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ETIP SNET
EUROPEAN TECHNOLOGY AND INNOVATION PLATFORM SMART NETWORKS FOR ENERGY TRANSITION

Flexible generation in a low-carbon RES dominated energy system

Christian Bergins,
Georgios C. Christoforidis,
Peter Stettner

ETIP SNET Working Group 3 « Flexible Generation »

30th June 2020,
Webinar

ETIP SNET

Scope

What you will be presented:

1. About ETIP SNET and the Working Group “Flexible Generation”
2. Starting point: Where are we today in Europe?
3. Evaluation of energy sources and conversion systems with regard to dispatchability
4. Integration of short, mid, and long term energy storage in flexible generation
5. Decarbonised “green” fuels: thermal power generation, co-generation; energy-intensive industries; transportation sector
6. How does the decarbonised future look like?

Webinar preparation task force

Members of WG3 preparation task force (in alphabetical order):

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Speakers

Today's speakers (in presenting order):

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Agenda

1. **About ETIP SNET and the Working Group "Flexible Generation"**
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From a fragmented EU advisory to an integrated framework

EEGI EUROPEAN ELECTRICITY GRID INITIATIVE

GRID+

GRID+ STORAGE

SMARTGRIDS

« European Technology and Innovation Platform

Smart Networks for Energy Transition »...

ETIP SNET
EUROPEAN TECHNOLOGY AND INNOVATION PLATFORM
SMART NETWORKS FOR ENERGY TRANSITION

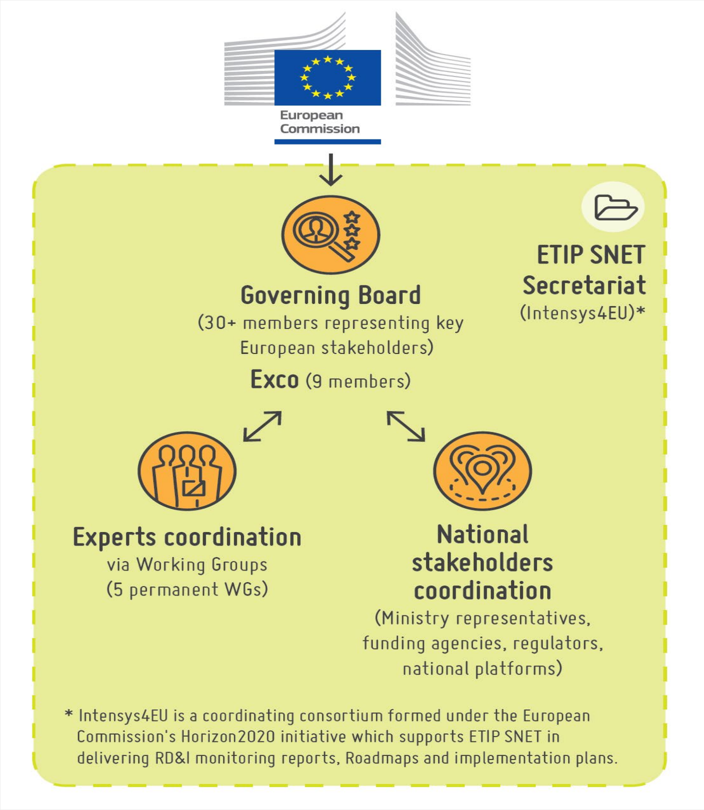
... addresses the innovation challenges in energy system and market evolution necessary for achieving climate protection and renewables integration with affordability and security of supply

... beyond smart electricity grids

ETIP SNET's mission

- **Set-out a vision for RD&I for Smart Networks for Energy Transition** and engage stakeholders in this vision.
- **Prepare and update the Strategic Research and Innovation Roadmap**.
- Report on the **implementation of RD&I activities at European, national/regional and industrial** levels.
- Provide **input to the SET Plan action 4** which addresses the technical challenges raised by the transformation of the energy system.
- **Identify innovation barriers**, notably related to regulation and financing.
- Develop enhanced knowledge-sharing mechanisms that **help bring RD&I results to deployment**.
- Prepare **consolidated stakeholder views** on Research and Innovation to European Energy Policy initiatives.

ETIP SNET's organisation



WG1
Reliable, economic and efficient smart grid system

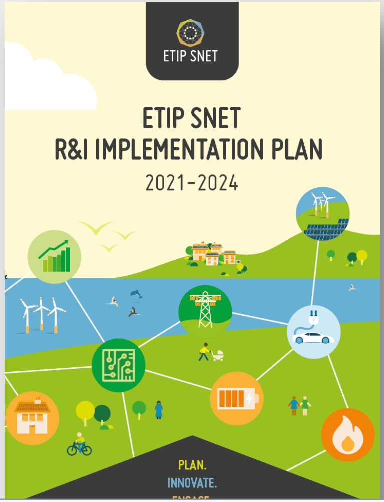
WG2
Storage technologies and sector interfaces

WG3
Flexible Generation

WG4
Digitisation of the electricity system and customer participation

WG5
Innovation implementation in the business environment

Vision 2050, Implementation Plan and WG3 – White Paper



Vision 2050 download here

Published in July 2018

The Vision: a low-carbon, secure, reliable, resilient, accessible, cost-efficient and market based **pan-European integrated energy system** supplying the whole economy and paving the way for a **fully CO2-neutral and circular economy by the year 2050**.

White Paper: Flexible Power Generation in a Decarbonised Europe

Published in March 2020

Defining the position of available and new power conversion technologies to meet all requirements of on-demand renewable power generation to all end-user sectors without any limitations.

download here

Implementation Plan 2021 - 2024

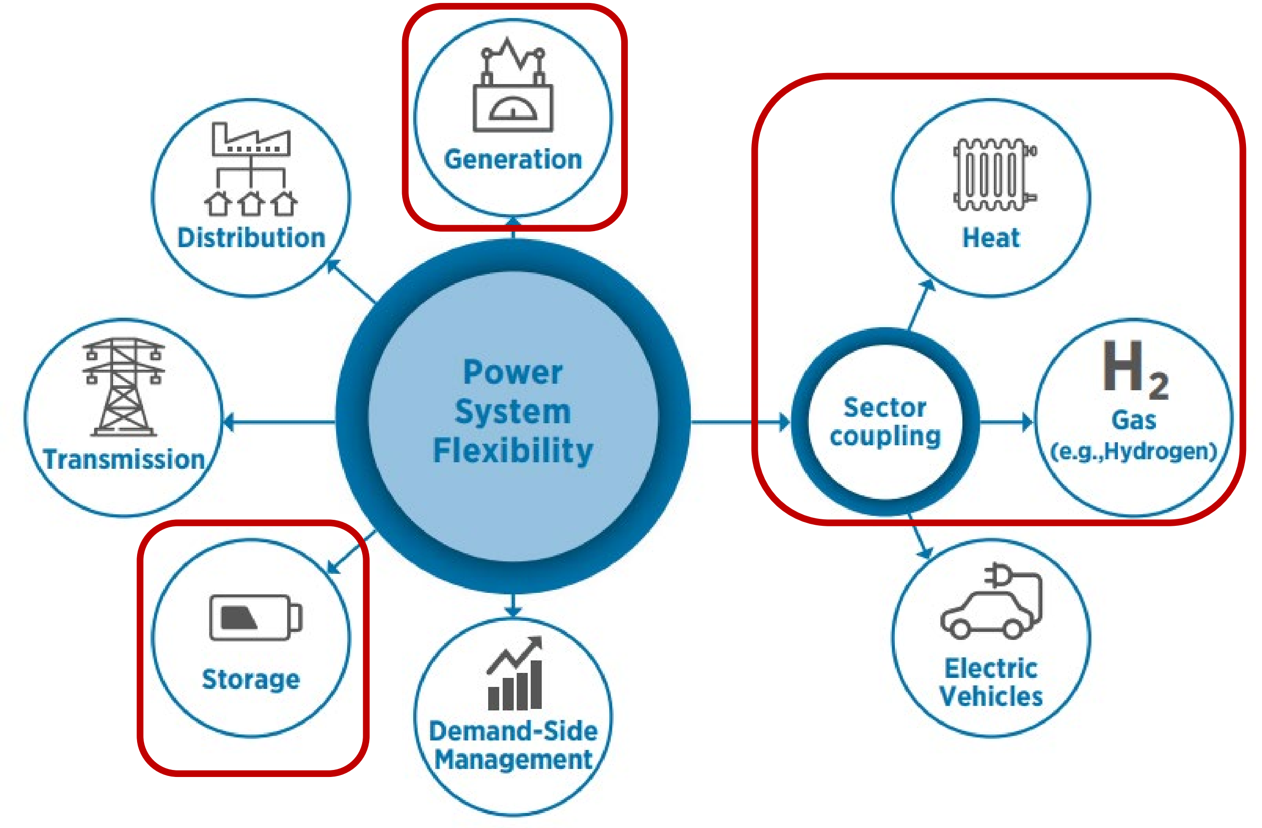
Published in May 2020

download here

describes the **required R&I activities that must be performed by 2024** in order of priority. 24 topics have been proposed and are based on the 6 Research-Areas These topic descriptions intend to **serve as a basis for the (co-funded) R&I projects to be launched in the coming four years..**

Flexibility in the energy sector

Addressed enablers



Source:IRENA (2018), Power System Flexibility for the Energy Transition, Part 1: Overview for policy makers.

