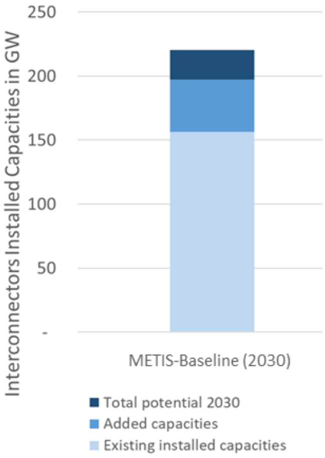
		Potential	Optimised capacity	Investment cost (€/kW)	Fixed O&M costs (% CAPEX)	Efficiency	Lifetime
Interconnectors	Additional capacities	+ 170 GW	✓	Based on line-by-line projects		-	50
Back-up power plants	OCGT	-	✓	600[23]	3%	40%	25
	CCGT	-	✓	750	2%	63%	30
	CCGT with CCS	-	✓	1500	2%	49%	30
Storage capacities	Pumped Hydro	+ 30 GW	✓	1212[24]	1,20%	81%	60
	Batteries	-	✓	120€/kW + 120€/kWh[25]	4,30%	90%	10
Power-to-X technologies	Electrolysis	-	✓	180[26]	6,50%	82%	20
	Methanation	-	✓	263	3,50%	79%	25

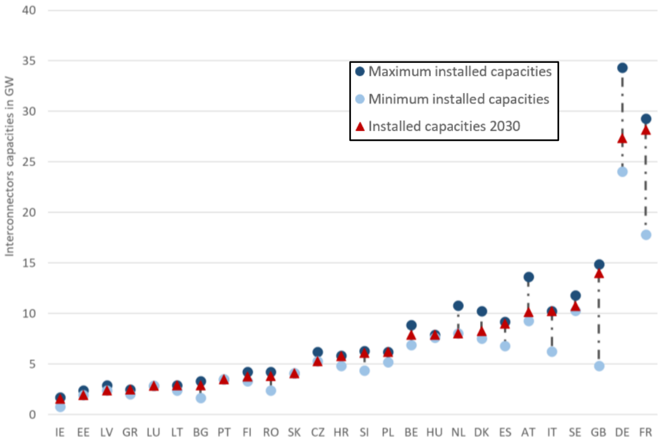
Results for 2030: lots of gas



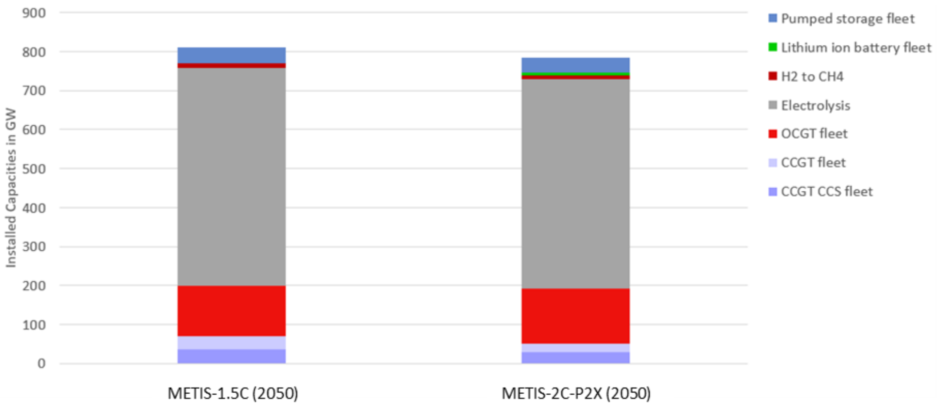
67GW batteries (31GW with a 4hour discharge time), no new hydro, +41GW interconnections (seems reasonable to Christos), limited demand response

2030 Interconnections: France, UK, and Italy build a lot



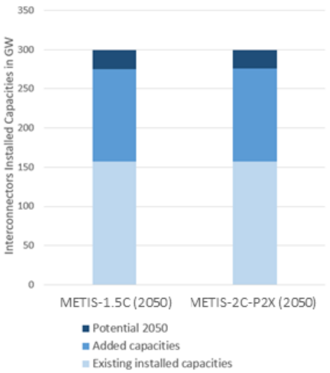


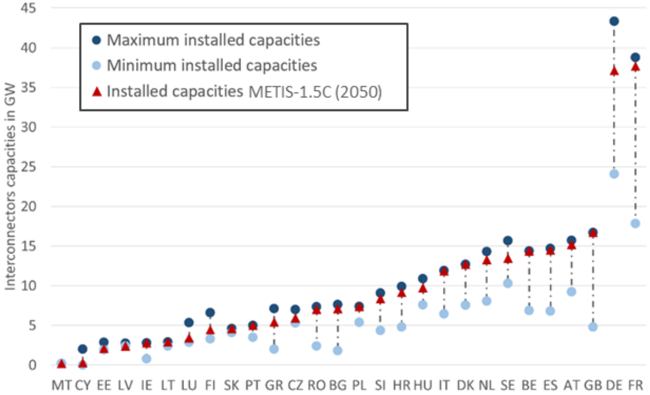
Results for 2050: lots of electrolysis



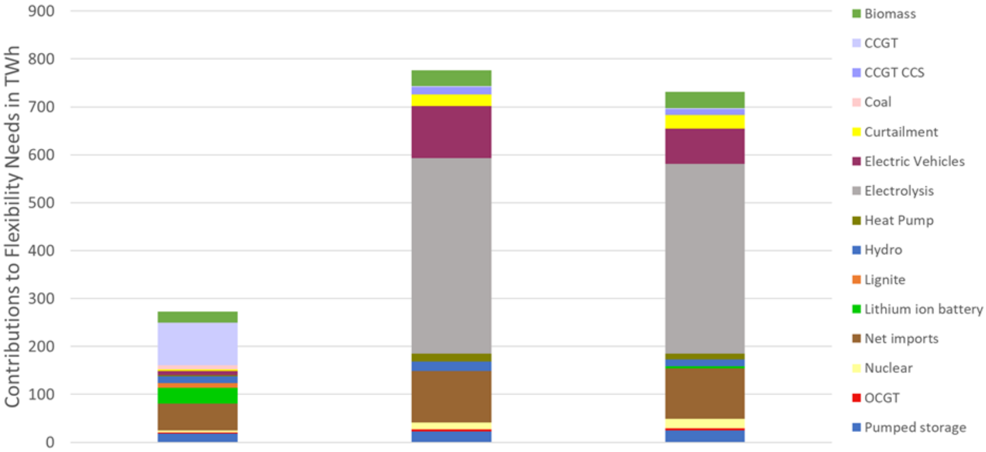
550GW of electrolysis, 50GW hydro, 1-5GW of batteries, 142GW of interconnectors
Need for batteries and hydro is 74GW if electrolysers are much more expensive
Antonio: Where is the gas stored? The report says in the gas grid and as CH_4 (11GW).

