

Common vision for a decarbonised electricity system by 2050

Ministerial meeting

The *Penta 2050 vision* project in a nutshell

▣ Objectives of the project

- | Develop a common understanding and vision on a **decarbonized Penta electricity system**
- | Identify “**likely developments** and remaining **uncertainties**” in transition pathways

▣ Approach

- | Review and comparison of scenarios and literature ⇒ *Observations*
- | Translation of observations into ⇒ *Convictions*
- | Convictions build the basis for the ⇒ *2050 vision building*



▣ The actual vision building will take place in 2023

























Shortlisted publications

4 Literature review relies on **national scenario reports**, **technical reports** and **international studies**

AT	BE	CH
<ul style="list-style-type: none">BNT (2019): Langfriststrategie 2050BMK (2021): Erneuerbares Gas in Österreich 2040Federal Ministry Republic of Austria (2019): Integrated National Energy and Climate Plan for Austria (not a net-zero scenario)	<ul style="list-style-type: none">Elia (2021): Roadmap to net zeroDGE (2021): Scenarios for a climate neutral Belgium by 2050	<ul style="list-style-type: none">SFOE (2020): Energy perspectives 2050+PSI (2020): Long-term energy transformation pathways
DE	FR	
<ul style="list-style-type: none">BMWi (2021): Langfristszenarien für die Transformation des Energiesystems in DeutschlandAgora Energiewende (2021): Klimaneutrales Deutschland 2045Agora Energiewende (2022): Climate-neutral power system 2035	<ul style="list-style-type: none">RTE (2021): Energy Pathways to 2050ADEME (2022): Transition(s) 2050	
LU	NL	
<ul style="list-style-type: none">CREOS (2020): Scenario Report 2040LIST (2021): Luxembourg in transition	<ul style="list-style-type: none">Netbeheer NL (2021): The Energy System of the Future	

4 Short-listed scenarios feature a high level of **regional cooperation** and meet **net-zero** objectives in 2050

Overview of convictions

Tag	Category	Conviction	Penta lever	Urgency
CO2	CO2	Power sector decarbonisation by 2035		
RES	Supply	Renewables are the main pillar of decarbonisation		
EE	Demand	“Energy efficiency first” releases pressure from the power system		
Elec		Direct electrification comes with immediate benefits		
H2use		Decarbonised molecules will play a limited but crucial role		
H2infra		Hydrogen economy needs to be established now		
Grids	Infra-structure	Power grid capacities need to increase substantially		
Planning		A coordinated approach to energy system planning		
Flex	Stability	Flexibility - a key element of the energy transition		
DSF		Additional power demand can and must be flexible		
Storage		Energy storage facilitates RES integration		
Market	Market	The transition requires a future-proof market design		

Power sector decarbonisation by 2035

CO2

RES

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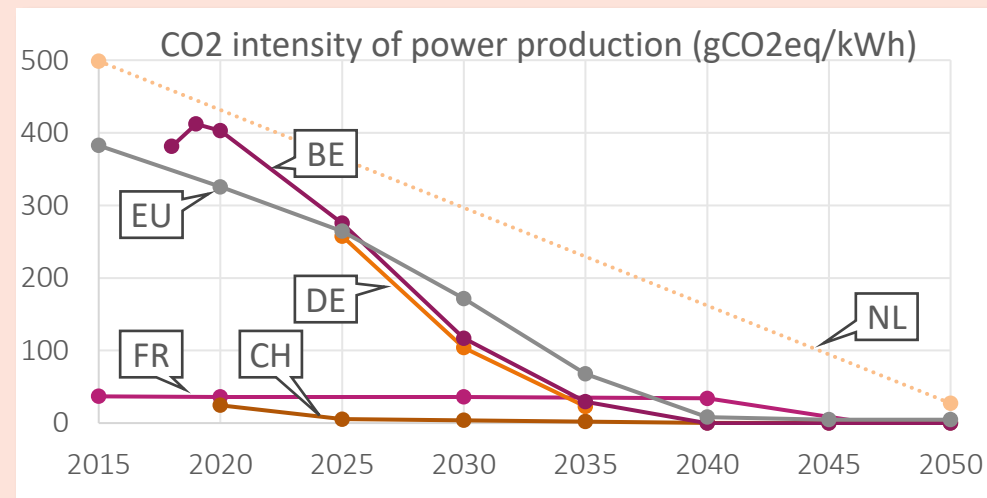


Conviction

- ▮ **Decarbonisation** of the power sector required as early as possible, ideally by **2035**
- ▮ The role of the power sector will increase as it enables the **decarbonisation of other sectors**

Uncertainties

- ▮ **CCS** not foreseen for power generation, yet might be required in the long-run, in particular for **negative emissions** (BECCS)