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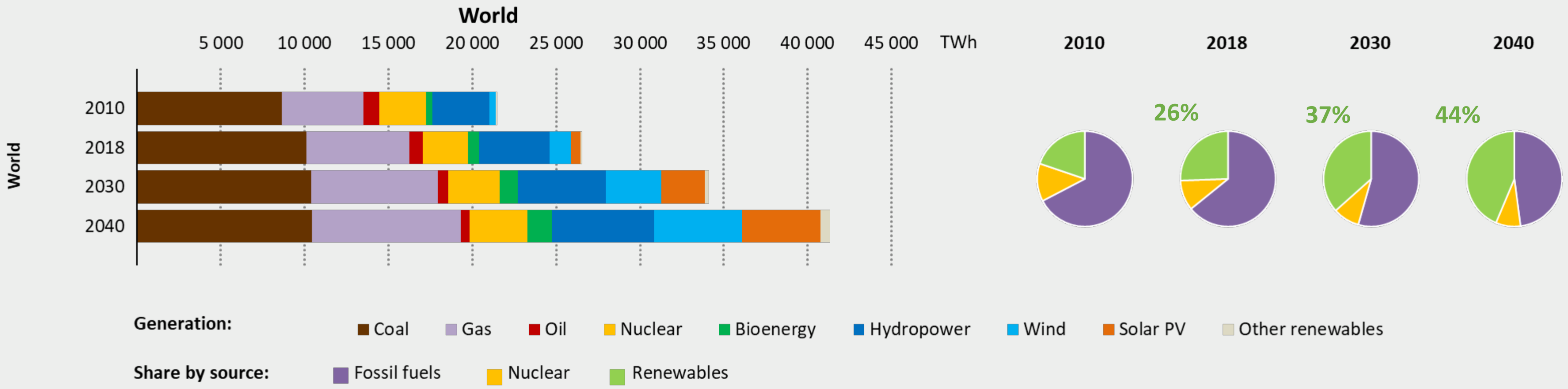
Electricity Generation Status and Outlook - Worldwide

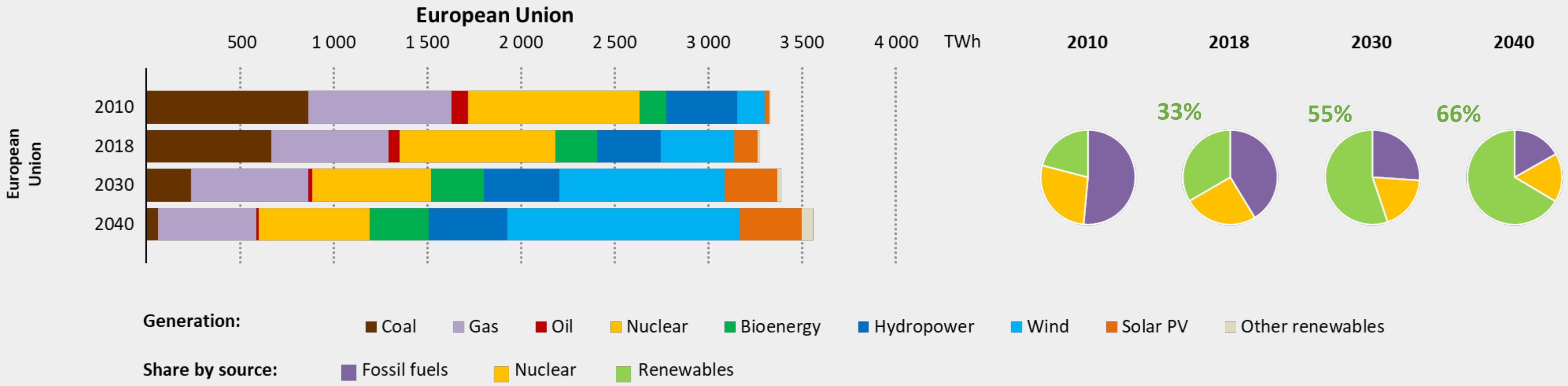


The **Stated Policies Scenario** reflects the impact of existing **policy** frameworks and today's announced **policy** intentions.

The Stated Policies Scenario is neither sustainable nor able to fulfill Paris climate targets !

Source: IEA, World Energy Outlook 2019; Figures for Stated Policy Scenario

Electricity Generation Status and Outlook - EU



Even in Europe this Scenario would not be enough !

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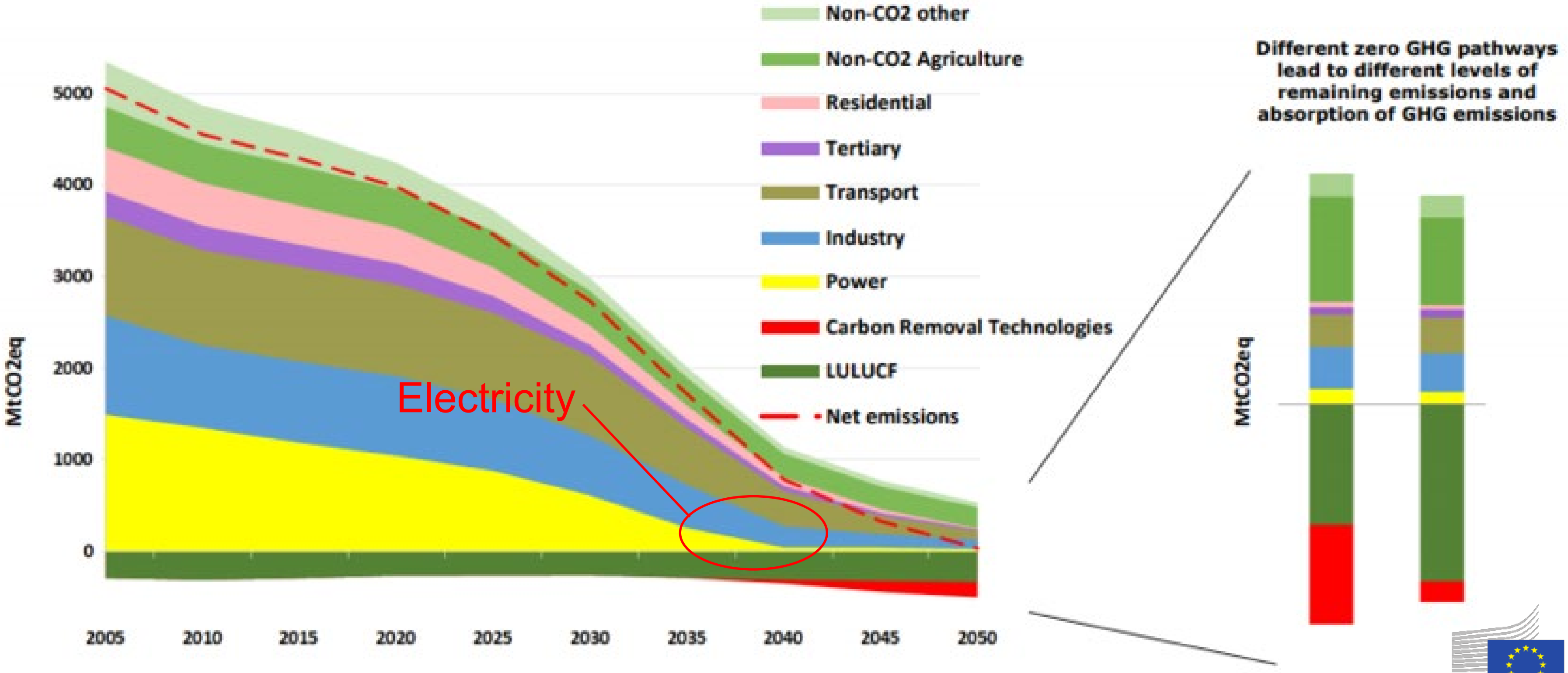
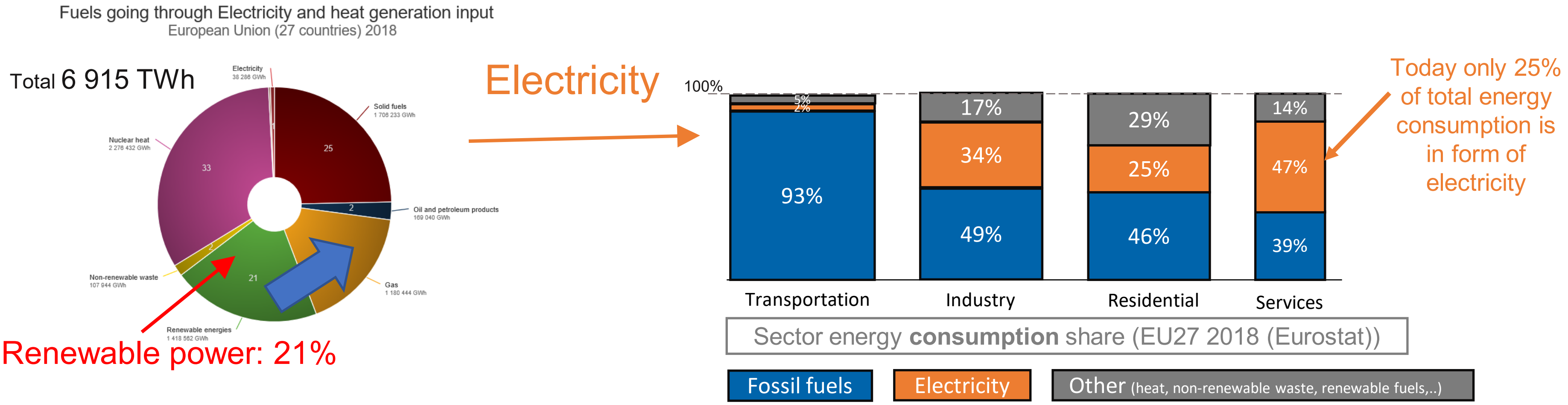
Vision of a clean Europe by 2050