2050 Interconnections: Most countries build a lot





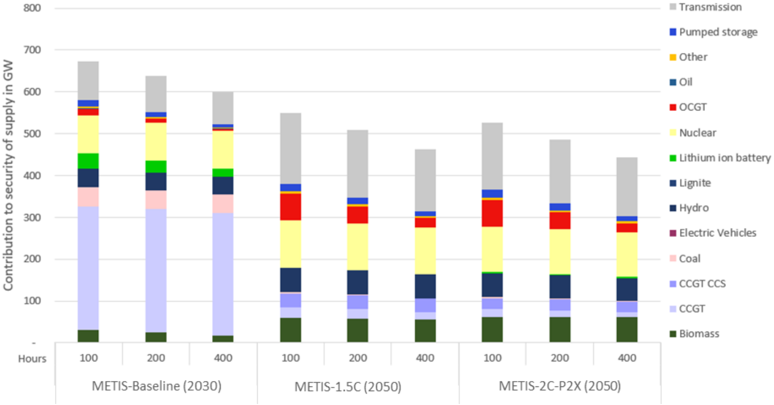
Contribution to daily flexibility needs: first gas, then electrolysis



Net imports (interconnections) and demand response (electric vehicles) come next.
This is *daily* flexibility! I find it a bit surprising that electrolysis is so dominant.

Security of supply: cover peak residual demand

Which technology is producing how much during the 100, 200, and 400 hours with the highest residual demand?



Gas, nuclear, and transmission (interconnections) are most important. Here too, sub-hourly dynamics are neglected.

Other scenarios: demand response, electrolysers, and H_2 flexibility

Demand response:

- **low** EVs and heat pumps (HPs) are not flexible.
- **baseline** 30% of EVs and HPs (2h thermal storage) are flexible, 70% by 2050.
- **high** All EVs and HPs are flexible.
- **+V2G** All EVs and HPs are flexible, and EV charging is bidirectional.

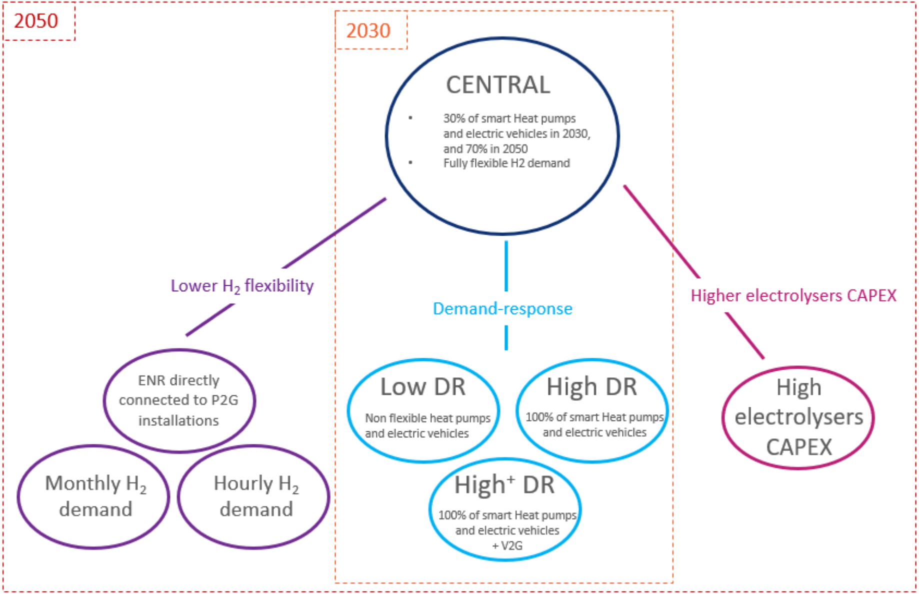
Cost of electrolysers:

- **high** Solid Oxide Electrolyser CAPEX (600€/kW), 3× higher than alkaline CAPEX.

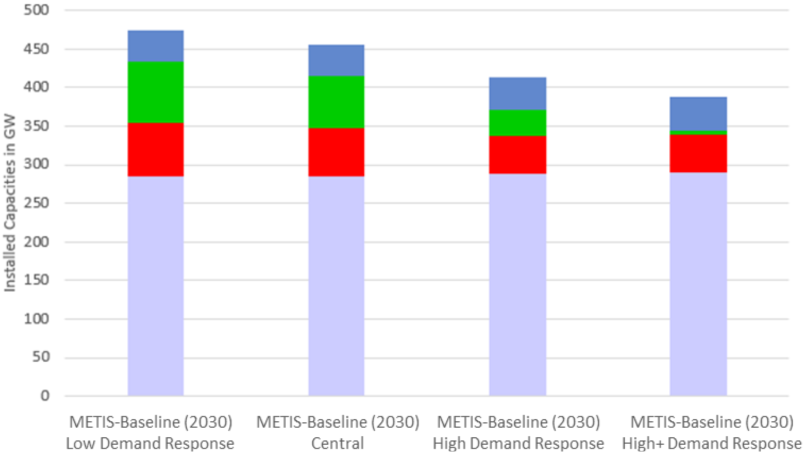
Hydrogen flexibility:

- **baseline** the whole demand for H_2, e-gas, and e-liquids is translated into an annual volume of H_2 to be supplied, without further constraints on the dynamics of H_2 demand.
- **monthly** H_2 demand evenly spread b/w the months of the year, no inter-month storage.
- **hourly** constant hourly H_2 demand throughout the year, no flexibility, no H_2 storage
- **off-grid** Dedicated renewables for H_2 production (15% of PV, 22% of onshore wind, 59% of offshore wind; based on TYNDP 2020), lower demand for grid-connected electrolysers, lower flexibility from modulating H_2 production

Scenario overview

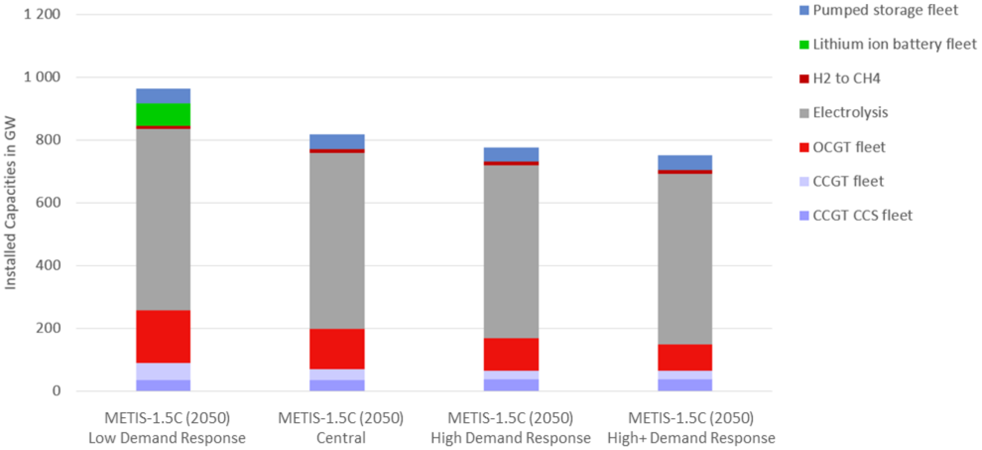


2030: The more demand response, the lower the need for batteries



With no demand-response, the need for batteries goes up by 12GW (2-4hour storage).
High demand-response: only 34GW of batteries (half the original demand)
V2G: reduces battery, PHS, and OCGT investments by 30GW, 4GW and 17GW: 51GW

2050: Little demand response eliminates the need for batteries



No demand response: 70GW of batteries (2-4hour storage)
Otherwise: less than 5GW of batteries
High demand-response: reduce gas by 30GW, electrolysers by 10GW
V2G: in addition, reduce gas by 20GW, PHS by 1GW, electrolysers by 6GW: 27GW

Vehicle-to-grid: unclear assumptions on plug and park ratios

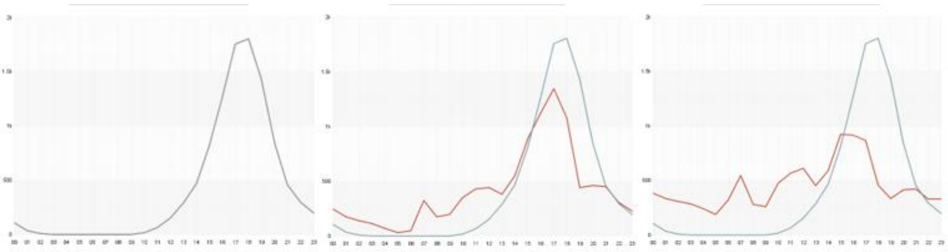
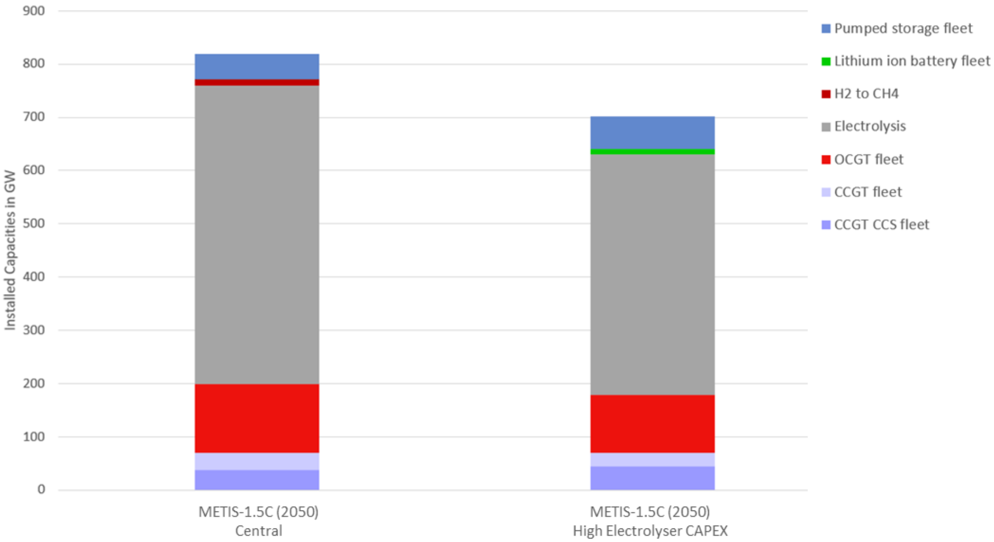


Figure 50 – Average recharge of electric vehicles at home per hour of day
Blue in the three graphs: immediate charging at arrivals
Red in the centre: smart charging
Red on the right: smart charging + V2G