Renewables are the main pillar of decarbonisation

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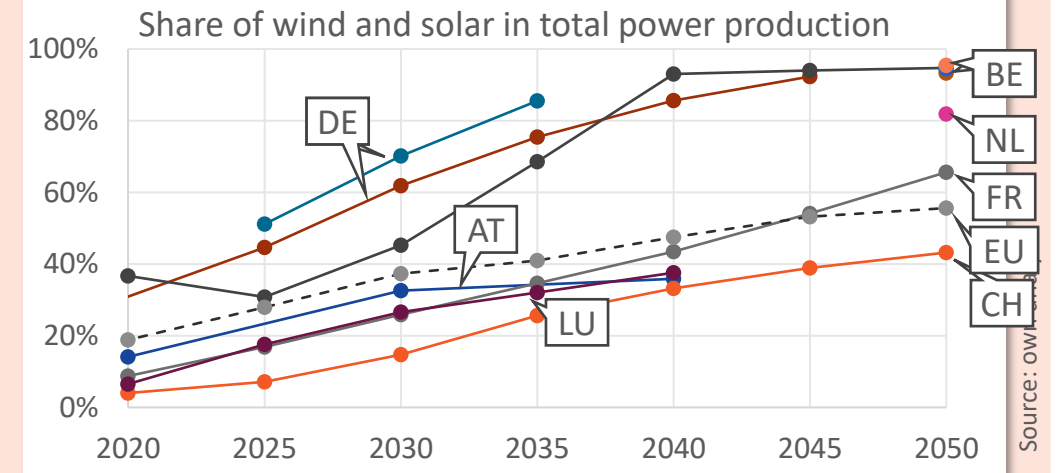


Conviction

- ▮ **Significant domestic power production** from wind and solar PV will play a vital role ⇒ requires **accelerated installation**
- ▮ Important amounts of renewable electricity will be **imported** ⇒ requires additional **cross-border capacities**

Uncertainties

- ▮ Long-term role of **immature technologies** (small modular nuclear reactors, tidal, wave, ultra-deep geothermal, fusion)
- ▮ **Import ratio** between electricity and green molecules



“Energy efficiency first” releases pressure from the power system

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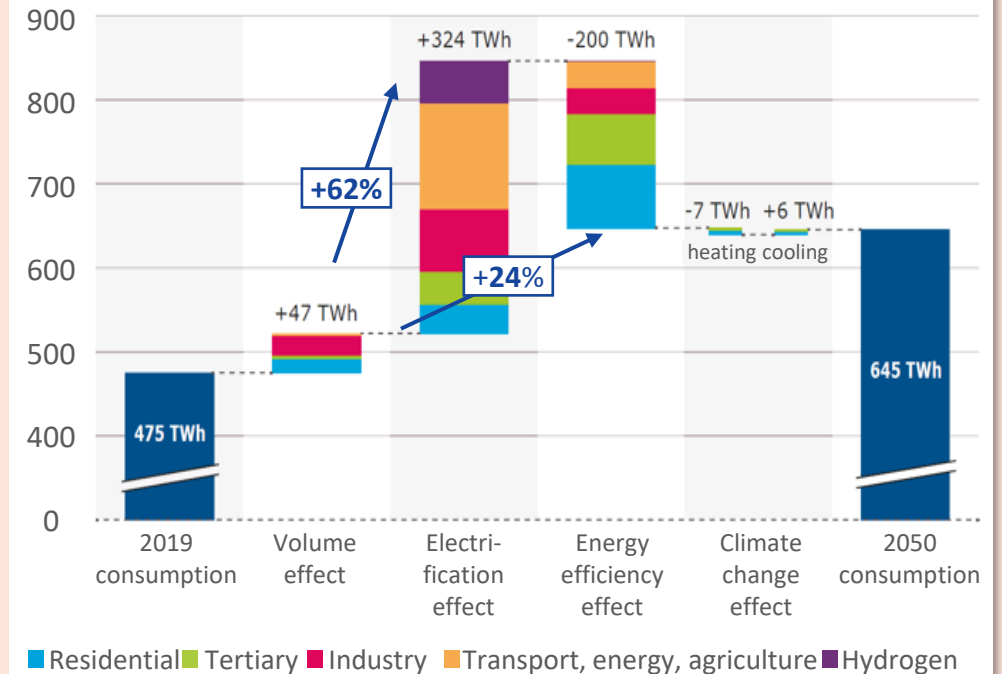
Conviction

- 1 Order of **priority in demand side decarbonisation**: energy efficiency, direct electrification, green/decarbonised molecules
- 1 **Energy efficiency** allows to **cap the expected increase** in power demand \Rightarrow reduced investment needs and import dependency

Uncertainties

- 1 Magnitude of **accelerating building renovation**
- 1 Feasibility and effectiveness of **circular economy, behavioural changes** (rebound)