GHG emissions trajectory in a 1.5°C scenario. Source: European Commission – "A Clean Planet for All", COM(2018) 773, Nov. 28, 2018

European Commission

Total primary energy consumption: Where we have to decarbonize



Decarbonization necessary by

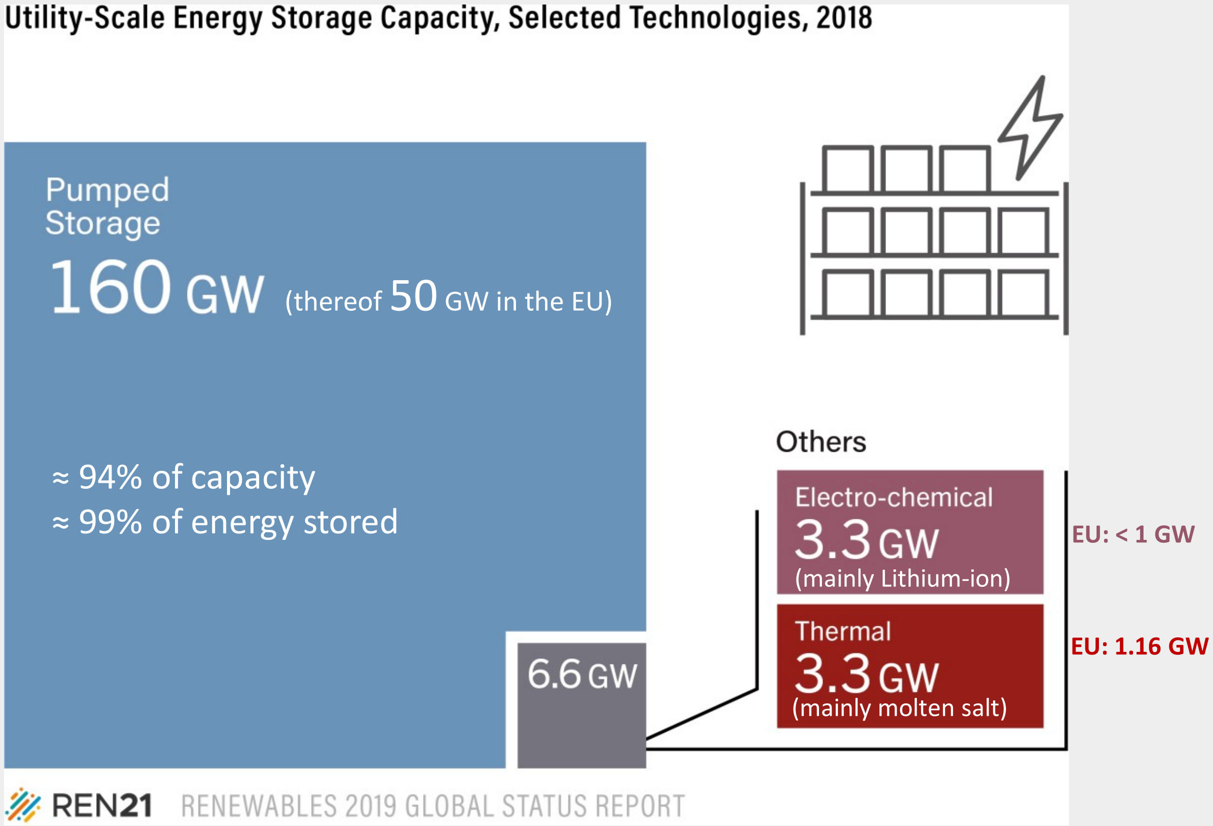
- Increased renewable power generation

but also by

- Electrification
- and substitution of fossil fuels by synthetic fuels, biofuels and hydrogen

in all sectors

Pumped storage dominant for utility-scale energy storage / Worldwide and EU



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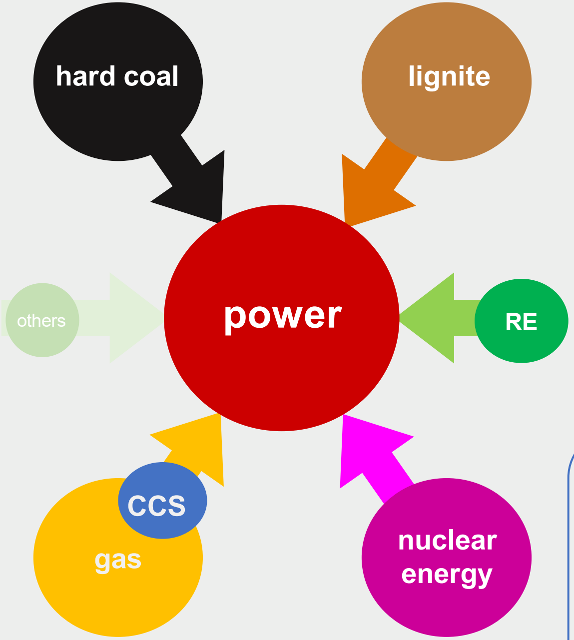
Primary Energy Sources for power and heat

Large share of RES expected, and mostly VRES!

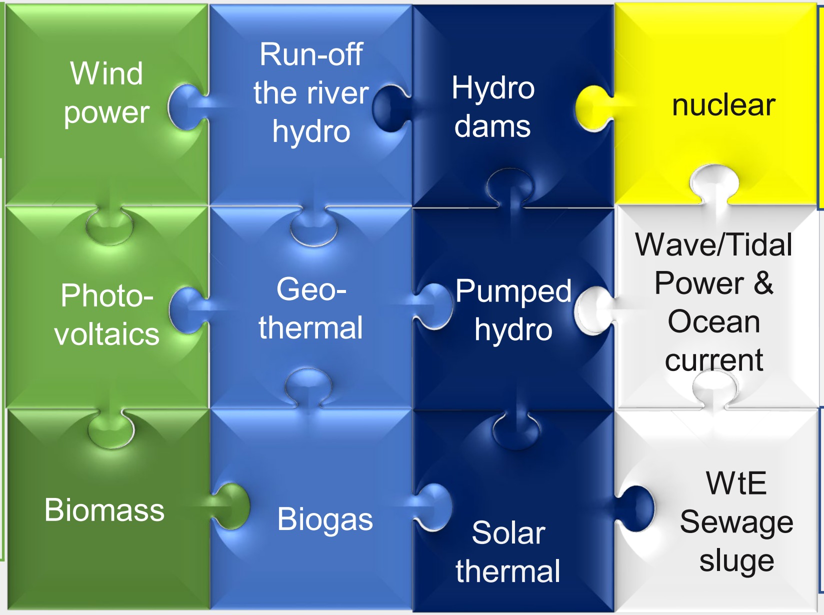


Expecting more than 80% of electricity coming from RES in 2050 – or 50-60% of gross energy consumption

Primary Energy Sources for power and heat

High potential (TW scale) for large scale deployment

- Intermittent/ variable
- Predictability only on daily / weekly basis
- Especially rooftop PV & offshore wind have high potential



Questionable in many EU countries

Restrictions in maturity / environmental aspects

Must-run capacity (for hygienic reasons)

Limited resource but excellent storability

Reasonable Potential (multi GW)

- Baseload with low demand response / small storage capability

Reasonable Potential (multi GW / GWh to TWh)

- Dedicated to storage /storage capability
- Reasonable limitations by geology, geography & permitting

