# Modellers' Exchange Workshop

## Accelerating full decarbonisation:
## Resource optimisation in energy infrastructure planning

**2nd of February | 9:30-13:00**

Supported by:

Federal Ministry for Economic Affairs and Climate Action

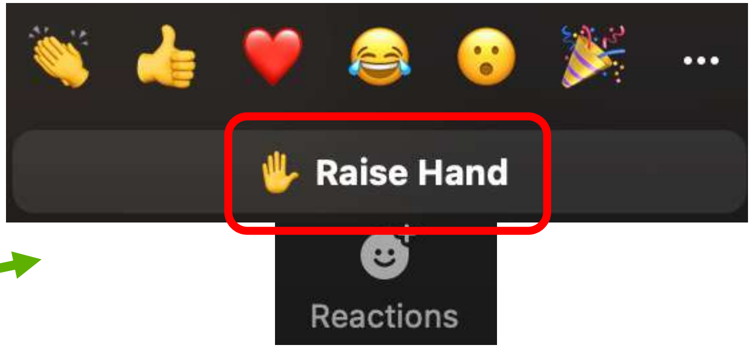
on the basis of a decision by the German Bundestag

Paris Agreement Compatible Scenarios for Energy Infrastructure

This project has been financed by the German Federal Ministry for Economic Affairs and Climate Action.

# House rules

- Stay muted
- Turn your camera on (if possible)
- Raise your hand to take the floor
- Full name + institution
- Use the chat function in case of questions/comments
- Use reactions (if you like)





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# Workshop's proceedings

09:30-10:05 Opening plenary session

10:05-11:05 Parallel thematic breakout sessions – Part I

11:05-11:25 Virtual coffee break

11:25-12:30 Parallel thematic breakout sessions – Part II

12:30-13:00 Closing plenary session

# Workshop's objectives

1. Present and discuss main findings and features of **modelling the infrastructural needs** of the European energy system **in line with the decarbonisation targets** outlined in the Paris Agreement

2. Collect feedback from energy system modelling and planning experts to **improve the Hitachi Energy / RGI cooperation focused on modelling and decide on the next steps**

3. Enhance **energy modelling community exchanges** dedicated to decarbonisation pathways and connected implications in the EU energy and climate community

4. Share experience and knowledge among the participants and **search for synergies in approaches and experienced challenges**

# Reasons for this work – the past

- 2018-2020: RGI led the PAC Project consortium; CAN Europe and EEB have developed the PAC-scenario

- Political ambitions of the PAC scenario:
  - A 65% reduction in greenhouse gas emissions by 2030
  - Net-zero greenhouse gas emissions by 2040
  - 100% renewables in Europe by 2040 in all energy sectors

- The PAC-request to Adapt European Energy Planning Scenarios signed by 50 organisations




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# Reasons for this work – now

- We see an urgent need to accelerate & scale decarbonisation with RES within this decade
- We need to better understand infrastructure needs including in relation to resource scarcity. Provide input to the TYNDP
- We need to optimize the use of infrastructure and services across the entire energy sector
- We have taken the political ambitions described by the PAC scenario and, with Hitachi Energy, started this modeling collaboration
- The PAC Project 2.0 will run until 2024

# Energy system 2050: towards a carbon-neutral vision

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“Electricity will be the backbone of the entire energy system

**01**
Accelerated shift from fossil-based to renewable power generation

**02**
Growing electrification of Transportation, Industry and Buildings sectors

**03**
Sustainable energy carriers, complementary to direct electrification

## Fast facts

“ Global electrification will be more than 50% of total energy demand

“ Electrification improves energy efficiency

“ All market sectors converting towards electrification

“ Energy sector-coupling beneficial

## So what?

Digital and energy platforms are needed…

…to manage the enormous power system energy transition challenges:

increased complexity
additional capacity

**for reduction of $CO_2$ emissions**

**Accelerating the transition to a carbon-neutral energy system requires adapting and adopting policies and regulations to enable technology and new business models to support scalable, flexible and secure energy systems**

2022-02-02, On-line Energy System Modelers Exchange Workshop

# Infrastructure needs of an optimized European energy system

## Compatible with the Paris Climate Agreement

ALEXANDRE OUDALOV | MARKET INNOVATION, HITACHI ENERGY

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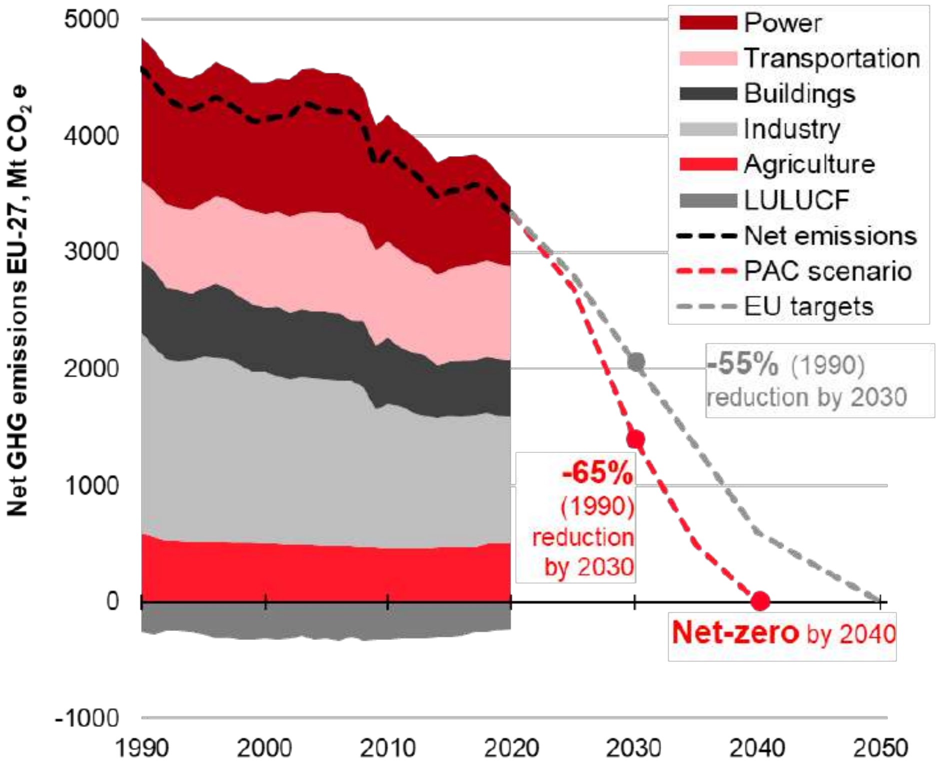
# Background and starting point