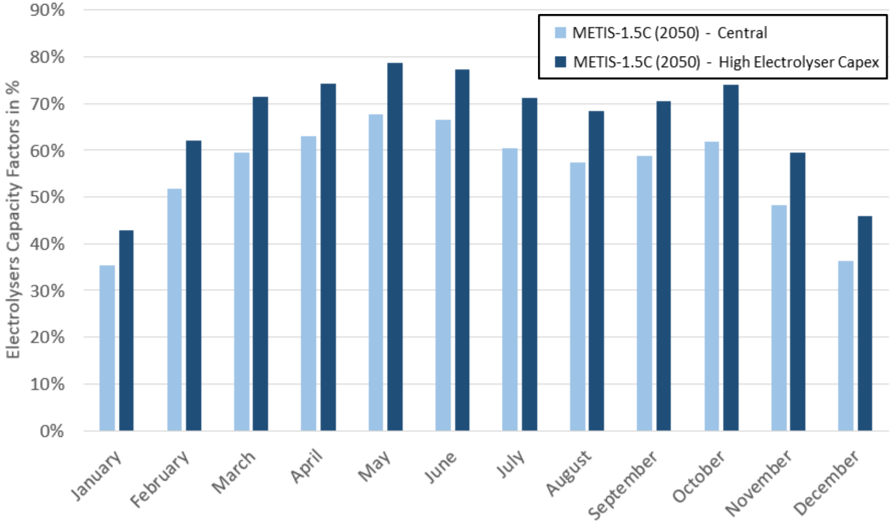
The graphics are almost illegible in the report.

Expensive electrolysers mean less gas and more batteries and PHS



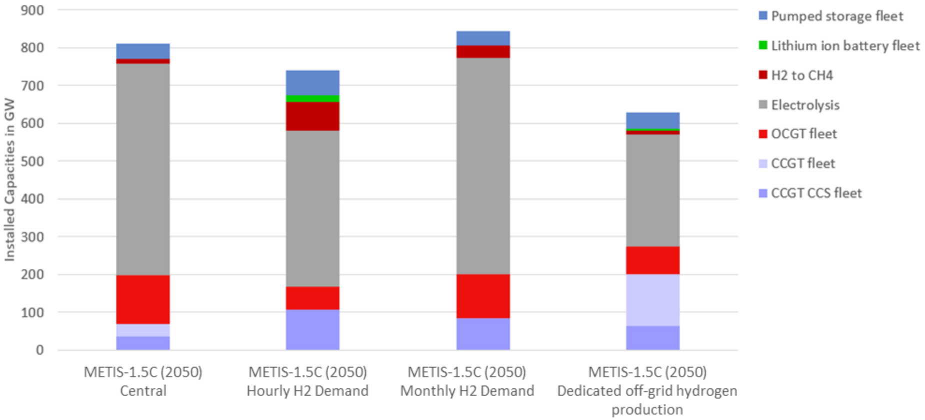
11GW of batteries instead of 1GW; 63GW of PHS (46GW already existing)

The cost of electrolyser flexibility: a low capacity factor



Baseline: 56% utilization; High CAPEX: 65% utilization

Less flexible H_2 demand: more gas and methanation



Hourly: 20GW batteries (4-8hour), 73GW PHS (26GW new), +methanation
Offgrid: 5GW batteries, 51GW PHS (5GW new), 273GW gas (37% over baseline)

Conclusions: electrolysers provide most flexibility by 2050

Battery storage: 4-43GW by 2030 and 0-100GW by 2050 (4hour storage)

Smart charging: up to 60GW by 2030 and 190GW by 2050
V2G: 51GW by 2030 and 27GW by 2050, would fully replace stationary batteries

Interconnections: +41GW by 2030, +142GW by 2050

Electrolysers: 0GW by 2030, 550GW by 2050, in baseline scenario, flexible operation

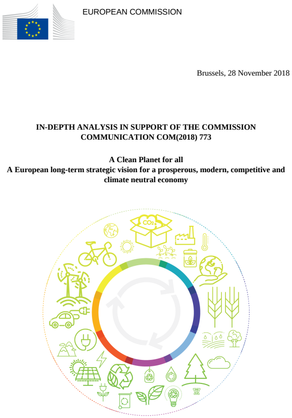
Electrolysers compete with and displace batteries. Presumably, because there is a massive demand for H_2 (true in 5 out of 9 scenarios in *"A clean planet for all"*) and because they are cheap enough to oversize and operate at small capacity factors.

V2G reduces the need for electrolysers, unfortunately, it is not quite clear what V2G parameters the study used.

No mention of second-life batteries. They may also be able to displace electrolysers.

Critique: strong focus on H_2, no mention of the fuel cell part to be comparatively inefficient, no use of (nonpumped) hydro for seasonal storage, no subhourly dynamics (ancillary services), no comparison with the results in *"A clean planet for all"*.

"*A clean planet for all*" (European Commission, 2018)


EUROPEAN COMMISSION

Brussels, 28 November 2018

IN-DEPTH ANALYSIS IN SUPPORT OF THE COMMISSION COMMUNICATION COM(2018) 773

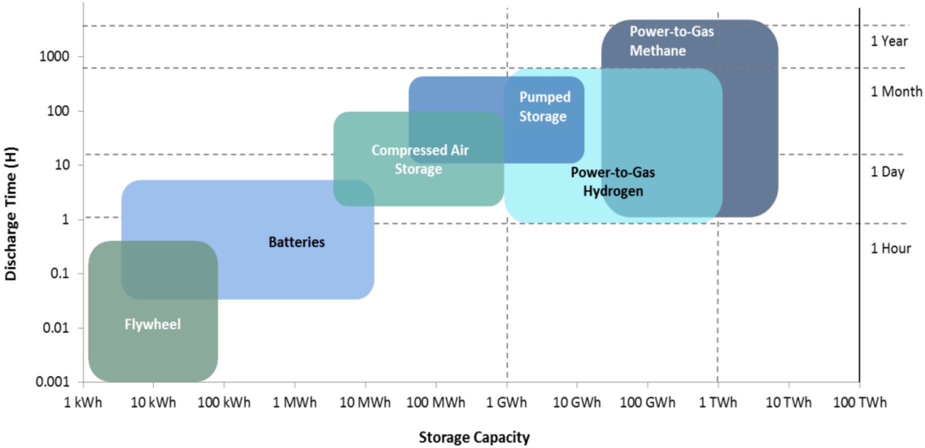
A Clean Planet for all
A European long-term strategic vision for a prosperous, modern, competitive and climate neutral economy

- No mention of *"frequency regulation"* or *"ancillary services"*.
- Two mentions of *"vehicle-to-grid"*.
- Higher numbers for battery storage capacity (power).
- Unclear numbers for battery storage capacity (energy).
- Numbers on EV penetration.