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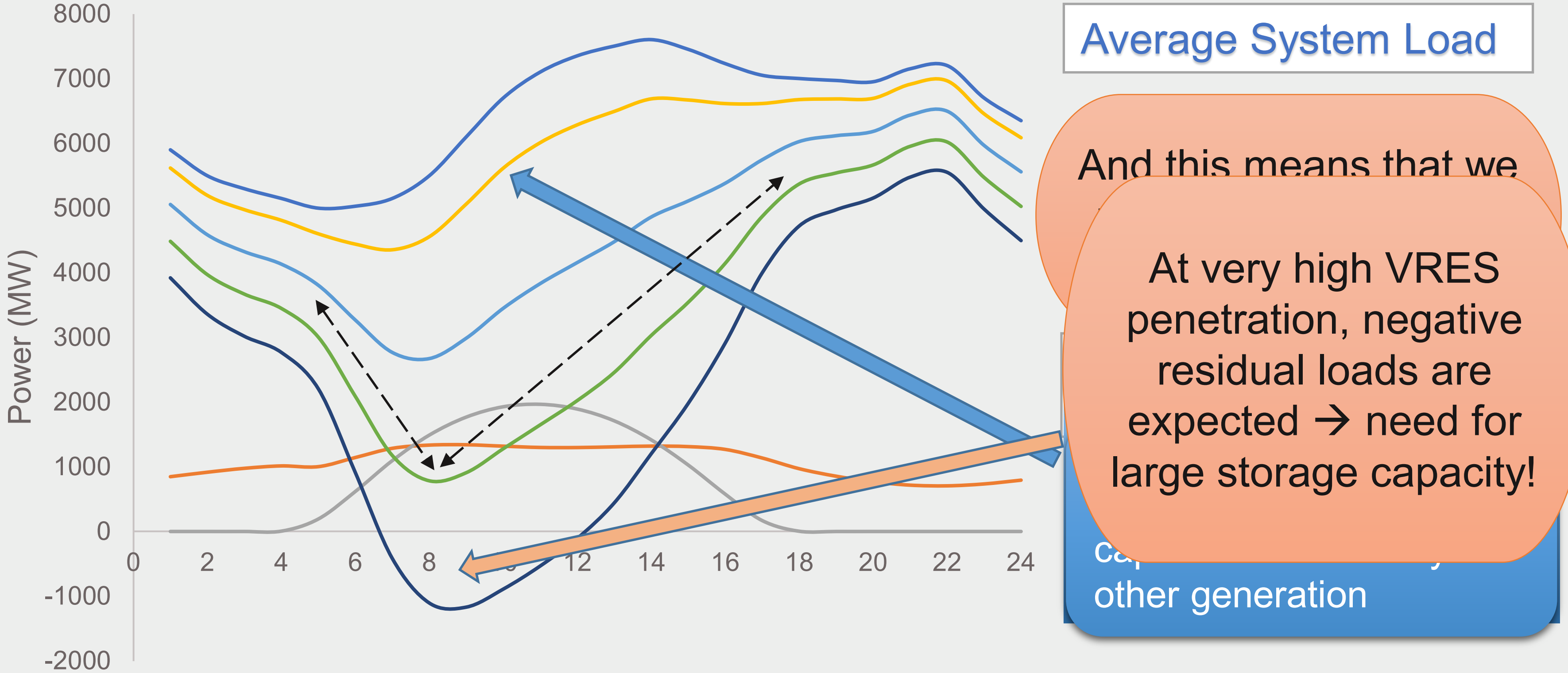
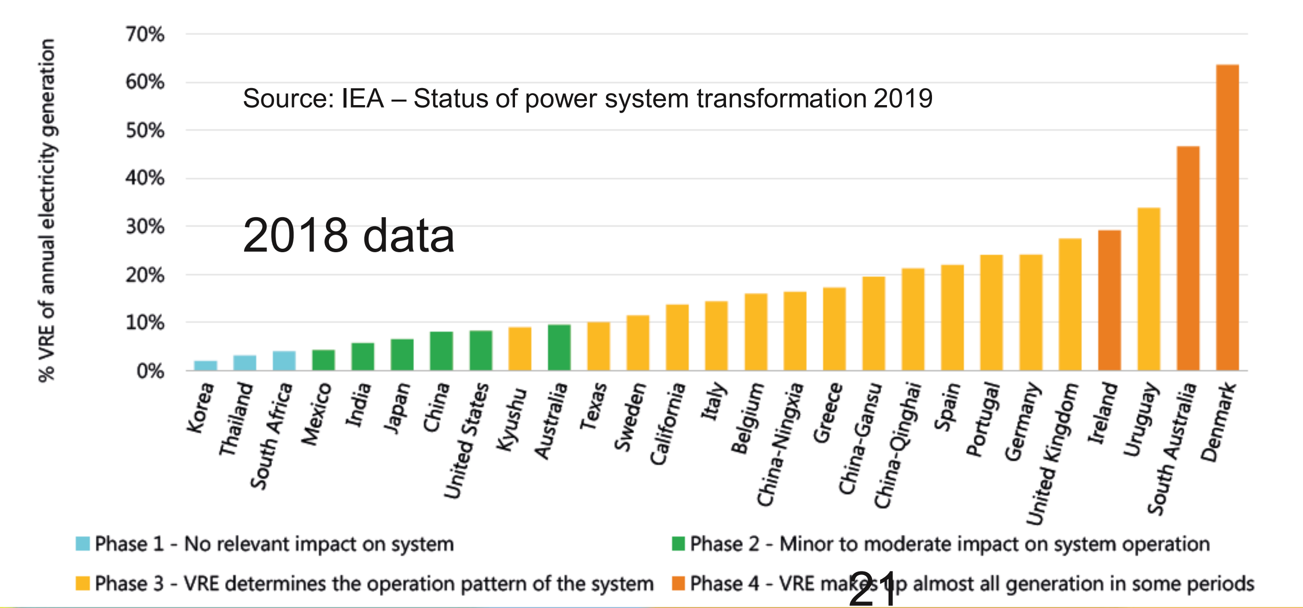
At a system level



At very high VRES penetration, negative residual loads are expected → need for large storage capacity!

Status of VRES penetration

Certain countries already with very high VRES share in the electricity sector



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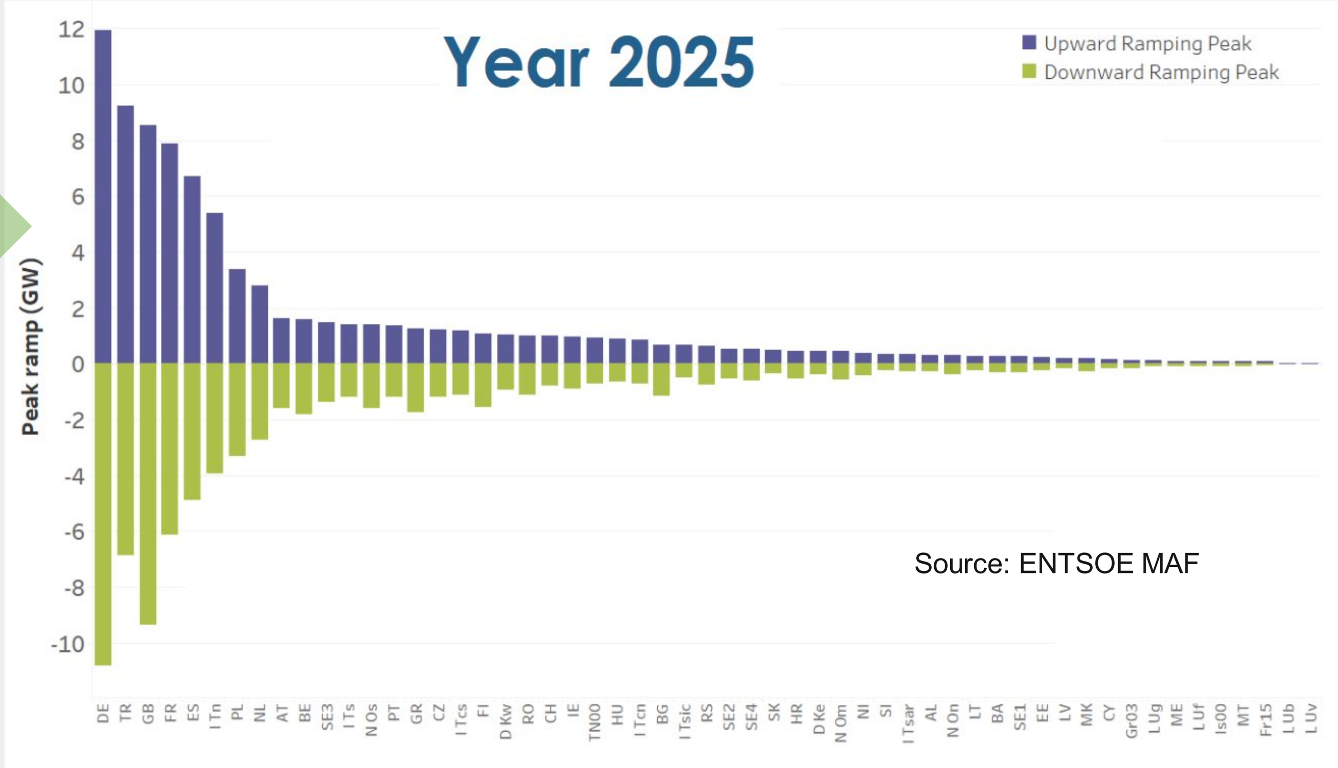
Flexibility needs in Europe

The expected increase in VRES shares will result in higher flexibility needs in Europe