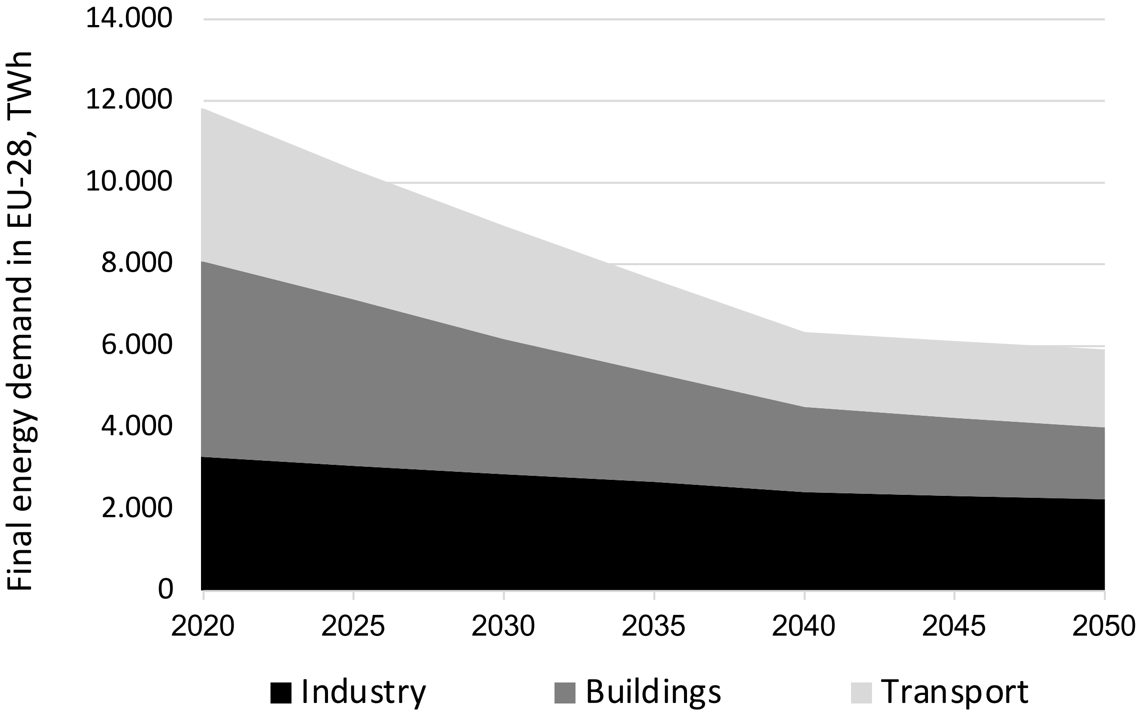
PAC scenario was developed by CAN and EEB and it sets more ambitious timeline for achieving net-zero carbon emissions in Europe and describes how to reach:

– 65% reduction in greenhouse gas (GHG) emissions by 2030,

– Net-zero GHG emissions by 2040 in all sectors.




PAC scenario's decarbonization pathway is characterized by 50% reduction of final energy consumption, massive direct electrification and more efficient energy use across all sectors.







Source: www.pac-scenarios.eu

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# Our key questions to be answered

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1. When, where and in what kind of energy infrastructure do we need to invest in Europe to deliver full decarbonization with RES by 2040 assuming global vs national resource allocation?
2. How to leverage interdependencies and complementarities of energy sectors (electricity, hydrogen) by taking a holistic energy system planning approach?
3. What are the capital and operating cost of the additional infrastructure elements required to meet the objectives?
4. How will the total cost of energy (electricity and hydrogen) evolve chronologically from 2020 until 2050?
5. How does the optimal solution depend on cost of imported hydrogen, cost of storage, availability of space for a massive energy infrastructure upscaling, changes in weather and climate patterns, etc.?

**Special topic**

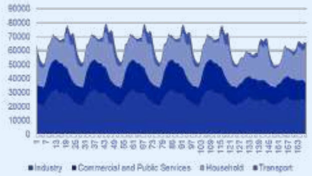
What are the consequences of delaying grid infrastructure deployment due to political and public reasons?

We expand data from the PAC scenario in two dimensions:

– **spatial** (from a lumped European model to a representation of each country as well as off-shore zones and neighboring regions).

– **temporal** (from an annual energy demand to annual profiles in hourly resolution).

**XYZ TWh/y**





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# Our multi-period/zonal/energy vector modeling framework

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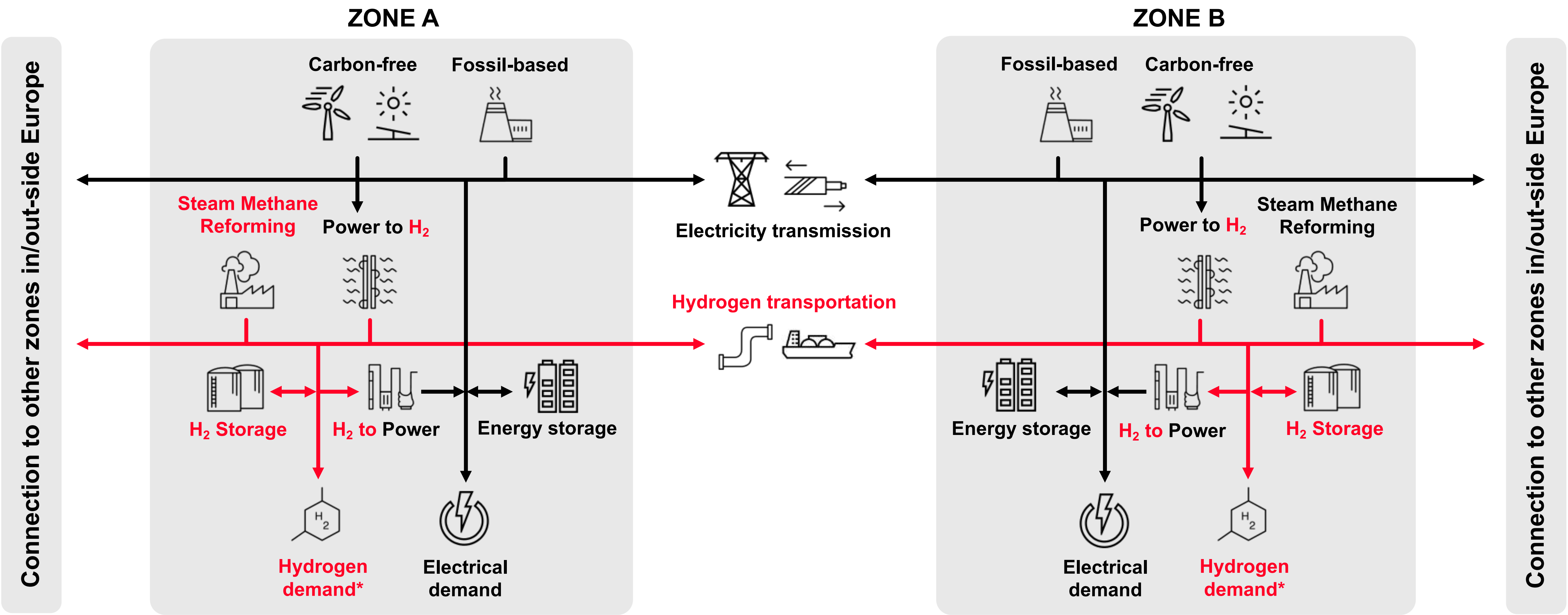


*Alternative fuels: synthetic methane, ammonia, kerosine, etc. are integrated in the model by estimating the amount of hydrogen required to synthesize these fuels.