Final energy demand, FR, 2019/2050, reference evolution



Source: RTE (2021), Futures énergétiques

Direct electrification comes with immediate benefits

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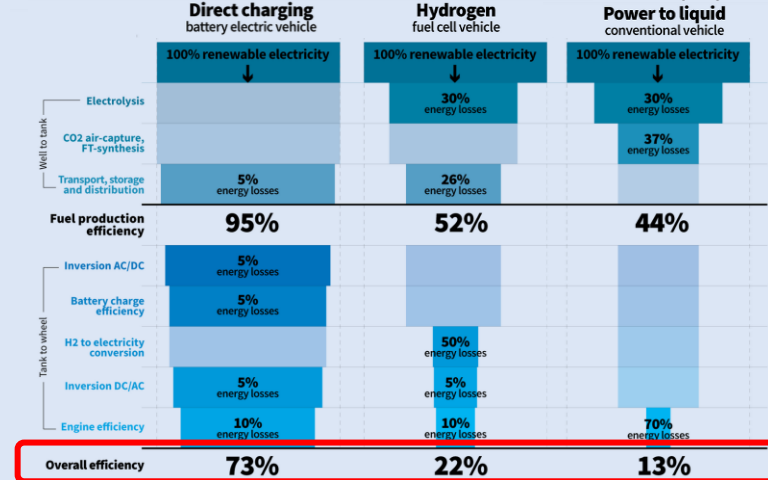
Conviction

- ⚠ We face a **significant increase in electricity demand**.
- ⚠ The **direct use of electricity** is the **preferred solution** over green molecules if technically feasible and cost-competitive.
- ⚠ Direct electrification needs to be **put in place already now** where undisputed ⇒ **immediate net emission reductions**

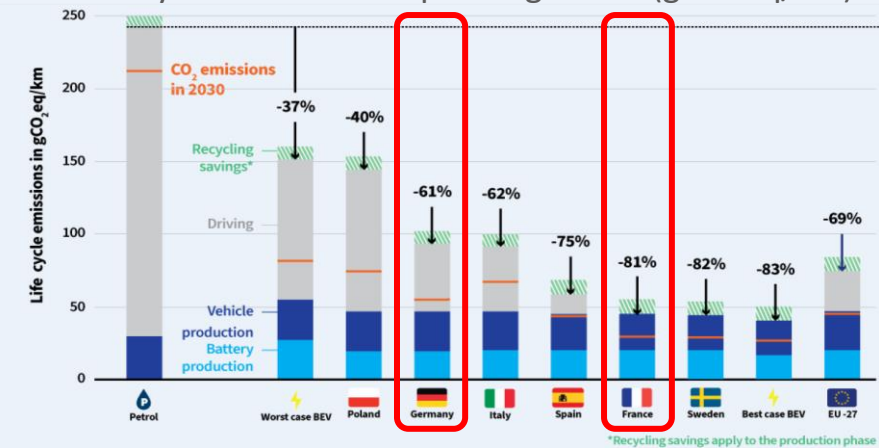
Uncertainties

- ⚠ **Feasibility of direct electrification vs hydrogen** (derivatives) vs sustainable biomass/biogas: short/medium-haul aviation, heavy road transport, high temperature industrial heat
- ⚠ Role of **hybrid heat pumps**, lowering power system stress but requiring gas infrastructure

Well-to-wheel efficiency by drive-train (%)



Life cycle emissions of passenger cars (gCO2eq/km)



Source: T&E (2022), Lifecycle analysis

Source: T&E (2022), Lifecycle analysis

Decarbonised molecules will play a limited but crucial role

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Conviction

- Decarbonised/green molecules (syngas, biomethane) will play a **limited but important** role.
- Hydrogen use (and its derivatives) should **focus first on hard-to-abate sectors** (feedstocks, steel, deep-sea shipping, aviation).
- Short-term: **replace grey by green hydrogen** in industry

Uncertainties

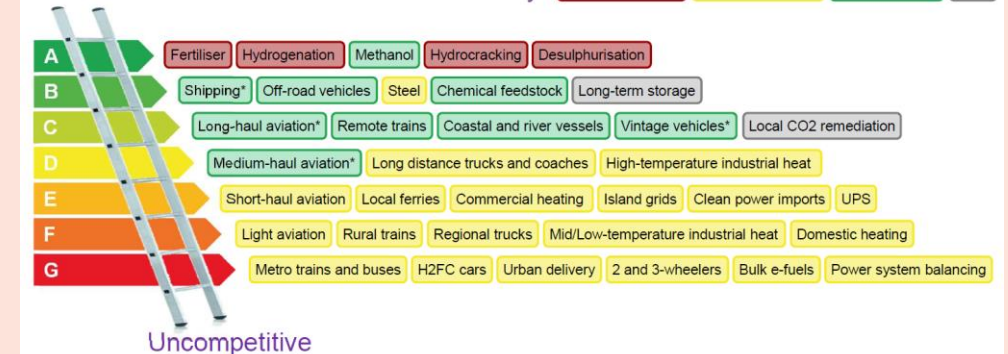
- Feasibility of hydrogen (derivatives) vs direct electrification** vs sustainable biomass/biogas: short/medium-haul aviation, heavy road transport, high temperature industrial heat => **long-term role/magnitude of hydrogen?**
- Sustainable biomethane vs hydrogen in **(peak) power generation**; need for hydrogen as seasonal power **storage**