Source: ENTSOE MAF

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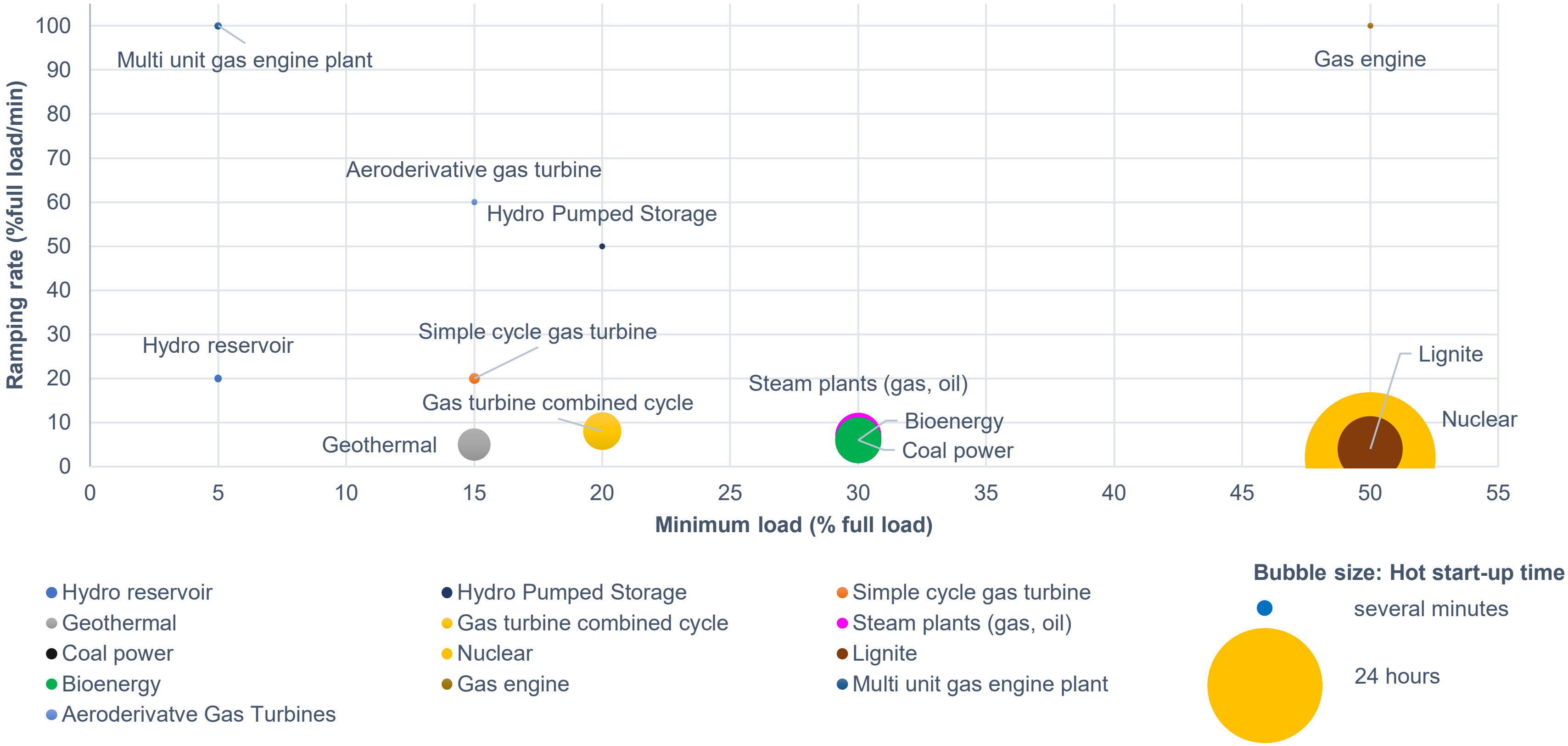
The *Flexibility* concept for power plants

- **Operational Flexibility:** Significantly improved last decade for thermal/hydro plants
  - Reduced minimum loads of generators/turbines
  - Quick starting
  - Fast ramp rates
  - Black-start capability
  - Challenges: Material stress and wear due to cycling / efficiency of part-loading
- **Fuel Flexibility:** To be able to operate with different fuels or mixtures
  - Retrofitting of existing power generation / or new equipment
  - Challenge to include hydrogen and mixing of different fuels at various qualities (e.g. natural gas/hydrogen mix)

Operational flexibility characteristics of power generation technologies



Generalised evaluation of energy sources with regard to flexibility

Technology	fuel flexibillty	load flexibility characteristics
Fuel cells	PEMFC/PAFC (w/o reforming): limited to H2 SOFC: gaseous (incl. H2), liquid, high-and low calorific fuels,	(PEM/SOFC) dispatchability ++/- fast load change ++/- frequency support ++/-
Gas turbine based (GT/CCPP)	**Yes:** gaseous (incl. H2), liquid, high-and low calorific fuels	dispatchability ++ fast load change + frequency support ++
Reciprocating	**Yes:** gaseous (incl. H2), liquid, high-and low calorific fuels	dispatchability ++ fast load change ++ frequency support +
Hydro turbines	**No** (Water only)	dispatchability + fast load change + frequency support ++
Thermal Plants	**Yes:** gaseous, liquid, solid, nuclear, waste, geothermal, concentrated solar	dispatchability O fast load change -- frequency support ++
Solar photovoltaic	**No** (Sun)	dispatchability -- fast load change O frequency support --
Wind energy based	No (Air)	dispatchability -- load change -- frequency support O

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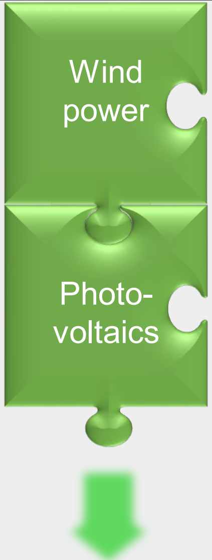
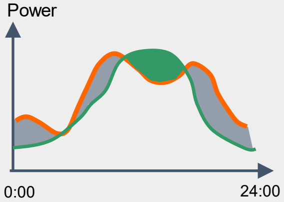
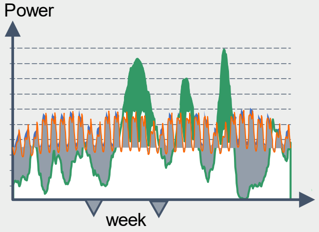
Residual load and future RES (Germany)



Need to think about how thousands of TWh in EU can be stored seasonally and transported

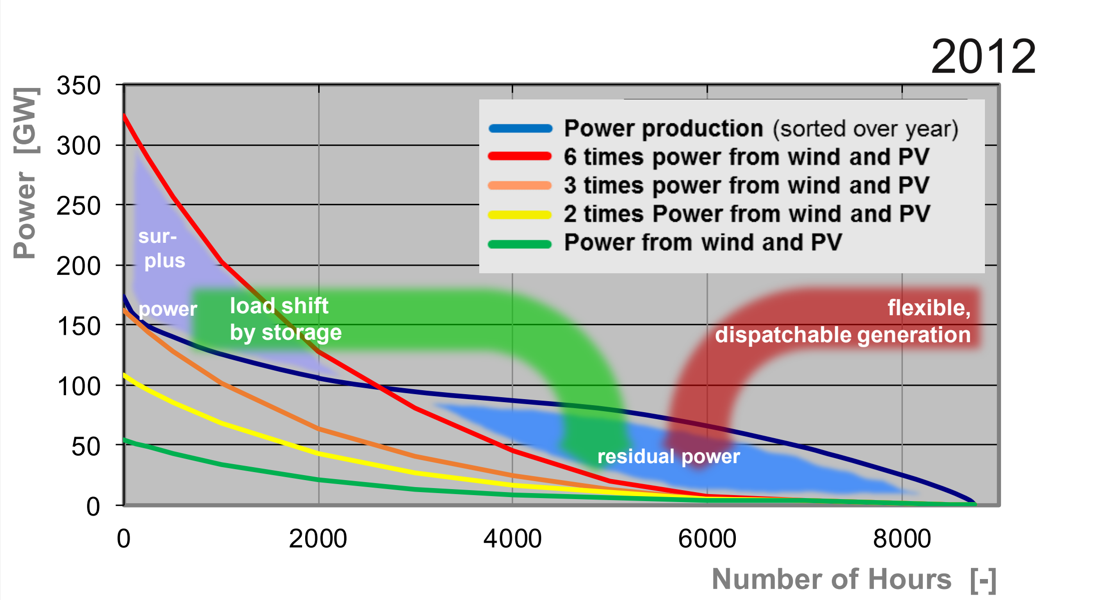




Problem of power production at the „wrong“ time

generation

storage



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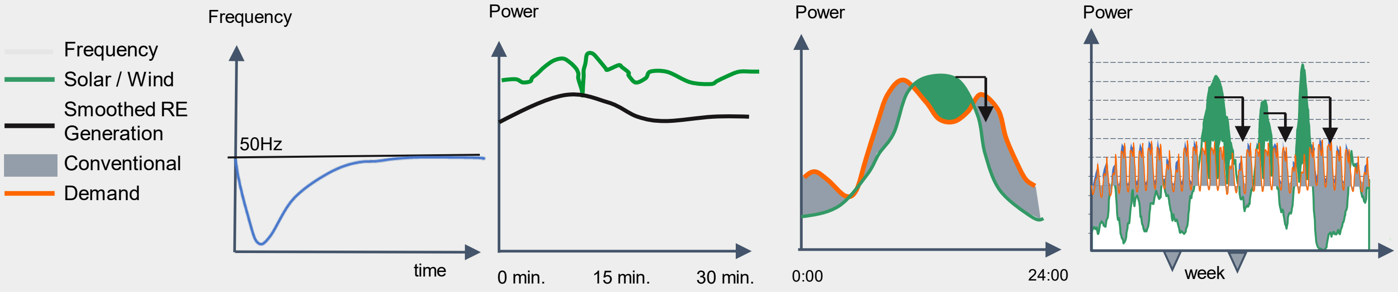
Storage is about balancing production and consumption on different times

Applications	Power System Stability	Capacity Firming	Time shift	Energy Reserve



Storage time	Sec - min	Intra-Hour	Intra-Day	Week+
Relevance	Near term ↗	Today ↗	Today ↑	Long term ↑↑

Large Scale Electricity Storage

CSP & Molten Salt

50MW/350 MWh

Battery
150MW/200MWh

Pumped Hydro
GW/GWh scale

Hydro dams
GW / TWh scale

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Large Scale Electricity Storage