**Electricity balance:**
Production – VRES curtailment + Import – Export – Losses + …
+ Estorage_production – E stored – P2G = Demand

**Hydrogen balance:**
Production + Import – Export – Losses – H2 stored + G2P = Demand




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# Reference case

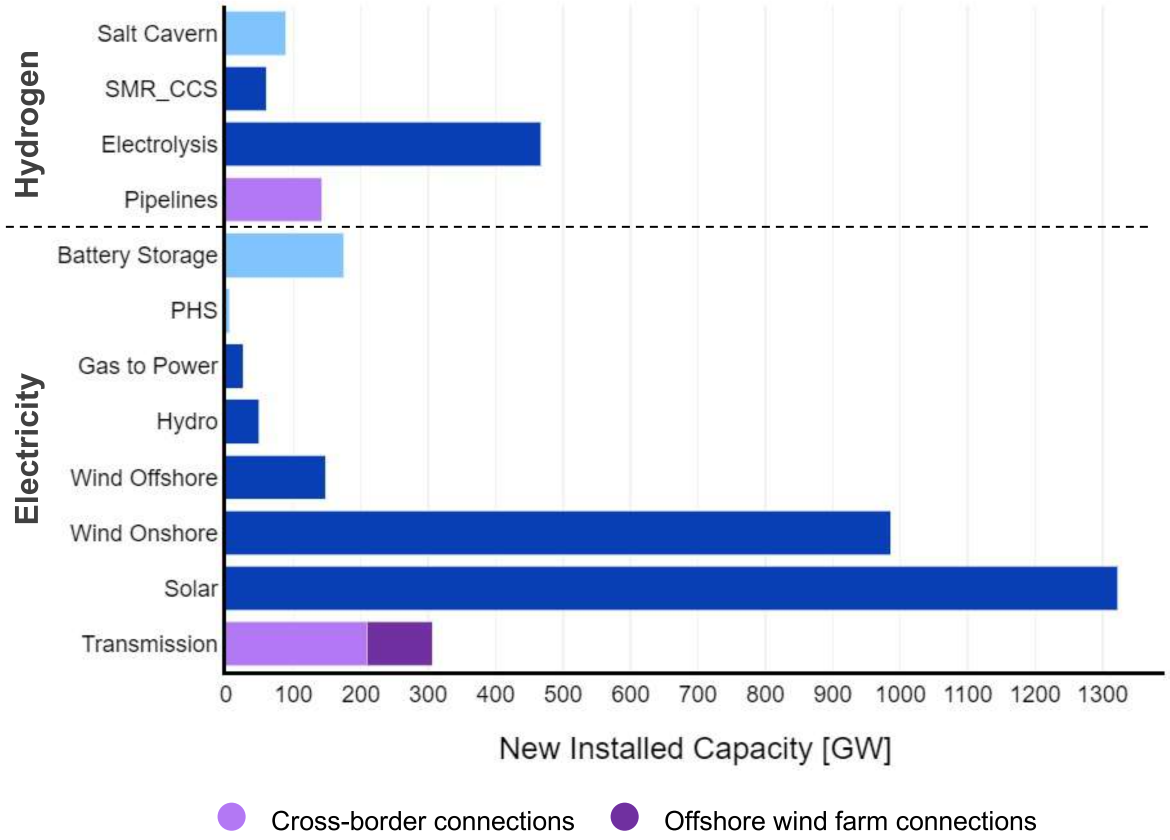
- The model consists of 30 individual country zones and 35 off-shore wind zones.
- The current generation, energy storage, cross-border and off-shore wind connection capacities, electricity demand are from ENTSO-E. The current hydrogen demand is from Hydrogen Europe.
- Max available regional wind and solar PV generation capacity is set equal to a reference technical potential from EC JRC ENSPRESO datasets.
- Regional wind and solar PV profiles and capacity factors are from renewables.ninja. The shape of profile does not change over simulation period. Hydro generation inflows are from ENTSO-E.
- Electricity and hydrogen demand projections for all Europe are from PAC scenario. Annual profiles are synthesized via a bottom-up process.
- All future capacities of renewable generation, energy storage, cross-border and off-shore wind connections, green and blue hydrogen production, pipelines and underground caverns are decision variables and optimized (size and location) at each investment decision step.
- The model runs with an investment decision step of 5 years (4 steps) and data sample time is set as hours = 2, days = 3 and weeks = 4.
- Technology cost (capex and open) and performance (efficiency, lifetime, ramping, emissions, etc.) as of today and future projections are same for all regions and are in the middle of range collected from publicly available sources.
- Infrastructure capacity growth is limited by 100% per each decision step and is a region independent. For technologies with a very low/zero installed capacity in 2020 the initial investment limit is set at 2GW.
- Max chronological CO2 emission cap is set according to PAC scenario targets.
- Cost of imports of electricity and hydrogen is set to a very high value to force the model self-sufficiency.