Clean Hydrogen Ladder: Competing technologies

Liebreich Associates

Unavoidable

Key: No real alternative Electricity/batteries Biomass/biogas Other



* Via ammonia or e-fuel rather than H2 gas or liquid

Source: Liebreich Associates (concept credits: Adrian Hiel/Energy Cities & Paul Martin)

Source: Liebreich (2021), Clean H2 ladder

Hydrogen economy needs to be established now

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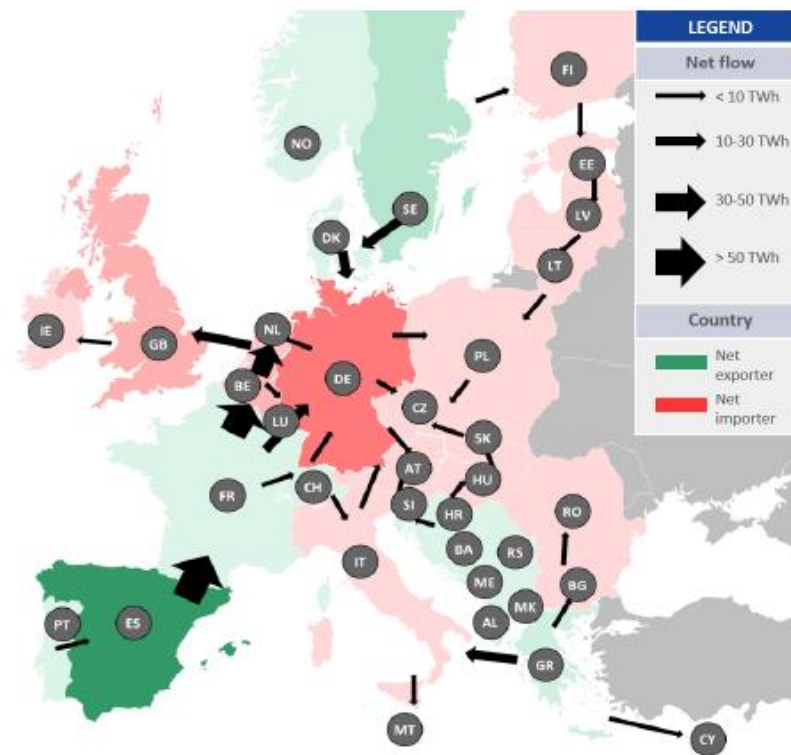
Conviction

- ▮ The way towards a **European hydrogen economy** needs to be paved **now** ⇒ establish networks, market, regulation
- ▮ **Penta plays a central role** in this process

Uncertainties

- ▮ Pan-European H2 network depends on **RES/electrolyser siting** and trade-off between **power lines** and **H2 pipelines**
- ▮ **Repurposing** of gas pipelines, LNG terminals, gas storage
- ▮ Magnitude, origin and form of **hydrogen imports**

Cross-border H2 flows, optimised scen.



Source: EC/Artelys (2021), METIS 3 – Study S3

Power grid capacities need to increase substantially

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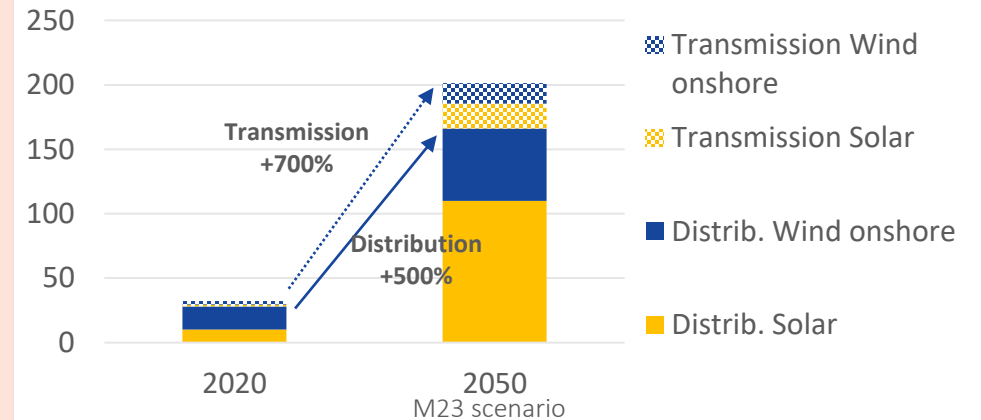
Conviction

- Sub-national **electricity transmission and distribution** networks face **unprecedented challenges**.
- Grid **capacities need to increase substantially** ⇒ smarter and more efficient operation and further grid reinforcement