LAES, Liquid Air Energy Storage

CAES, Compressed Air Energy Storage

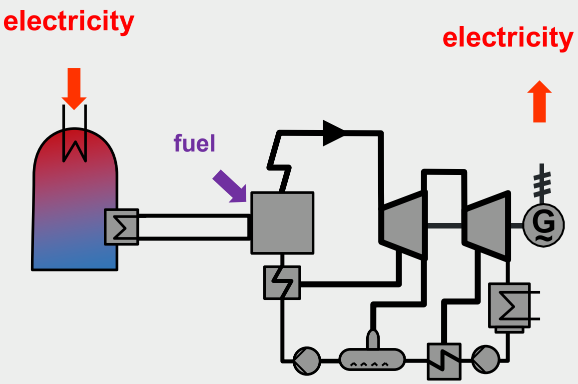
- Electricity Storage & fuel based peaker plant (different variants)
- >100MWel scale, GWh storage
- Stand-alone or integrated in (existing) power plants

Storage efficiency 50-60% & fuel efficiency up to 90%

High temperature heat storage

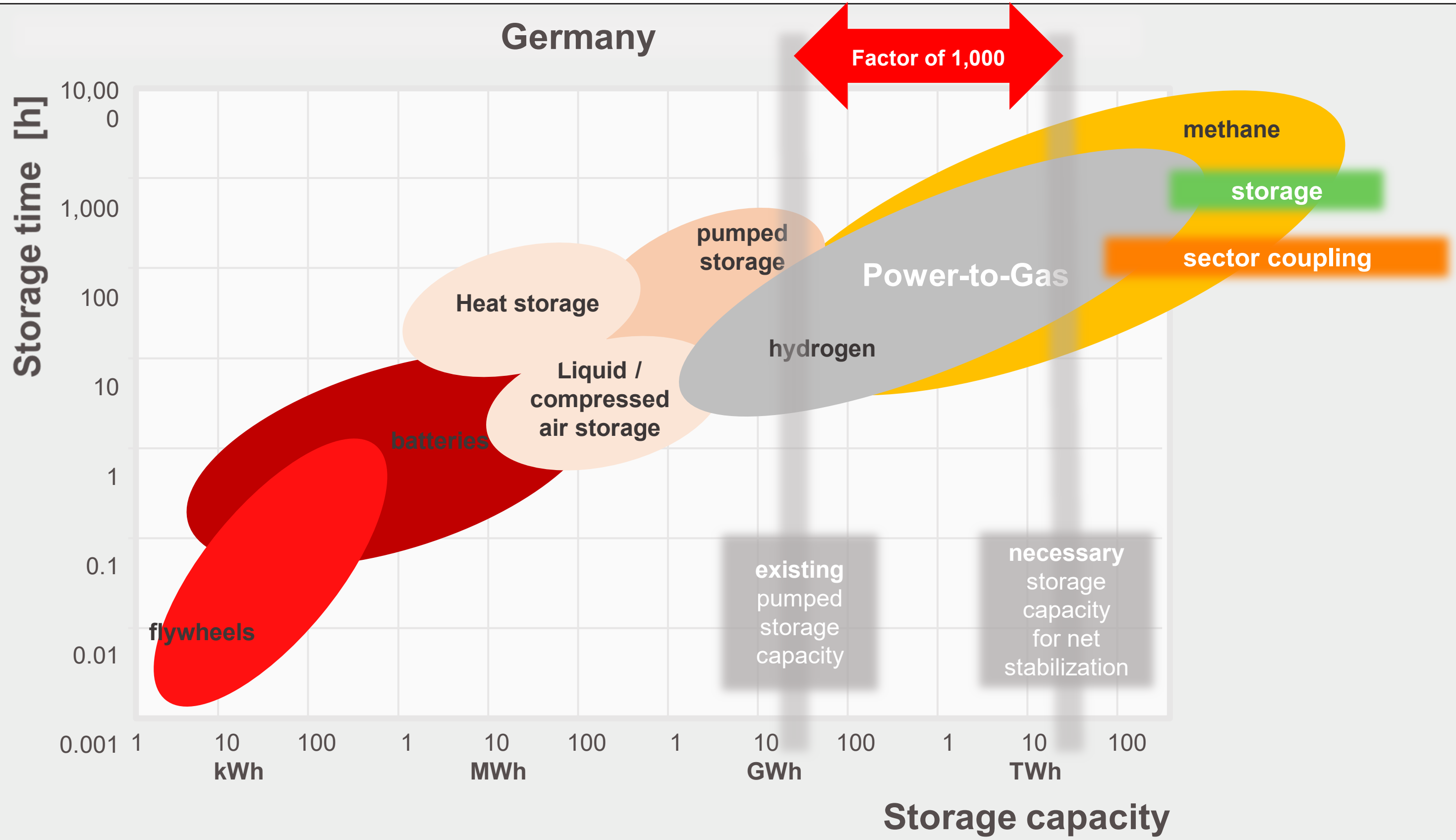
- Electricity Storage & fuel based peak plant (different variants)
- >100MWel scale, GWh storage
- Solid material or salt heat storage