Long term strategy options

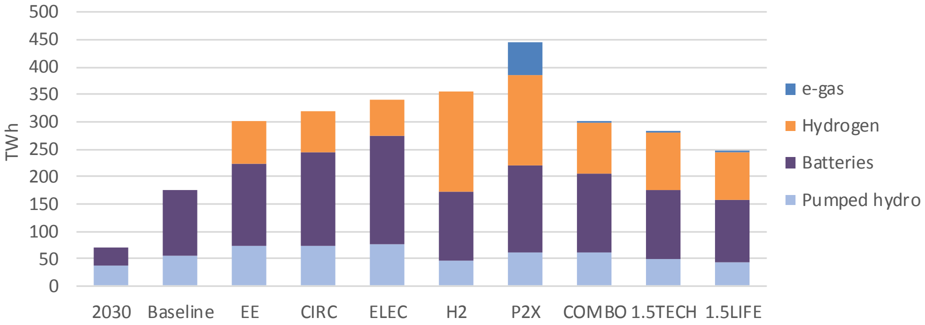
	Electrification (ELEC)	Hydrogen (H2)	Power-to-X (P2X)	Energy Efficiency (EE)	Circular Economy (CIRC)	Combination (COMBO)	1.5°C Technical (1.5TECH)	1.5°C Sustainable Lifestyles (1.5LIFE)
Main Drivers	Electrification in all sectors	Hydrogen in industry, transport and buildings	E-fuels in industry, transport and buildings	Pursuing deep energy efficiency in all sectors	Increased resource and material efficiency	Cost-efficient combination of options from 2°C scenarios	Based on COMBO with more BECCS, CCS	Based on COMBO and CIRC with lifestyle changes
GHG target in 2050	-80% GHG (excluding sinks) ["well below 2°C" ambition]					-90% GHG (incl. sinks)	-100% GHG (incl. sinks) ["1.5°C" ambition]	
Major Common Assumptions	• Higher energy efficiency post 2030 • Deployment of sustainable, advanced biofuels • Moderate circular economy measures • Digitilisation • Market coordination for infrastructure deployment • BECCS present only post-2050 in 2°C scenarios • Significant learning by doing for low carbon technologies • Significant improvements in the efficiency of the transport system.							
Power sector	Power is nearly decarbonised by 2050. Strong penetration of RES facilitated by system optimization (demand-side response, storage, interconnections, role of prosumers). Nuclear still plays a role in the power sector and CCS deployment faces limitations.							
Industry	Electrification of processes	Use of H2 in targeted applications	Use of e-gas in targeted applications	Reducing energy demand via Energy Efficiency	Higher recycling rates, material substitution, circular measures	Combination of most Cost-efficient options from "well below 2°C" scenarios with targeted application (excluding CIRC)	COMBO but stronger	CIRC+COMBO but stronger
Buildings	Increased deployment of heat pumps	Deployment of H2 for heating	Deployment of e-gas for heating	Increased renovation rates and depth	Sustainable buildings			CIRC+COMBO but stronger
Transport sector	Faster electrification for all transport modes	H2 deployment for HDVs and some for LDVs	E-fuels deployment for all modes	Increased modal shift	Mobility as a service			• CIRC+COMBO but stronger • Alternatives to air travel
Other Drivers		H2 in gas distribution grid	E-gas in gas distribution grid				Limited enhancement natural sink	• Dietary changes • Enhancement natural sink

Different storage technologies



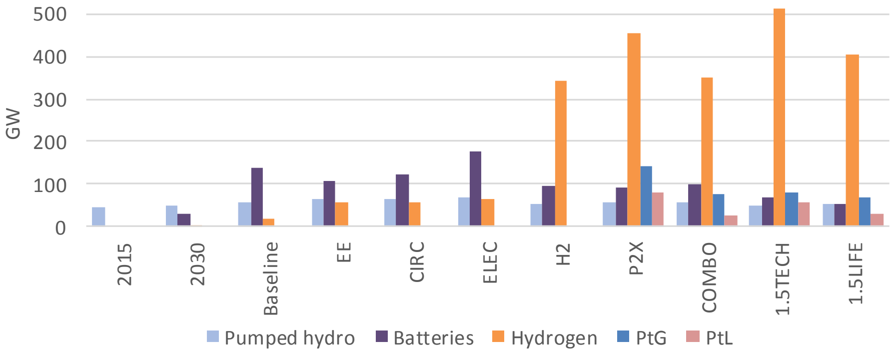
Source: European Commission (2017), Energy storage – the role of electricity[178].

Electricity storage (capacity?) in 2050



Increase from 30TWh today to 70TWh by 2030 and to between 160–270TWh by 2050.
Roughly: 30% hydro (incl. nonpumped?) and 70% stationary batteries.
According to Enerdata's list of storage facilities, we currently have a (nonseasonal) storage capacity of 2TWh.
CH: 9TWh of seasonal storage and 250GWh of pumped hydro storage

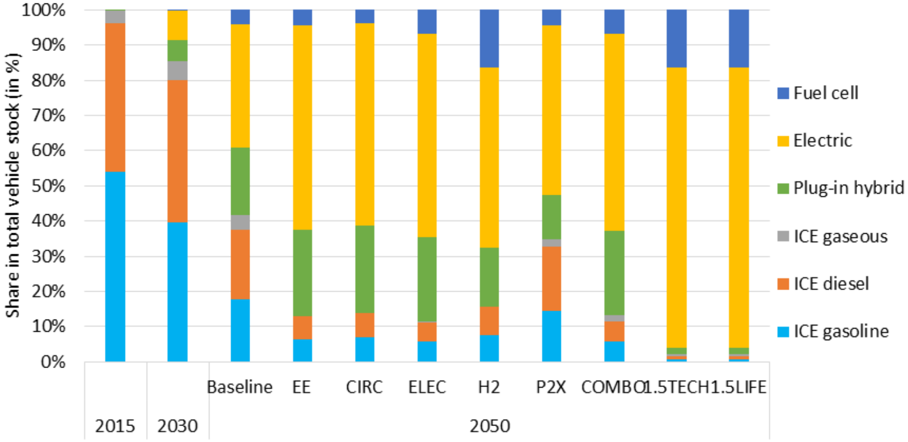
Electricity storage capacity (power)