# Prelimenary results

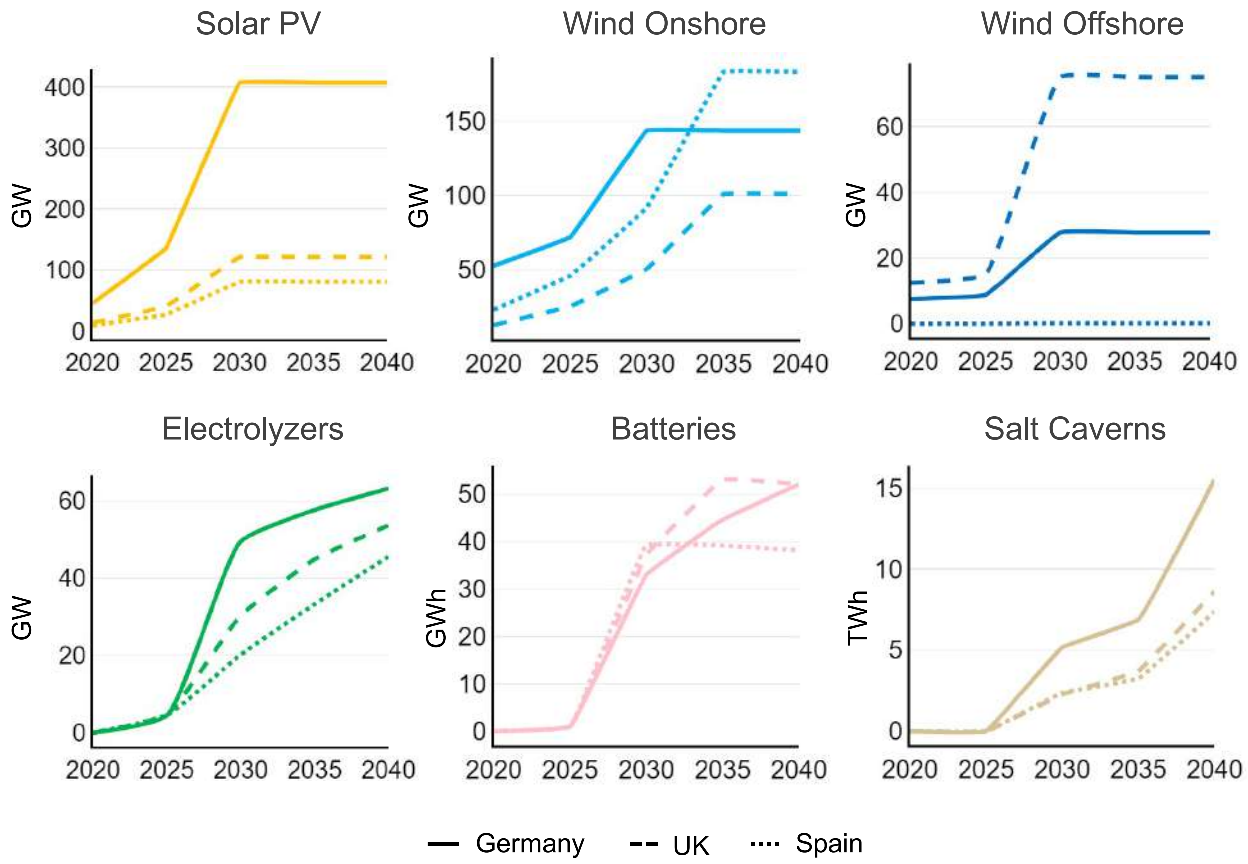
The results included in this presentation are preliminary and subject to revision upon completion of modeling and simulation work.

# Capacity expansion overview

## New installed capacity in Europe 2020-2040




## Country specific chronological capacity deployment




**Fast growth of all clean technologies is required in the next decade to decarbonize European energy supply by 2040**

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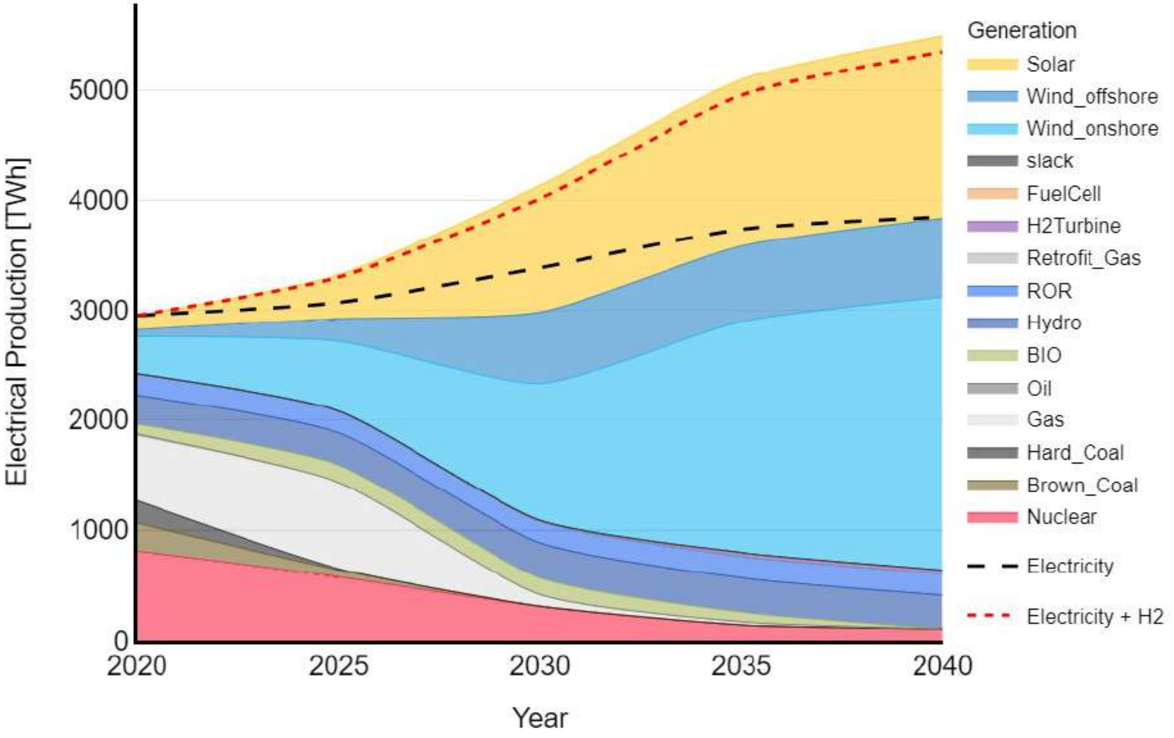
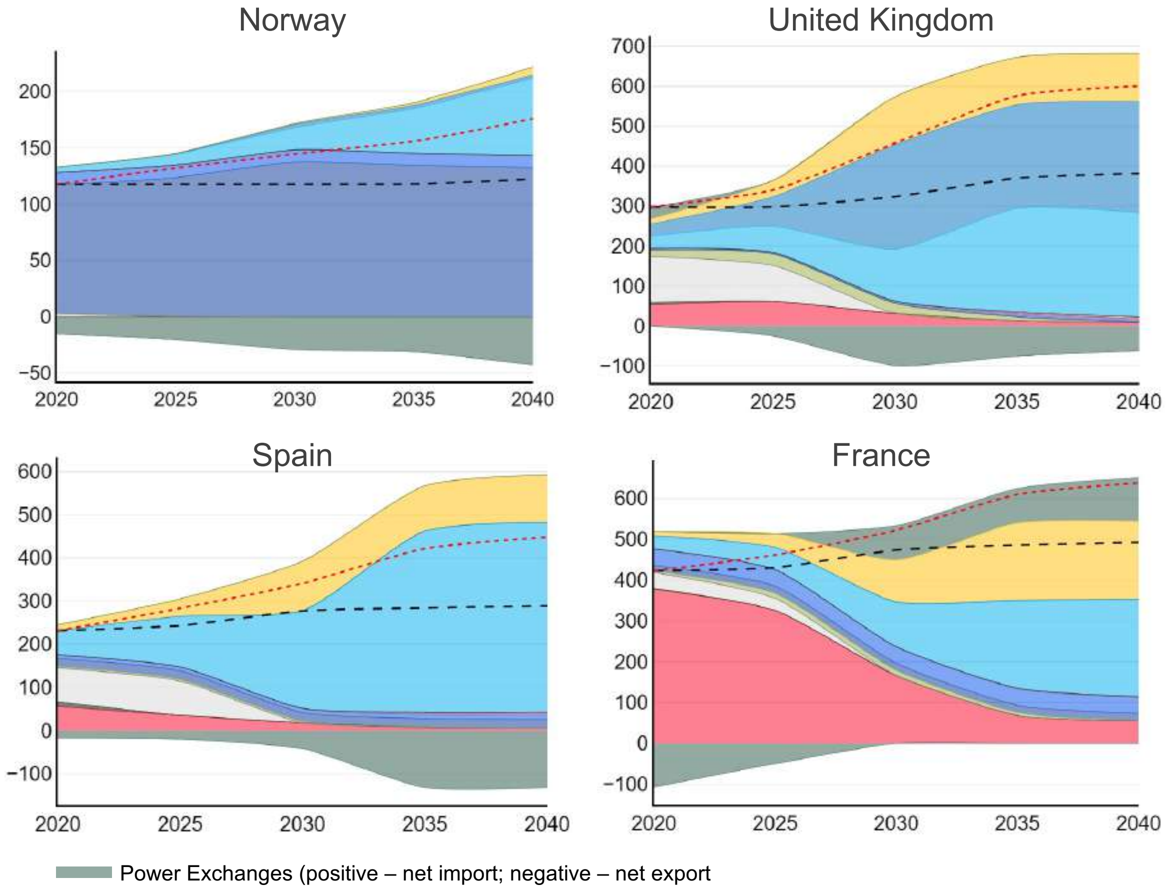
# Electricity generation mix