Uncertainties

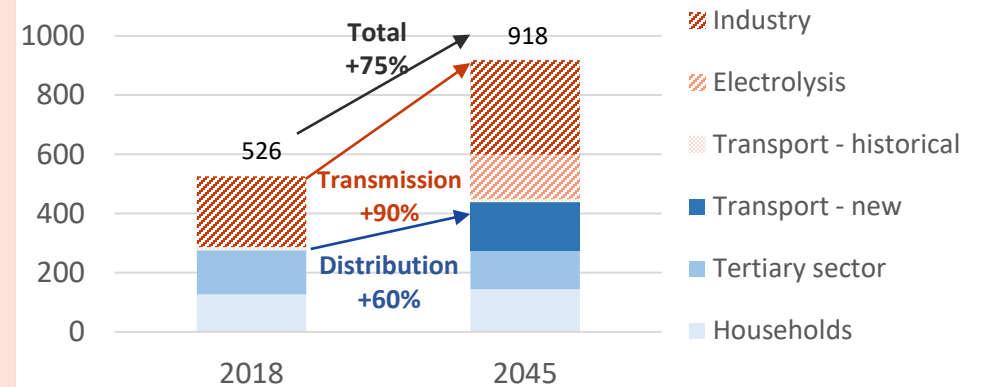
- Role of **operational optimisation** (subject to technological progress) **vs grid reinforcement**

RES capacities by grid connection, FR (GW)



Source: RTE (2021), Futures énergétiques

Power demand by grid connection, DE (TWh)



Source: Agora (2021), KND 2045

A coordinated approach to energy system planning

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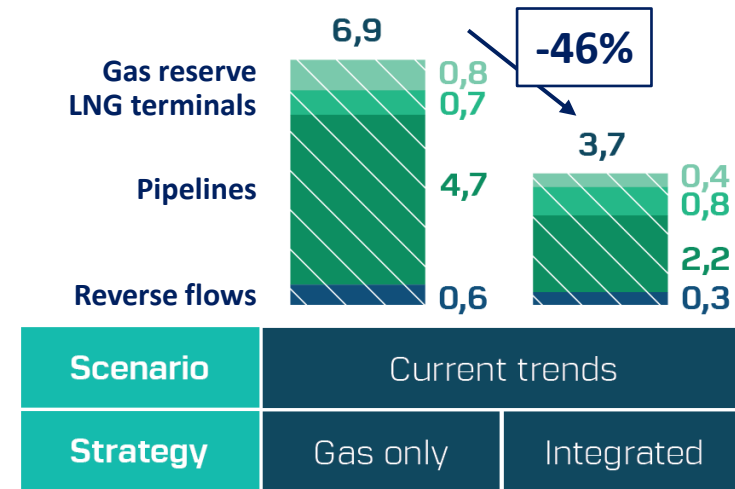
Conviction

- ✦ The **future** energy system and the pathway to get there is to be **designed in a fully coordinated and integrated manner**:
 - ✦ Coordination on **national plans and strategies**
 - ✦ **Network development plans** to cover electricity, gas and hydrogen, the local, national and regional level

Uncertainties

- ✦ **Pan-European H2 network** depends on RES/electrolyser **siting and trade-off** between power lines and H2 pipelines
- ✦ **Repurposing of gas pipelines**
- ✦ Magnitude, origin and form of **hydrogen imports**

Investment and maintenance costs, EU gas system, up to 2050 (bn€)



Source: ECF (2016): A Perspective on Infrastructure and Energy Security in the Transition

Flexibility - a key element of the energy transition

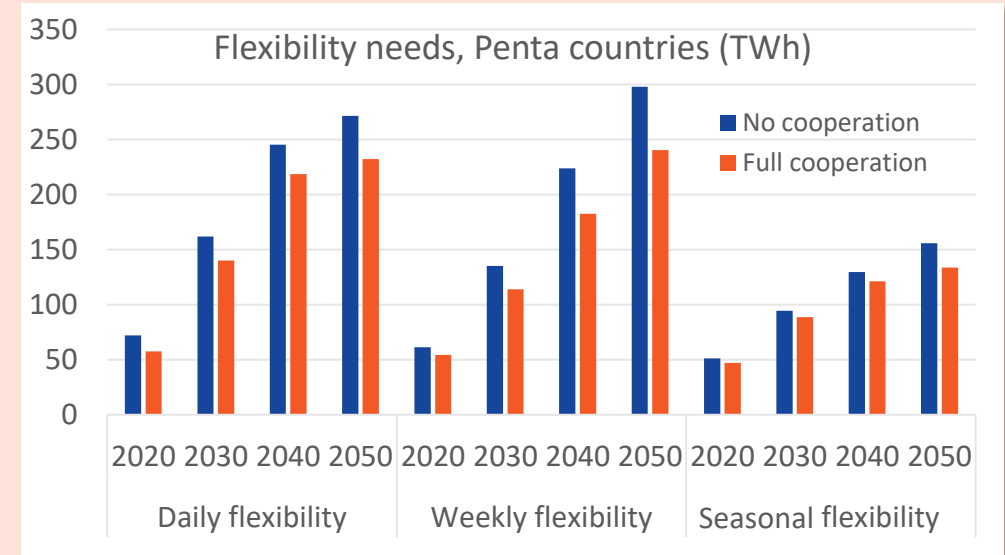


Conviction

- Flexibility needs will significantly increase both on short and long timescales.
- Regional cooperation and enhanced cross-border interconnection may soften the increase.
- Flexibility needs will be met by different technologies