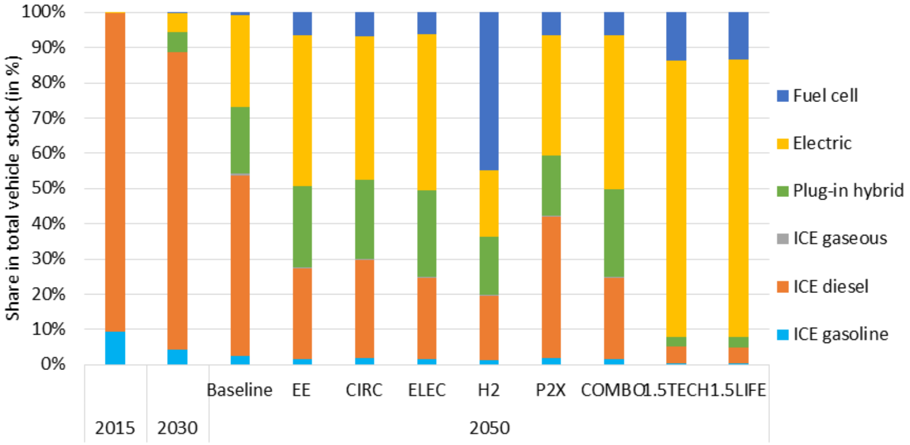
Stationary batteries grow from 29GW in 2030 to between 54GW and 178GW by 2050. This means that the previous slide does not show electricity storage capacity. In 2030, batteries with 29 GW cannot store 50TWh *at once*.

Up to 500GW of electrolysers.