Storage efficiency 40-45%



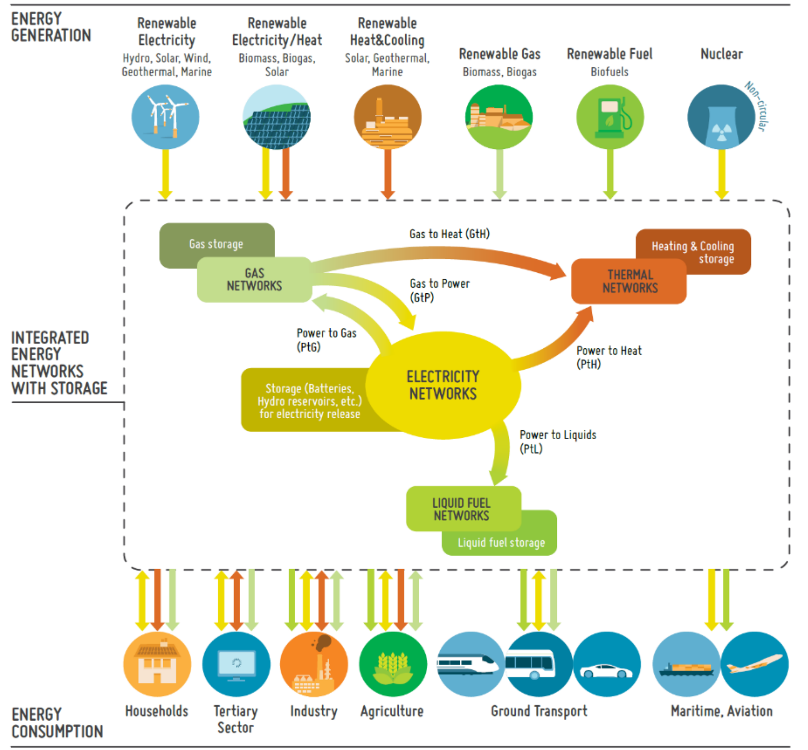
Storage – capacities and periods

Suitable technologies for the situation in Germany

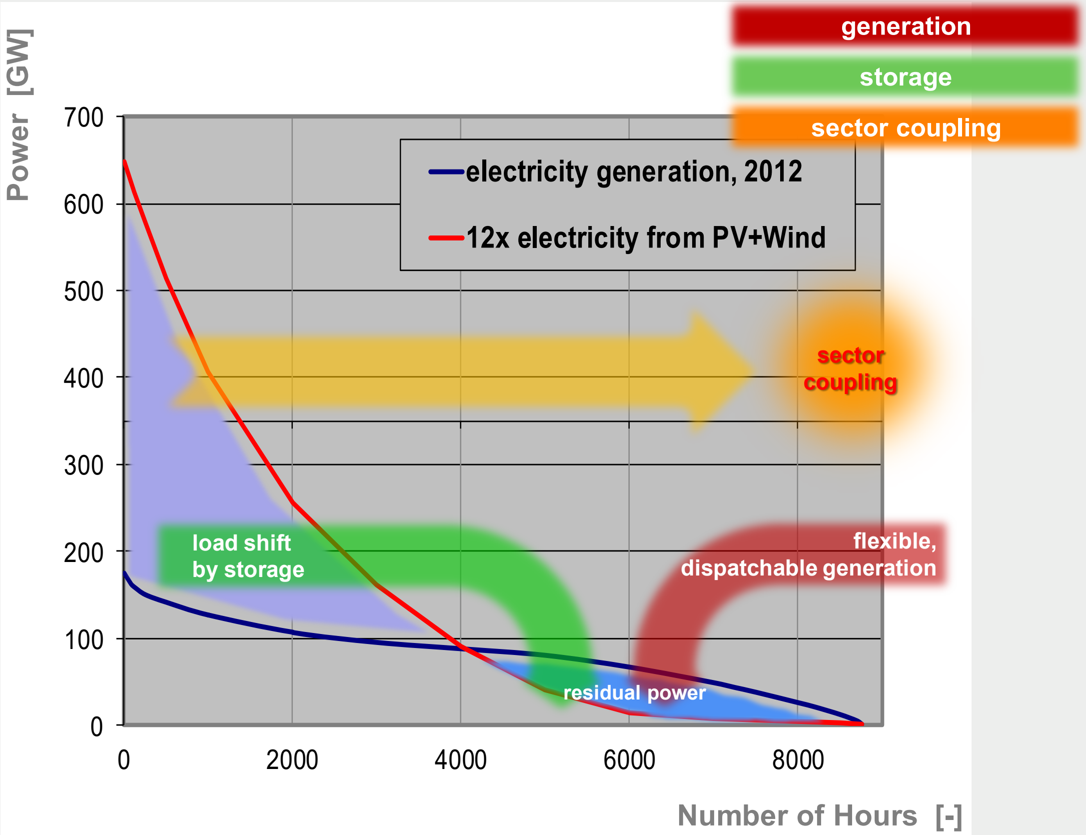


K. Görner: Sector Coupling as a Chance of Power Generation, Trends 2017, Aachen

Replacement of fossil fuels by electrification & sector coupling



Integrated energy networks with storage interacts with all sectors



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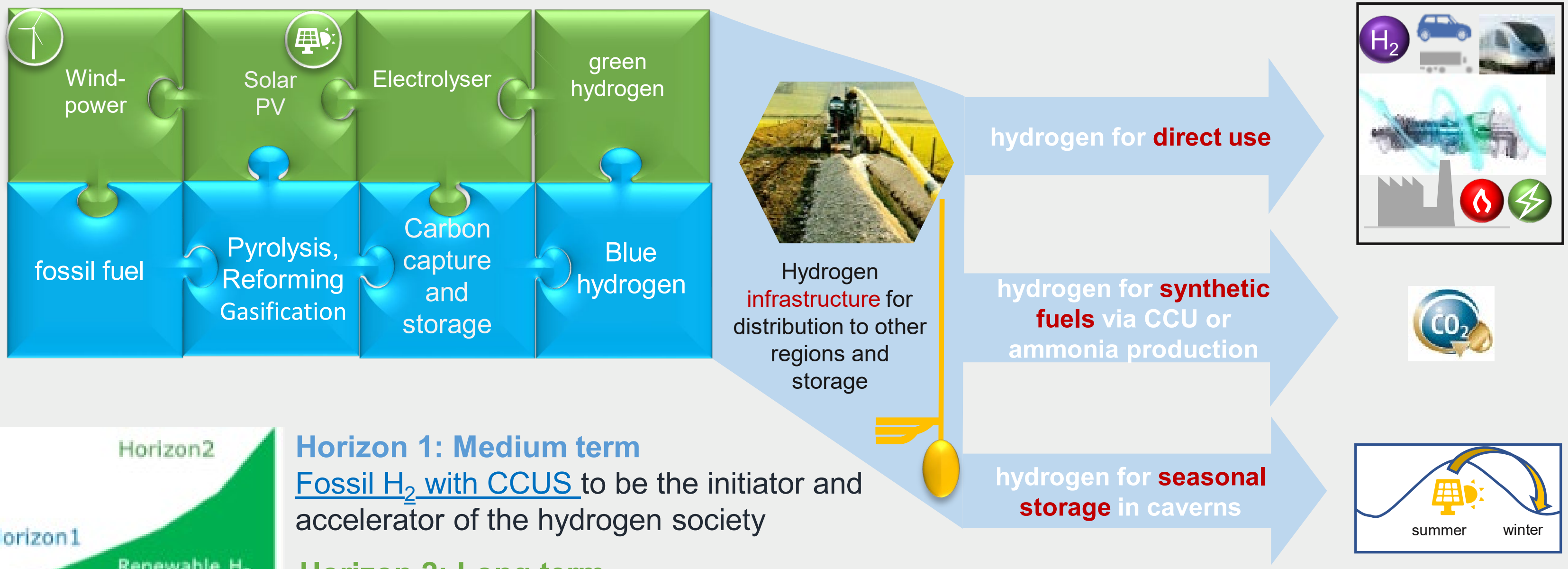
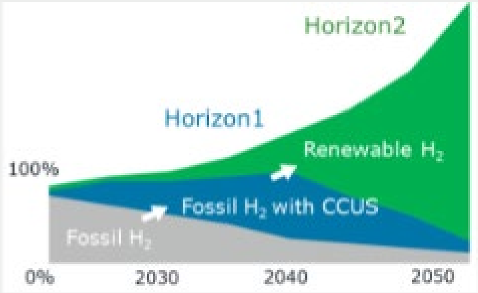
Green and blue hydrogen as key enabler to meet decarbonisation targets





Horizon 1: Medium term

Fossil H_2 with CCUS to be the initiator and accelerator of the hydrogen society

Horizon 2: Long term

Renewable H_2 to become dominant through successive /disruptive innovation & significant cost reduction

CCUS: carbon capture, utilisation & storage

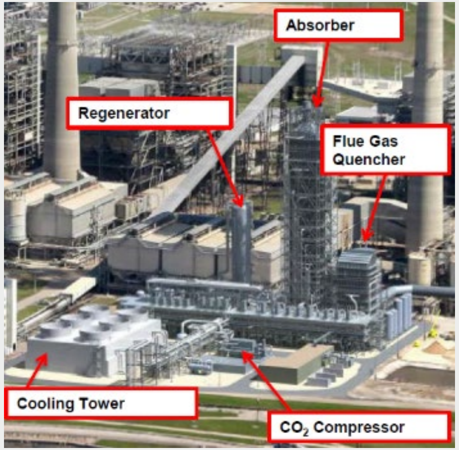
Carbon Capture and Utilization (CCU) Carbon Capture and Storage (CCS)

Up to 670 Million t of CO_2 per year required for EU chemical and fuel production until 2050*.
Carbon Capture and Utilisation (CCU) is a flexible solution for to store RES electricity and produce fuels/chemicals

Bioenergy CCS (BECSS) to create negative emissions is under consideration in UK, Scandinavia to enable compensation for industries, sectors which are hard to decarbonise

[BMBF]

Carbon Capture Works!
"Petra Nova": The world's largest CO2 capture plant
Capacity: 4776 t CO2 /d



Courtesy: Mitsubishi Heavy Industry, MHPSE 2018

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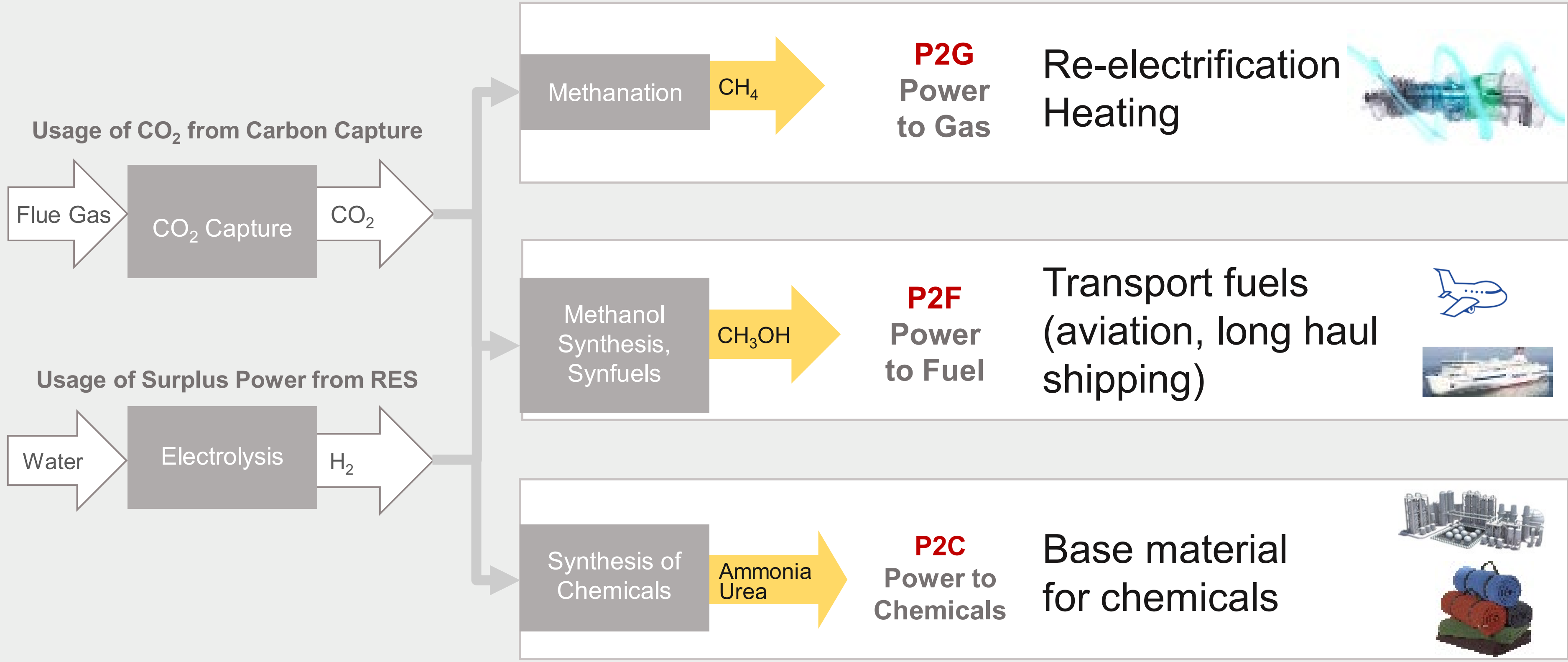
PtX Technologies: CCU, Carbon Capture & Utilisation



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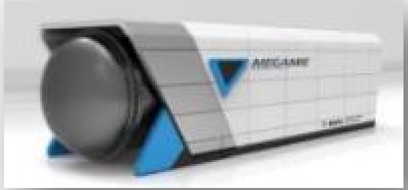
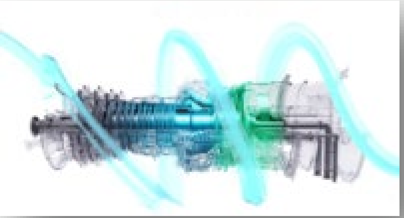
Power & Heat based on low carbon fuels

		max. electric efficiency	max. fuel efficiency
	(Solid Oxide) Fuel Cell kW to 1 MW scale*	45-55%	↑
	Gas engines kW to 10 MW* scale	40-49%	70-90%
	Gas turbine combined cycle power plants small to large MW scale (up to >800MWel*)	55-63%	↓