Uncertainties

- Sustainable biomethane vs hydrogen in (peak) power generation
- Need for power-to-gas-to-power (P2G2P) as seasonal storage



Source: Trinomics/Artelys (2023), Penta-Flex study

Additional power demand can and must be flexible

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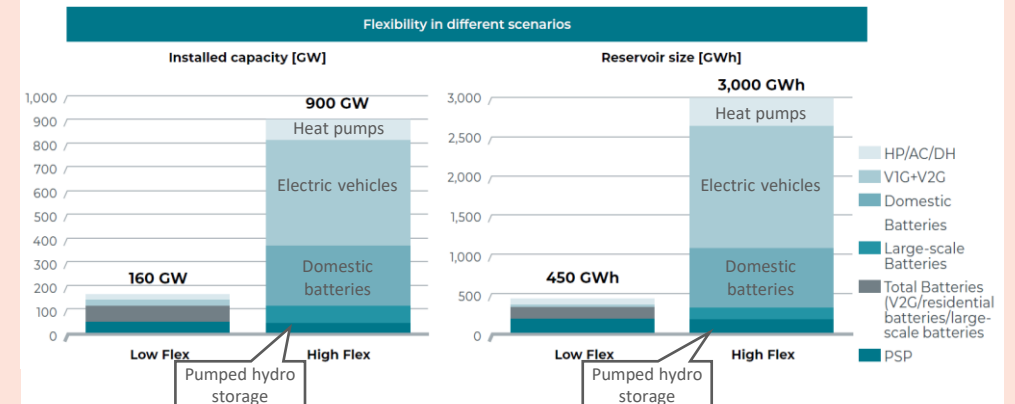
Conviction

- ▮ **Additional electricity demand** from direct/indirect electrification **requires to be flexible**.
- ▮ New electric end-uses (heat pumps, EVs or electrolyzers) but also industrial consumers feature **high demand side flexibility**

Uncertainties

- ▮ Role of **battery electric trucks**
- ▮ **Electrolysers**: flexibility vs profitability

Flexibility sensitivities, Europe, 2050, Elec pathway



Source: Elia (2021), Roadmap to net-zero

Energy storage facilitates RES integration

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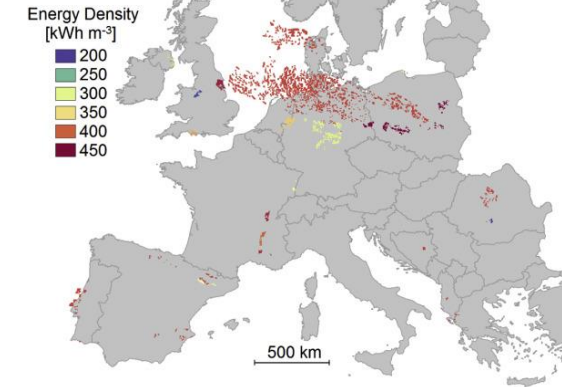
Conviction

- Energy storage (for power, heat, hydrogen) is a key enabler of **RES integration and supply/demand equilibrium**.
- Regional cooperation** facilitates the efficient use of geographically **unevenly distributed** storage potentials

Uncertainties

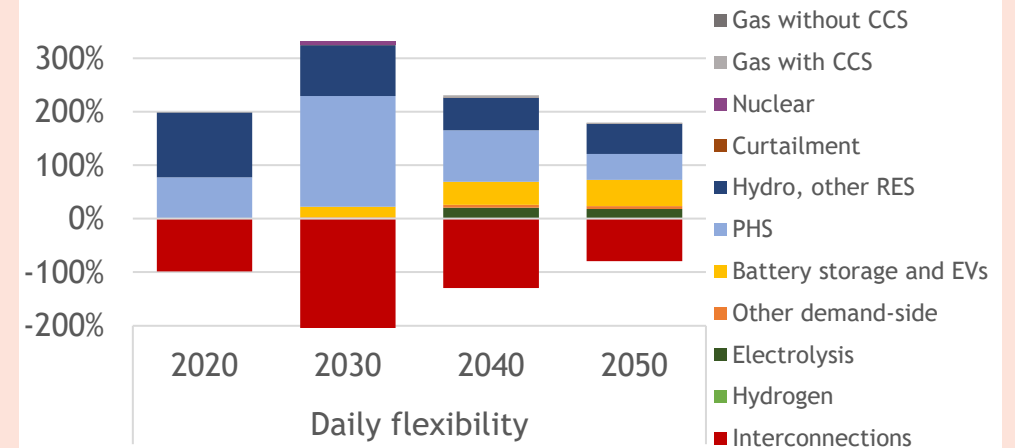
- V2G, electrolyzers** may decrease the need for **stationary batteries**
- Hydrogen storage potentials** (depleted gas fields, aquifers, lined rock caverns)