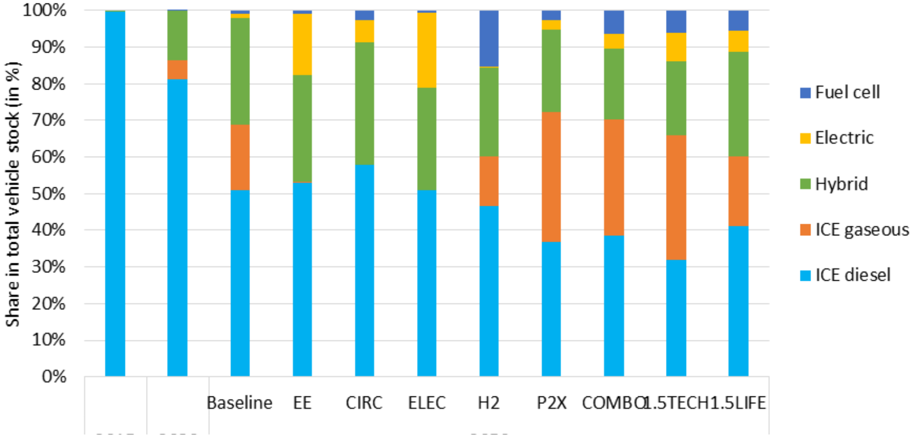
Passenger cars



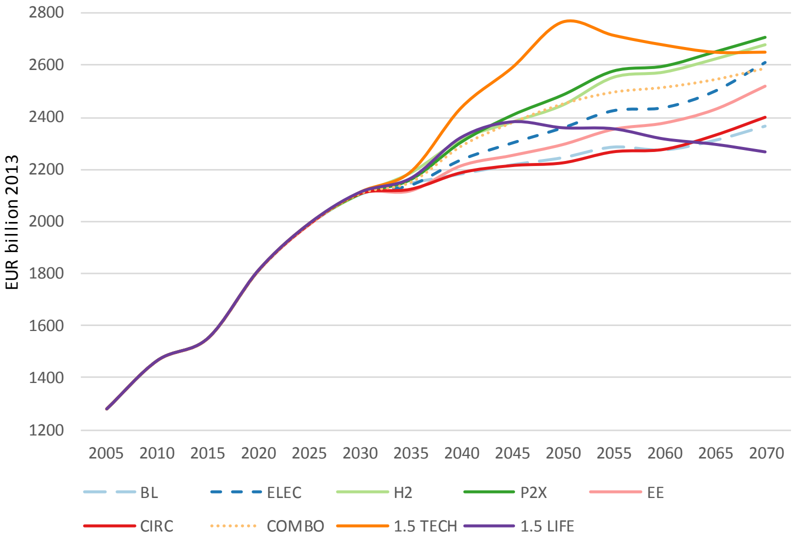
Light commercial vehicles



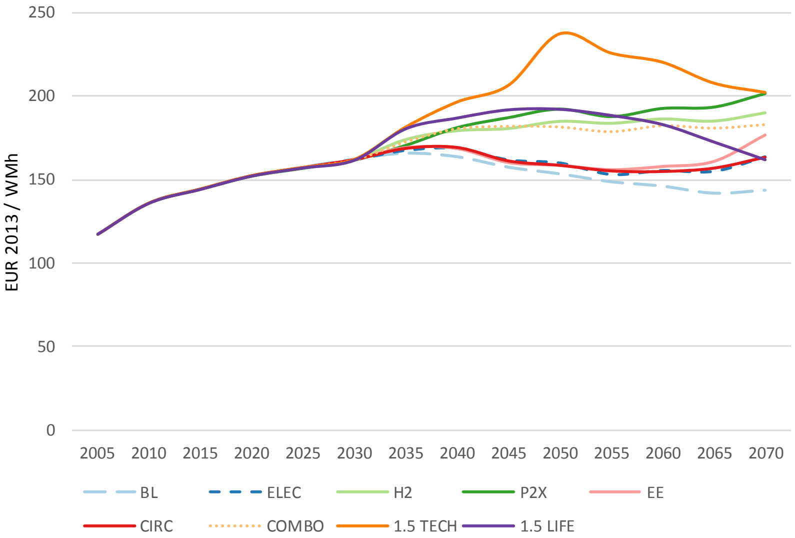
Heavy goods vehicles



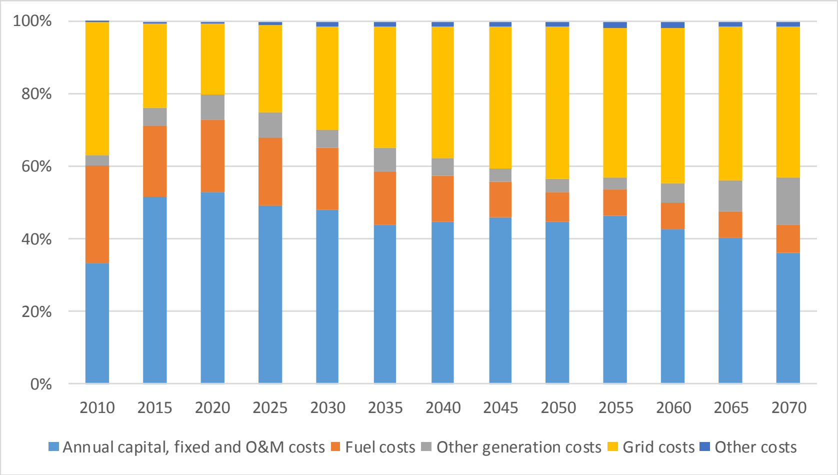
Total energy system costs, 2005-2070



Projected avg. electricity prices for final users



Composition of electricity costs in the high electrification scenario

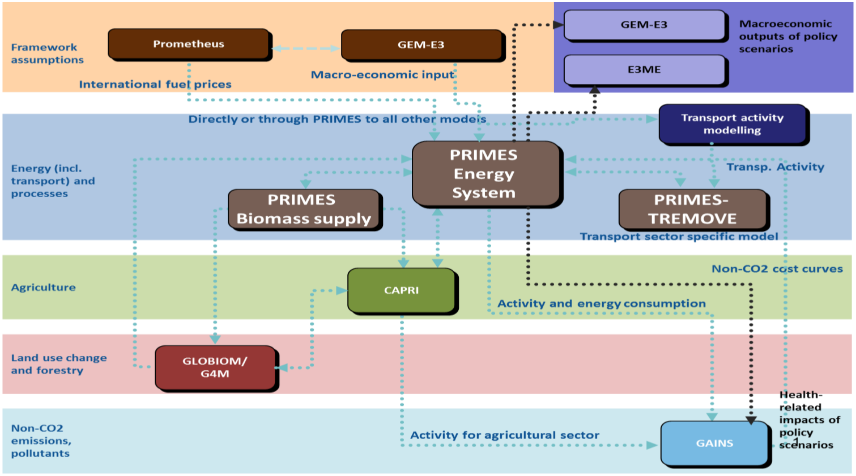


Modeling

Main models used: PRIMES, GAINS, GLOBIOM, GEM-E3, E3ME

- covers the entire energy system: demand, supply, prices, investments; all GHG emissions and removals
- Time horizon: 1990 to 2070 (5-year time steps)
- Geography: all EU member states (incl. UK), EU candidate countries, and where relevant Norway, Switzerland, Bosnia and Herzegovina.
- Impacts: all energy sectors (PRIMES), agriculture (CAPRI), forestry and land use (GLOBIOM-G4M), atmospheric dispersion, health and ecosystems (GAINS), macroeconomy (GEM-E3)

Modeling interconnections



Conclusions: 9 different scenarios

H_2: 4 out of 9 scenarios do *not* require massive amounts of H_2. They are: baseline, energy efficiency, circular economy, and electrification.

Pumped hydro stays more or less constant in all scenarios.

Batteries grow from 29GW in 2030 to 54-178GW by 2050.

V2G is only mentioned in passing. No mention of second-life batteries.

No mention of ancillary services or frequency regulation.

The scenarios describe the drivetrain of cars by 2030 and 2050, but don't give absolute numbers on how many cars there will be of each type.

“Stepping up Europe’s 2030 climate ambition” (EU Commission, 2020)

EUROPEAN
COMMISSION

Brussels, 17.9.2020
SWD(2020) 176 final

PART 1/2

COMMISSION STAFF WORKING DOCUMENT

IMPACT ASSESSMENT

Accompanying the document

COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS

Stepping up Europe’s 2030 climate ambition

Investing in a climate-neutral future for the benefit of our people

{COM(2020) 562 final} - {SEC(2020) 301 final} - {SWD(2020) 177 final} - {SWD(2020) 178 final}

EN **EN**

- No mention of *“frequency regulation”*, *“ancillary services”*, or *“vehicle-to-grid”*.
- About 120GW of battery storage capacity (power) by 2050.
- No numbers for battery storage capacity (energy).
- No numbers on EV penetration.
- Includes COVID

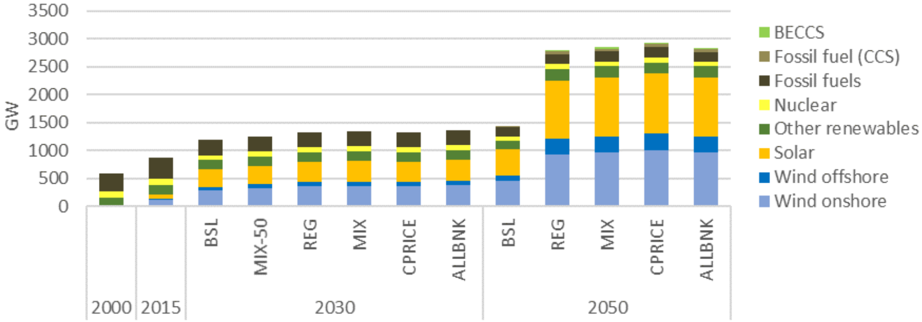
More ambitious policy scenarios for 2030