## European electricity generation mix, TWh




- Nuclear generation capacity is phased out according to PAC scenario. Coal and gas generation is pushed down by emission cap.
- Generation above a total electricity demand (dashed red line) is due to grid and storage losses.

## Country specific electricity generation mix, TWh




**Wind and solar PV will account for more than 85% of electricity generation in Europe by 2040**

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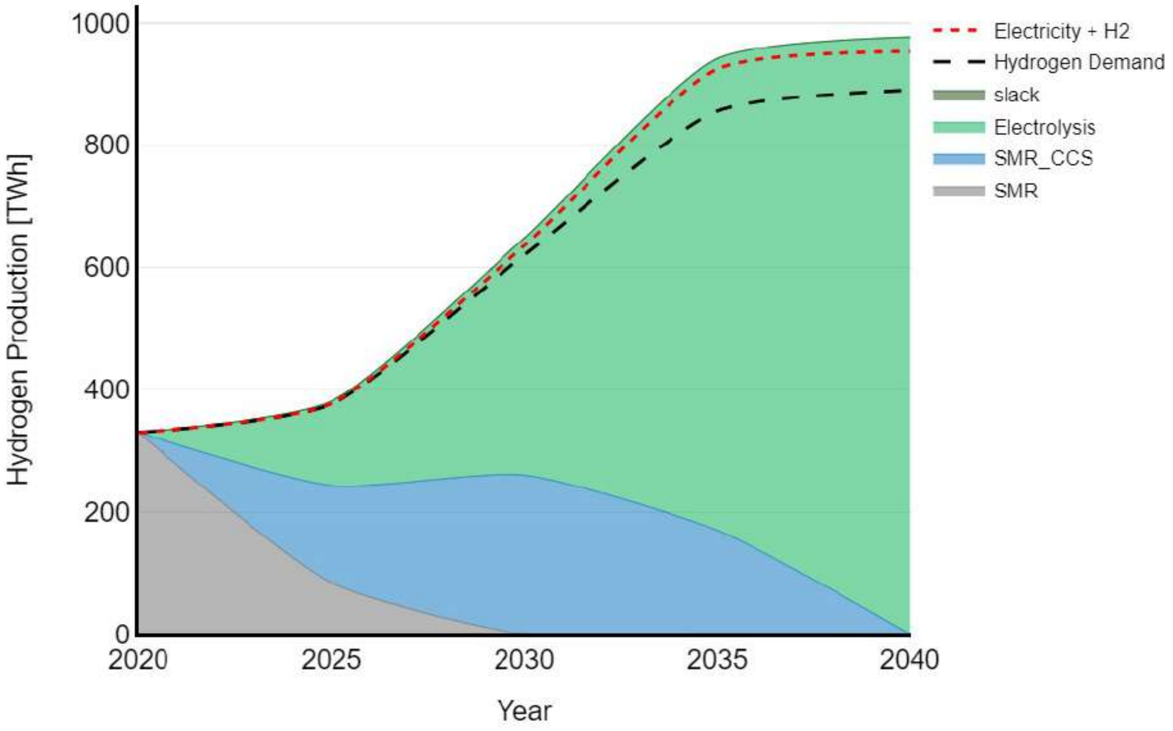
# Hydrogen production mix