Hydrogen storage potentials: salt caverns



Source: Guidehouse/GfC (2021), EHB storage

Share of flexibility solutions, CH



Based on Ember (2022), Clean Power Europe 2035

Source: Trinomics/Artelys (2023), Penta-Flex study

The transition requires a future-proof market design

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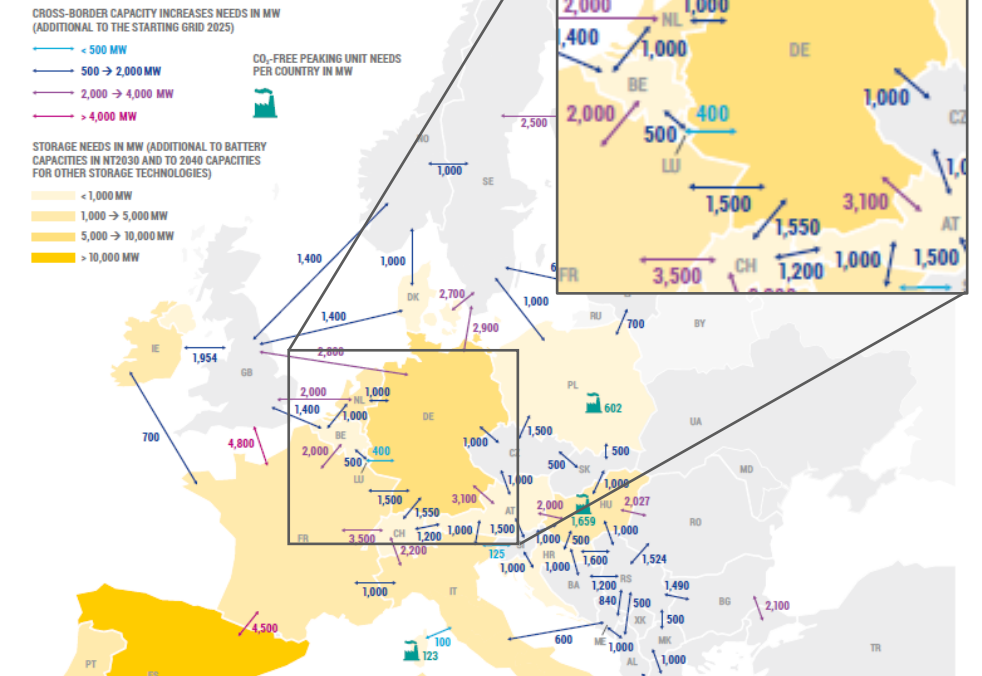
Conviction

- ▣ All these developments require a **future-proof electricity market design** to integrate these technologies in the system and to ensure resource and transmission adequacy.
- ▣ Non-exhaustive list of **fields of action**:
 - ▣ Market areas are to be further interlinked
 - ▣ Provide sufficient investment incentives
 - ▣ Enable the participation of all flexibility sources
 - ▣ Potential reconfiguration of bidding zones

Uncertainties

- ▣ Ability of (continuously) developing an **appropriate market design** that facilitates the transition and that countries are able to stay up-to-date with

Opportunities for increases in cross-border transmission, storage and peaking units capacity in 2040