2030 Target Plan Policy Scenarios

	(REG) Policies and measures as main driver for GHG 55% target	(MIX)/ (MIX-50) Policies, measures and carbon pricing combined for GHG 55%/GHG 50% target	(CPRICE) Carbon pricing as main driver for GHG 55% target	(ALLBNK) Inclusion of all bunkers for GHG 55% target
Scope to asses GHG target ambition	All sectors including intra EU bunkers and LULUCF			All sectors including intra and extra EU bunkers and LULUCF
ETS Scope / Carbon Pricing	ETS scope: - Power, Industry, - Intra-EU aviation and navigation*	ETS scope: - Power, Industry, - Intra-EU aviation and navigation*, - Road transport, Buildings		ETS scope: - Power, Industry, - All aviation and navigation, - Road transport, buildings
EE policies	High intensification policies	Medium/low intensification policies	No additional measures compared to Baseline	Medium intensification policies
RES policies	High intensification policies	Medium/low intensification policies	No additional measures compared to Baseline	Medium intensification policies
Transport measures	High intensification policies (CO2 standards in road transport + RES, aviation and maritime fuel mandates + measures improving transport system efficiency)	Medium/low intensification policies (CO2 standards in road transport + RES, aviation and maritime fuel mandates + measures improving transport system efficiency)	Low intensification policies (CO2 standards in road transport + aviation and maritime fuel mandates + measures improving transport system efficiency)	Medium intensification policies (CO2 standards in road transport + measures improving transport system efficiency) High intensification of RES, aviation and maritime fuel mandates
non-CO2 policies	Medium intensification policies			High intensification policies
LULUCF policies	Baseline policies			

*Carbon pricing and carbon values are applied on extra EU aviation and navigation to represent ETS or other policy instruments regulating these sector's emissions (which can also stand for other policy instruments like CORSIA for aviation and technical and operational measures for both aviation and maritime).

Installed power production capacities: *triple* by 2050

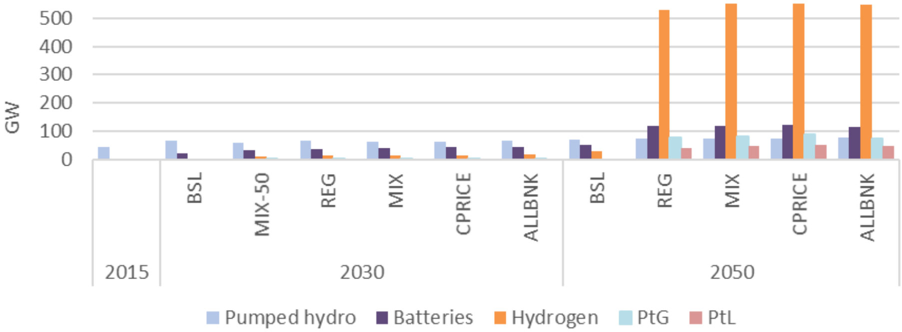


Source: 2000, 2015: Eurostat, 2030-2050: PRIMES model

As opposed to the 2018 plan, the non-baseline production capacities are much more uniform: from 0.9TW today to 1.3TW by 2030 and 2.9TW by 2050.

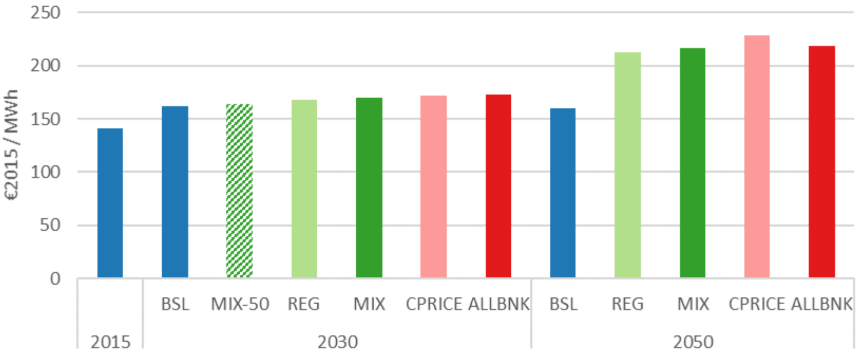
Nuclear stays constant, solar and onshore wind expand massively.

Electricity storage capacity (power): set on H_2



PHS: from 45GW today to 64GW by 2030 and stays about constant until 2050.
Batteries: from 0 today to 20-40GW by 2030 and 50-120GW by 2050. The lower number is from the BSL scenario.
H_2: from 0 today to 1.5-12GW by 2030. Policy scenarios: 40-70GW by 2035 and 530-580GW by 2050. BSL: 20GW by 2050. H_2 requires the most policy effort.
As opposed to the 2018 plan: more uniform battery and H_2 needs. H_2 increases, batteries are about equal to the average of the 2018 scenarios.

Average price of electricity: more expensive than previously



In the previous plan, the electrification, circular economy, and energy-efficiency scenario had costs of about 160€ /MWh (2013). The H_2 scenarios were more expensive (∼200€ /MWh). With a wider H_2-deployment, all policy scenarios now have costs over 200€ /MWh (2015).

The yearly investments into the energy system are about 450bn€ .

Overall conclusion: how safe is a system that relies massively on one flexibility option?

In 2018, the Commission defined 9 scenarios for the energy system of the future. Five of them rely heavily on electrolysers for flexibility.

In spring 2020, the Commission published a report about supply security showing that modulating electrolysers around their operating point almost eliminates the need for battery storage. The latter would be a bridge technology until enough electrolysers become operational. V2G could displace some electrolysers.

In fall 2020, the Commission released more ambitious targets with new scenarios for the energy system of the future. They all rely heavily on electrolysers (500GW by 2050) and, to a lesser extent, on batteries (100GW by 2050). Batteries would again be most important for the near future (2030) in which electrolysers would be negligible.

None of the reports mentions ancillary services or frequency regulation. How much would it be compared to the 100GW the Commission reports for super-hourly flexibility?