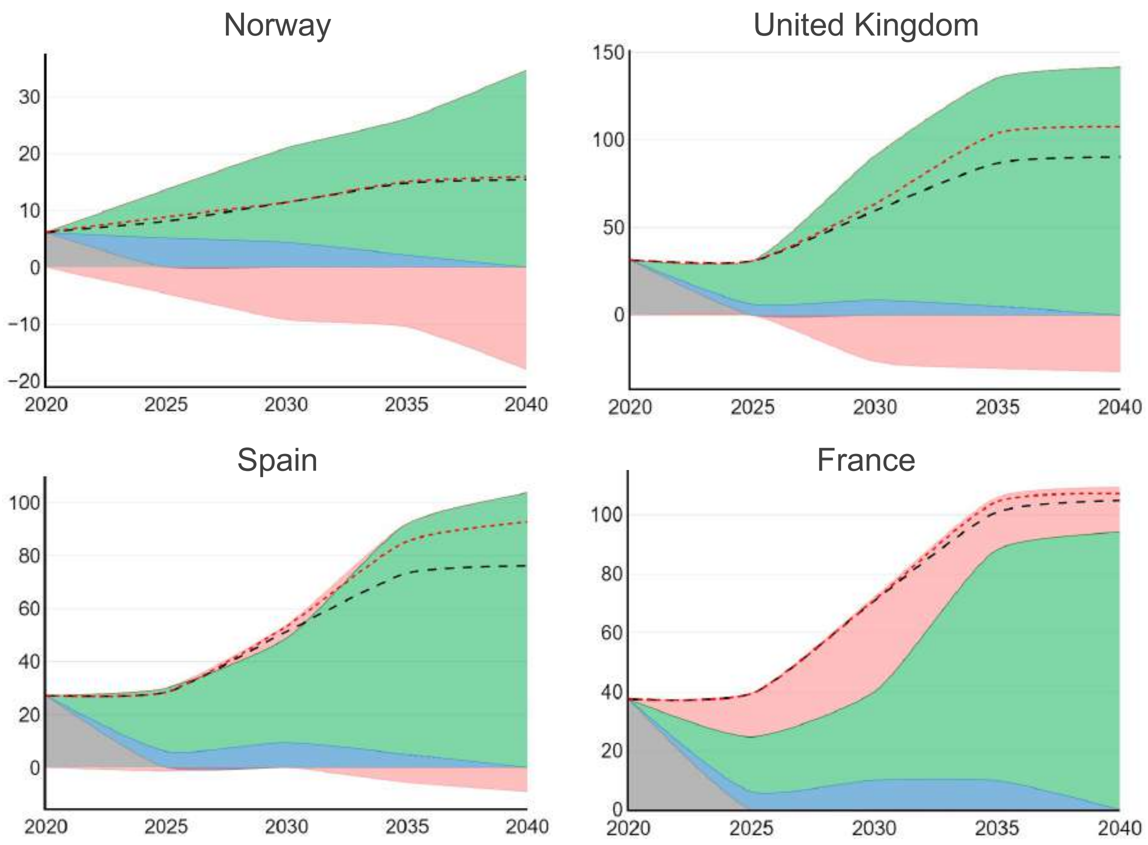


## European hydrogen production mix, TWh




- Grey (SMR) and blue (SMR+CCS) hydrogen production is pushed down by emission cap.
- Hydrogen production above a total hydrogen demand (dashed red line) is due to pipeline and storage losses.

## Country specific hydrogen production mix, TWh




Hydrogen Exchanges (positive – net import; negative – net export

**Electrolyzers fueled by clean electricity will cover a rapid growth of hydrogen demand to decarbonize industrial and transport sectors.**

# Balancing time-varying supply and demand

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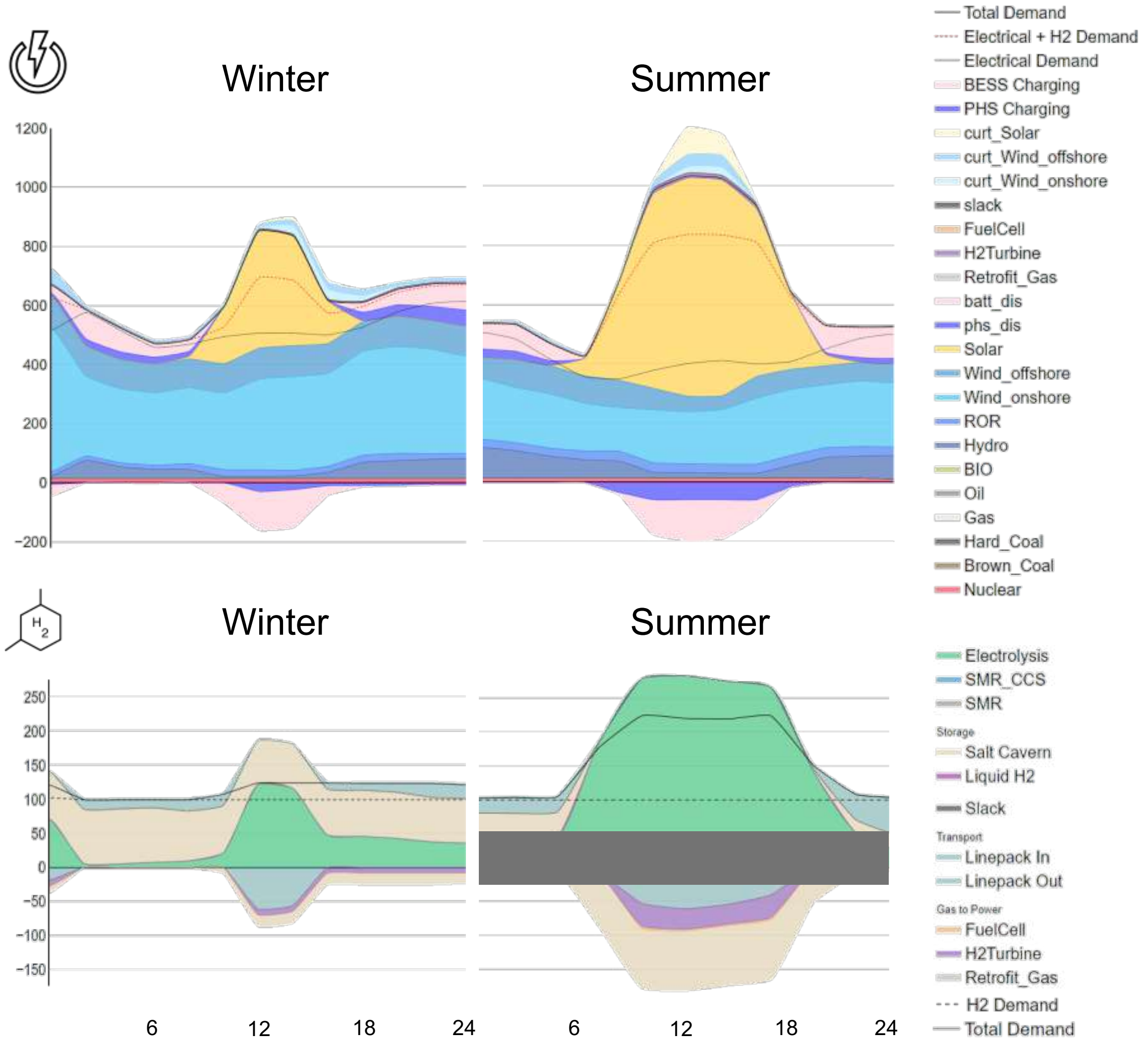
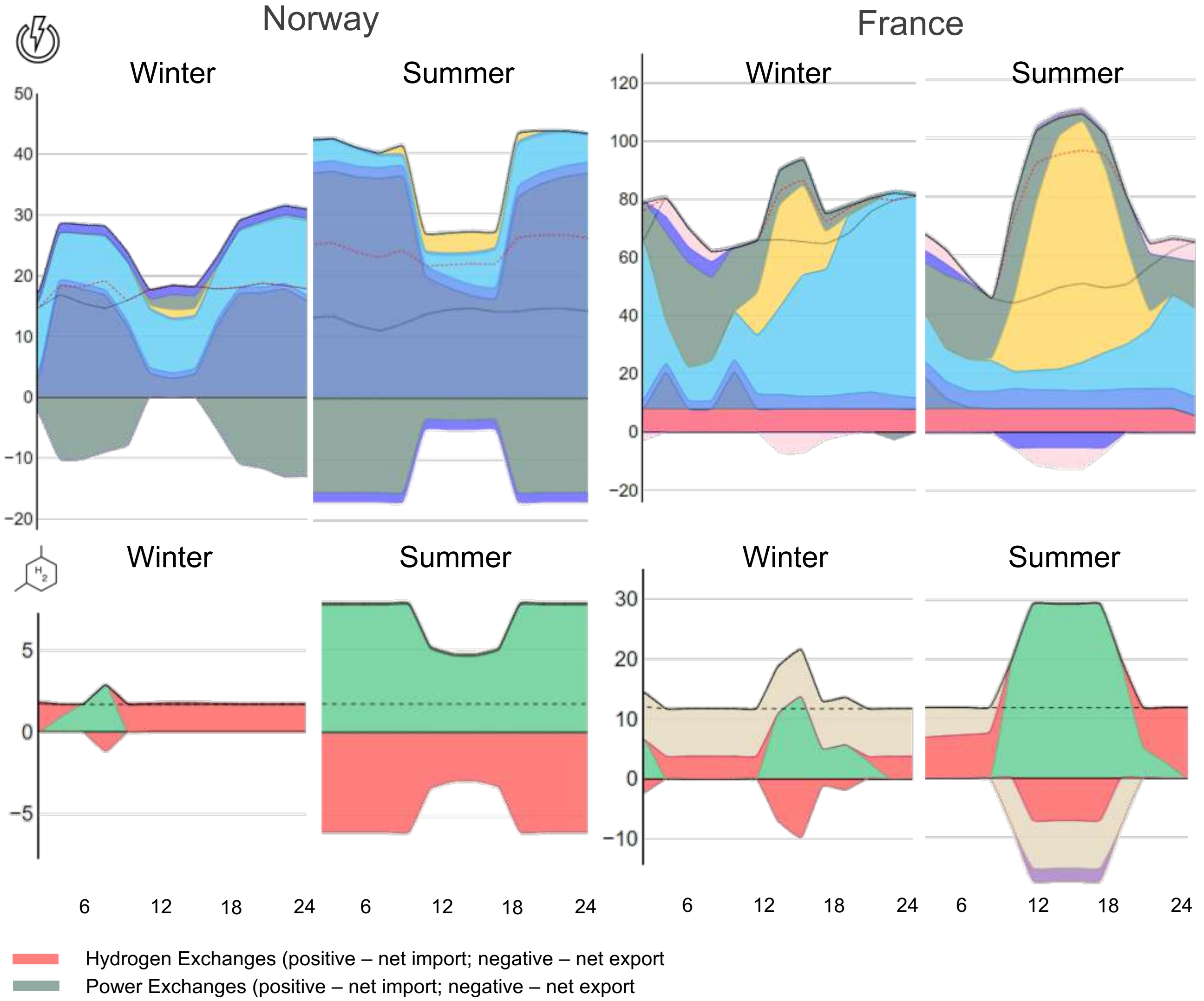
## Europe supply and demand, GW