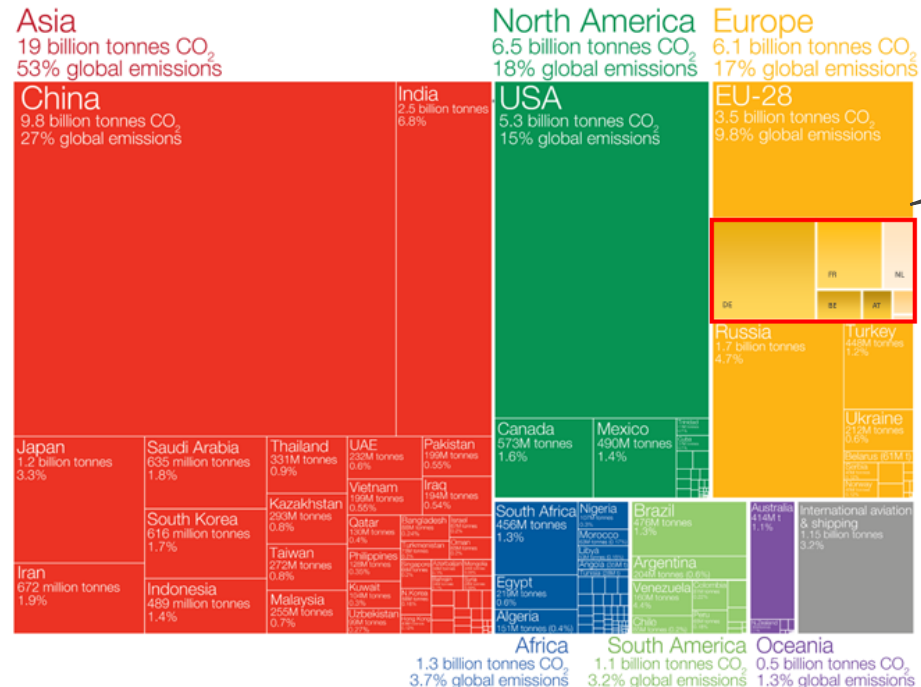


Bottom-line

- There is an **urgency to act**. IPCC, April 2022: “The time for action is now.” Otherwise 1.5°C is beyond reach.
- Power sector decarbonisation** is the key to economy-wide decarbonisation.
- Penta is uniquely positioned** to showcase the compatibility of decarbonisation and economic prosperity
- Regional cooperation & coordination** enables an effective, cost-efficient and sustainable transformation

Who emits the most CO₂?

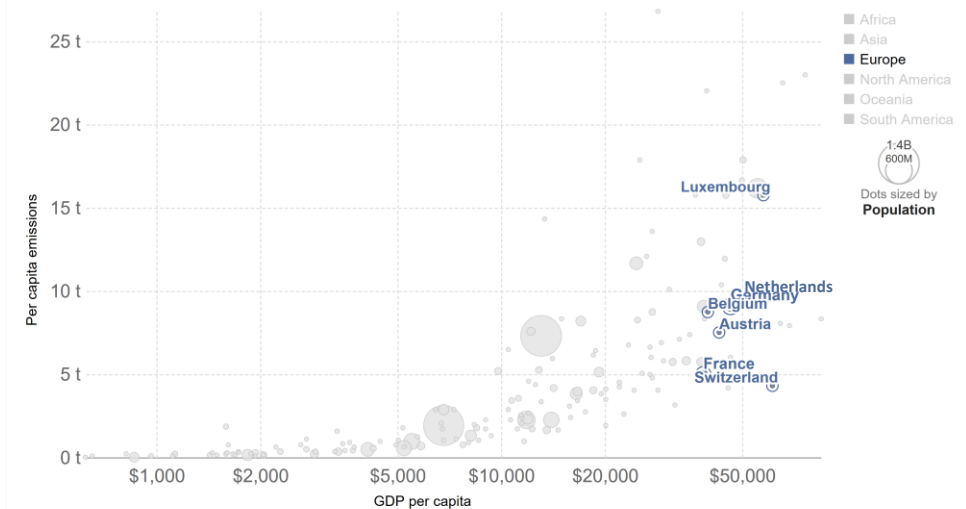
Global carbon dioxide (CO₂) emissions were 36.2 billion tonnes in 2017.



Source: Our world in data (2022)

CO₂ emissions per capita vs GDP per capita, 2018

This measures CO₂ emissions from fossil fuels and industry¹ only – land use change is not included.



Source: Our World in Data based on the Global Carbon Project; Maddison Project Database 2020 (Bolt and van Zanden, 2020)

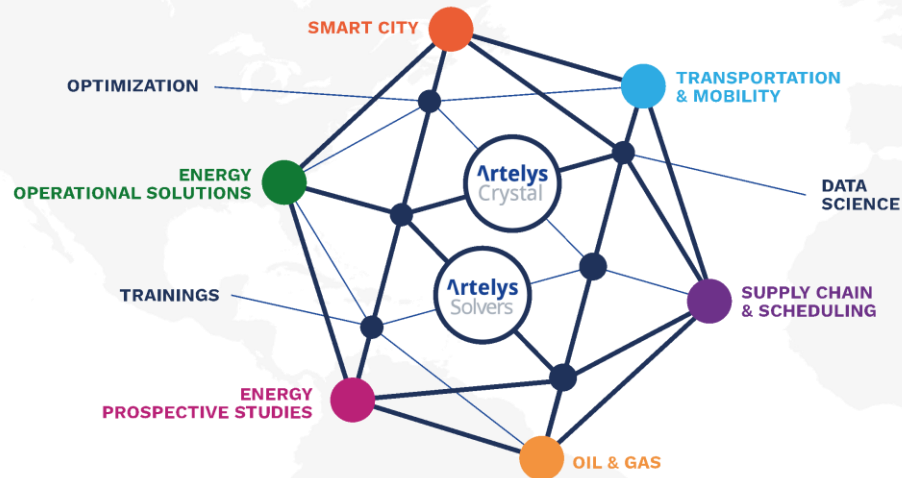
Note: GDP figures are adjusted for inflation.

OurWorldInData.org/co2-and-other-greenhouse-gas-emissions/ • CC BY

1. Fossil emissions: Fossil emissions measure the quantity of carbon dioxide (CO₂) emitted from the burning of fossil fuels, and directly from industrial processes such as cement and steel production. Fossil CO₂ includes emissions from coal, oil, gas, flaring, cement, steel, and other industrial processes. Fossil emissions do not include land use change, deforestation, soils, or vegetation.

Source: Our world in data (2022)

Thank you for your attention.



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