* single unit

Efficiencies depend on scale and technical optimisation / specific cost

Power & Heat based on low carbon fuels

- Hydrogen directly can be burnt in gas engines, gas turbines, fuel cells (Substitute of NG)
- Ammonia can be used as energy carrier for long distance transport
- Splitting Ammonia to *hydrogen+nitrogen* allows direct use in combustion
- Combustion systems for 100% hydrogen are under development towards 2025-2030

- **100% Hydrogen Conversion Project**
  - Magnum PP, 440MW NG CCG, Groningen, NL
  - Led by Nuon/Vattenfall, Equinor and Gasunie
  - To reduce CO_2 emission by 1.3 million t/y in 2025
- **The project will prove the principle "hydrogen readiness" of existing/new assets!**

Past fuel switches: Coal to NG

- Municipality of Kiel, Germany

- ➢ 20 x 9.5 MW GAS ENGINES
  Replacing old coal boiler
- ➢ 190.4 MW plant net electric output
- ➢ 191.8 MW thermal output
- ➢ Highly flexible operation
- ➢ 5 min. start up time
- ➢ 4 MW minimum stable load

- Oeresundsverket, Malmö, Sweden

- ➢ New 447 MW Combined Cycle Power Plant
  Build in existing (protected) building
- ➢ up to 250 MWth heat extraction
- ➢ Replacing coal boiler
- ➢ Serving Malmö heating grid

- ▪ Up to 90% fuel efficiency with gas engines and gas turbines
- ▪ > 70% CO2 reduction
- ▪ Flexible operation

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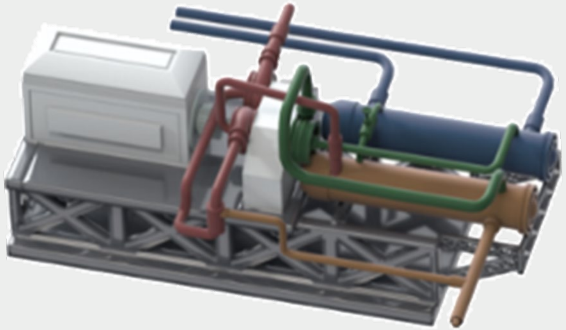
Flexible generation coupled with Power to Heat & Heat storage

1. Industrial scale high temperature heat pump technology, multi MW scale

- heat for heating grids
- steam for industrial use



Heat sources
- Sea, rivers, air
- Waste water, industrial processes
- In future: electrolyser waste heat

2. GWh scale heat storage

3. Flexible Generation, **Combined heat & power (CHP)**

- ✓ Use of heat pump when electricity is cheap (oversupply of RES)
- ✓ Producing electricity via CHP when RES power is not available
- ✓ Serve heat demand from storage & generation

Power & Heat from Combustion Plants biomass & non recyclable waste

- Over the last 20 years the sector has done new builds and retrofits (Coal to Biomass) in utility scale heat & power generation adding to more than 3GWel in EU

- Clean, modern WtE Plants (Waste to Energy) are located in city centers to provide base load heat and power

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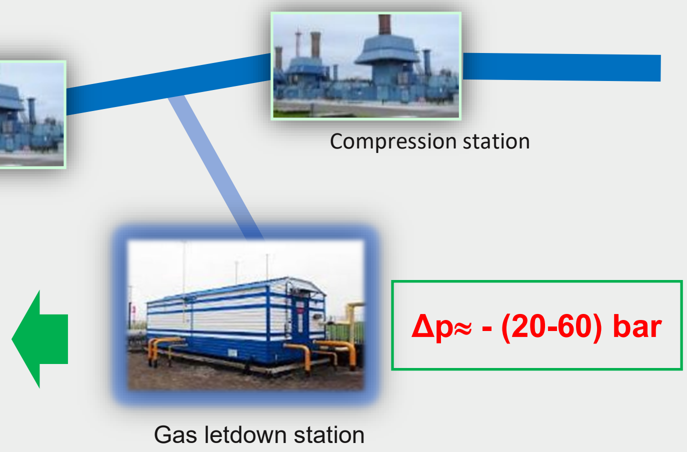
Energy efficiency technologies - The "non regret strategy" to avoid wasting energy

Pressure – to – Power

(turboexpanders to re-use energy from compressed gases in pielines)

CH4 + H2



Power production

43 TWh/year

Or

About 3% of the overall gas consumption

Overall consumption 1500TWh/year

Organic Rankine Cycle

(recover industrial waste heat from stacks)

Potential is up to 20.5 TWh/year at industrial waste heat recovery only

What comes next?

1. Further efficiency increase of thermal generation, e.g. new thermodynamic cycles like sCO2

2. Improved and new turbomachinery for hydropower & wind turbines

3. New technologies to capture untapped ressources

50 MWth pilot plant in La Porte (Texas)

Semi-closed, supercritcal CO2, Brayton cycle

sCO2 - Carbon dioxide as process fluid in power generation

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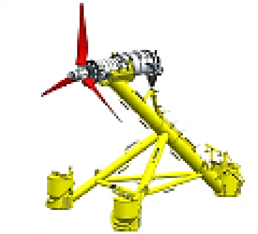
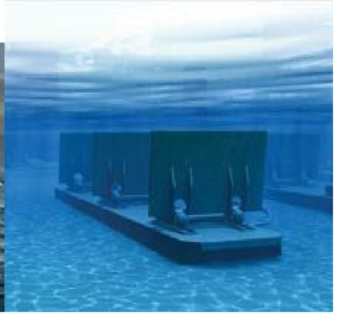
Hydro Marine Energy Solutions

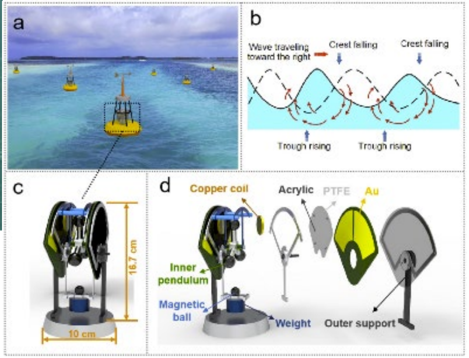
a) Energy from tidal range and currents



Sihwa Tidal (2005)
10x 26 MW Bulb; largest tidal power plant in the world

b) Wave Energy Devices

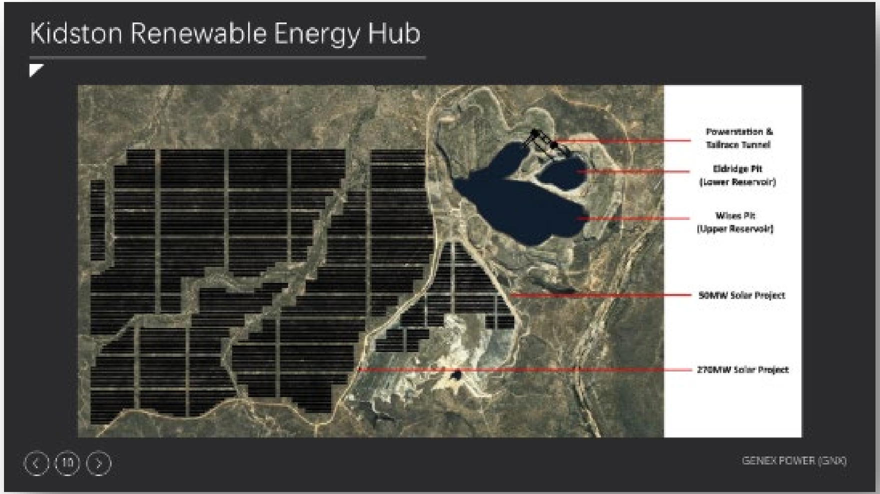





ETIP SNET PLAN. INNOVATE. ENGAGE.

Hybrid Hydro Power Plants with PV, Wind, Desalination ….

Kidston Renewable Energy Hub, Australia
The World's first Integrated "base load renewables" project: Solar / Pumped Storage / Wind



https://www.genexpower.com.au/about.html

3MW floating PV power plant on Jipyeong Reservoir, Korea

Fully decarbonising the Energy System?

RES electricity

There is **not** one technological Silver Bullet!

Storable RES,
Low carbon fuels

Easy ⟵ complexity to decarbonise ⟶ Hard

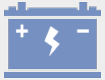
Transport

Battery (mostly) plus Hydrogen & eFuels

Hydrogen Fuel-Cell Trains & eFuels for Heavy Duty Vehicles

Liquid Hydrogen, eFuels and Fuel-Cells for long haul Big Ships

Power



Large Battery Systems for Daily Swing (hours)

Hydro-Power as Battery (days)

Backup-Power
- H_2 CCGT
- Biomass PP
- SOFC

Industry

Light Industry powered by Renewable

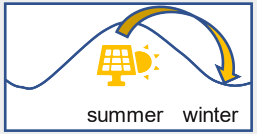
Heavy Industry powered by Hydrogen from Natural Gas + CCS

CC(U)S for Industry without other Alternatives

Heat

Heat Pumps For Efficient Use of Electricity in Homes and Industry

Hydrogen for Efficient Transfer of Energy from Production to End-Users



H_2 & biomass & CCU/eFuels for Seasonal Storage & Operational flexibility

Thank you for your attention!

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