## Country specific generation and flexibility profiles, GW







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# Electricity and hydrogen network expansion

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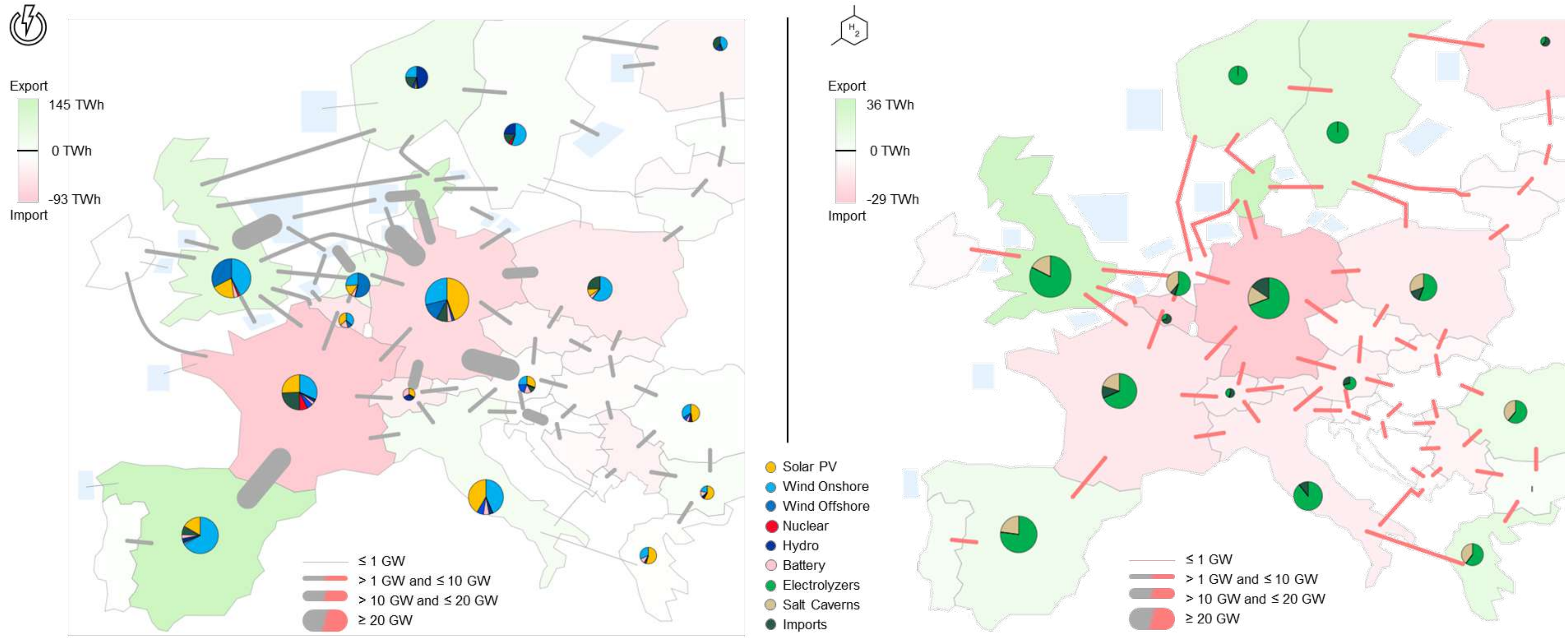


**There will be more cooperation between different geographic areas in Europe. Hydrogen pipeline network complements electricity transmission backbone.**



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# Investment cost of additional infrastructure elements

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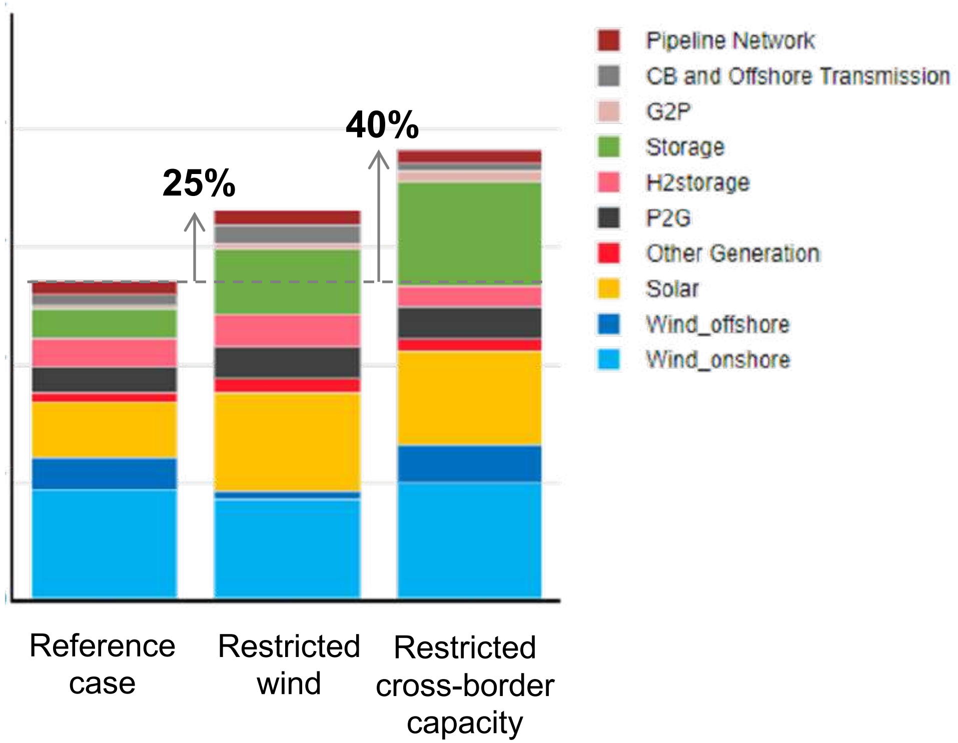
| Sensitivity case | Special settings | Key differences compared to the reference case |
|---|---|---|
| **Restricted wind** | High restriction of on-/off-shore wind technical potential [JRC ENSPRESO]. | 1. On-shore wind geographically redistributed. Off-shore wind significantly reduced.<br>2. Increased cross-border transmission.<br>3. Increased solar PV and storage capacity. |
| **Restricted cross-border capacity** | No new investments in cross-border interconnection capacity affecting OHL and cables. | 1. Local allocation of renewable resources.<br>2. Increased solar PV capacity.<br>3. Storage capacity almost triples. |

**Investment cost in Europe 2025-2040**



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# What is next?

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- Continue information exchanges with energy modeling community.
- Further increase spatial and temporal resolution of the model.
- Introduce region dependent input parameters and constraints.
- Perform extended sensitivity analysis across a wide range of model parameters.
- Present final findings and recommendations and publish report in Spring 2022.
- Phase II: include neighboring regions (North Africa, Middle East, Ukraine, etc.).




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# Four parallel breakout sessions…

- **Energy system expansion modelling: methods, assumptions, and tools**
- **Evolution of energy demand and renewable generation profiles in Europe**
- **Projection of future energy technology trends**
- **Environmental, resource availability, supply chain, financial and other constraints**

# You will join two of them

**Session 1: Energy system expansion modelling: methods, assumptions, and tools**

Katarina Knezovic & Hei Kern Leong – Hitachi Energy



**Session 2: Evolution of energy demand and renewable generation profiles in Europe**

Anser Shakoor & Meijun Chen – Hitachi Energy

**Session 3: Projection of future energy technology trends**

Alexander Oudalov – Hitachi Energy & Léa Hayez – RGI



**Session 4: Environmental, resource availability, supply chain, financial and other constraints**

Jochen Kreusel – Hitachi Energy & Alexandros Fakas Kakouris – RGI

# Breakout sessions – Part I

| Session 1: Energy system expansion modelling: methods, assumptions, and tools | |
|---|---|
| Christoph Kost (Fraunhofer ISE) | Robbie Morrison (openmod initiative) |
| Olivier Lebois (RTE) | Andrzej Ceglarz (RGI) |
| Tom Brown (TU Berlin) | Tobias Bossman (Artelys) |
| Markus Groissboeck (Uni Innsbruck) | Damon Coates (Elia) |
| Elli Tessier (CAN Europe) | |

| Session 2: Evolution of energy demand and renewable generation profiles in Europe | |
|---|---|
| Tim Felling (Amprion) | Jörg Mühlenhoff (CAN Europe) |
| Ricardo Coelho (ULisboa) | Modassar Chaudry (Cardiff University) |
| Vincent Minier (Schneider Electric) | Sean Collins (IRENA) |

| Session 3: Projection of future energy technology trends | |
|---|---|
| Rüdiger Barth (Amprion) | Luis Galiano (EEB) |
| Abhimanyu Kaushal (KULeuven) | Maud Perilleux (Elia) |
| Elisabeth Zeyen (TU Berlin) | Ivan Komusanac (WindEurope) |

| Session 4: Environmental, resource availability, supply chain, financial and other constraints | |
|---|---|
| Kevin Johnson<br>(Nordic Energy Research Council) | Stefan Reschwamm (50Hertz/RGI) |
| Cristina Madrid López<br>(University of Barcelona) | Matteo De Felice<br>(Joint Research Centre) |
| Barbara Mariani (EEB) | Bernard Swoczyna (Instrat) |
| Antonella Battaglini (RGI) | |

# Welcome back!

**Coffee break – until 11:30**

**When we are back, you will be sent to one of the 4 sessions (according to your preference).**



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# Breakout sessions – Part II

| Session 1: Energy system expansion modelling: methods, assumptions, and tools | |
|---|---|
| Tim Felling (Amprion) | Maud Perilleux (Elia) |
| Kevin Johnson (Nordic Energy Research Council) | Sean Collins (IRENA) |
| Elisabeth Zeyen (TU Berlin) | Modassar Chaudry (Cardiff University) |
| Luis Galiano (EEB) | |

| Session 2: Evolution of energy demand and renewable generation profiles in Europe | |
|---|---|
| Olivier Lebois (RTE) | Tobias Bossman (Artelys) |
| Abhimanyu Kaushal (KU Leuven) | Bernard Swoczyna (Instrat) |
| Barbara Mariani (EEB) | |

| Session 3: Projection of future energy technology trends | |
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| Session 4: Environmental, resource availability, supply chain, financial and other constraints | |
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