RES, GAS, ELECTRICITY AND STORAGE NEXUS

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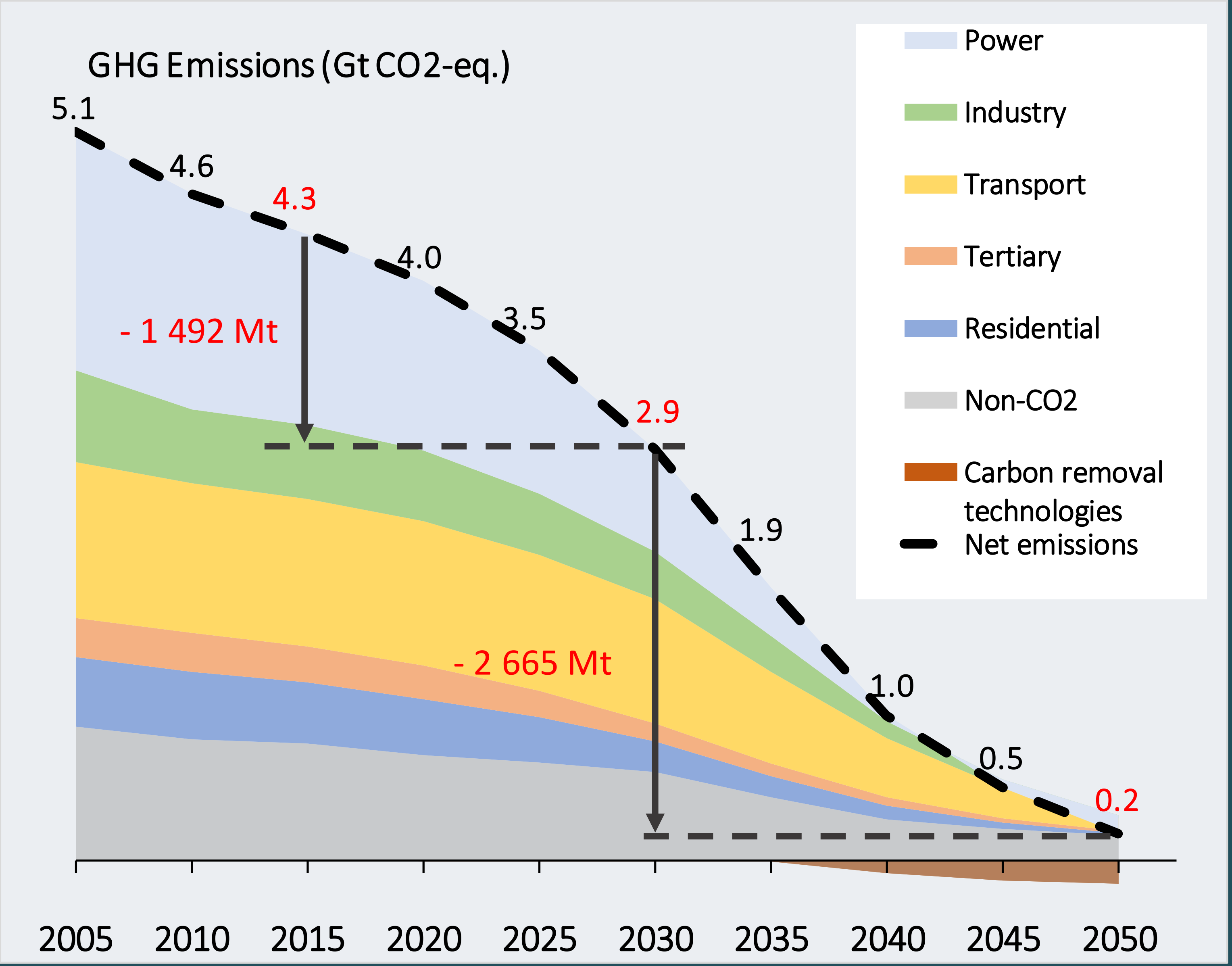
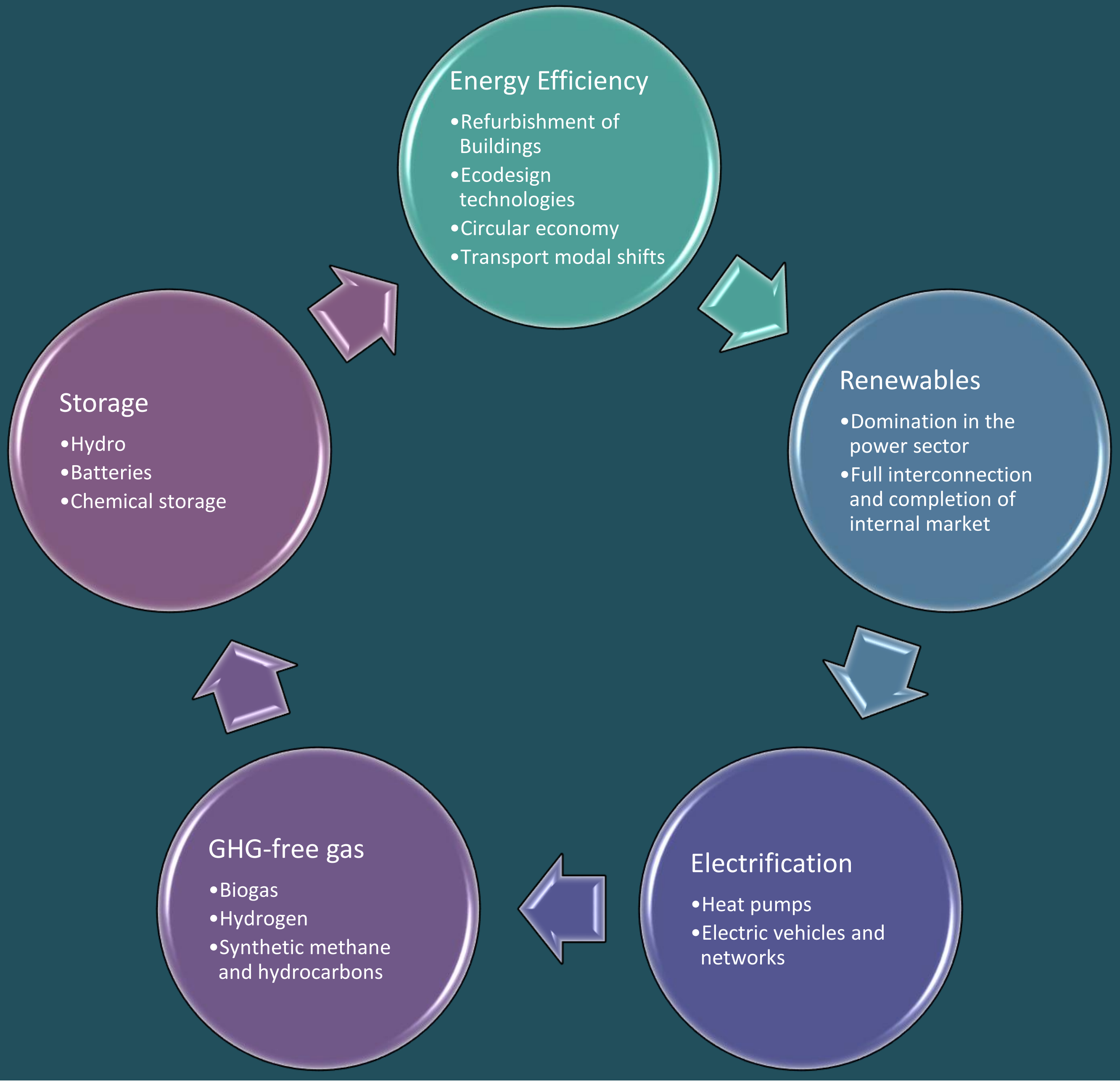


Carbon neutrality by 2050 – 1.5°C

- Including LULUCF emission sink, the 1.5°C strategy variants achieve carbon neutrality of the EU by 2050 and beyond
- Almost zero emissions of CO_2 in all energy sectors
- The carbon removal technologies are BioCCS and CCUS
- Negative emissions, albeit small in magnitude, compensate for few remaining GHG emissions in 2050 (from agriculture, gas combustion and process emissions)

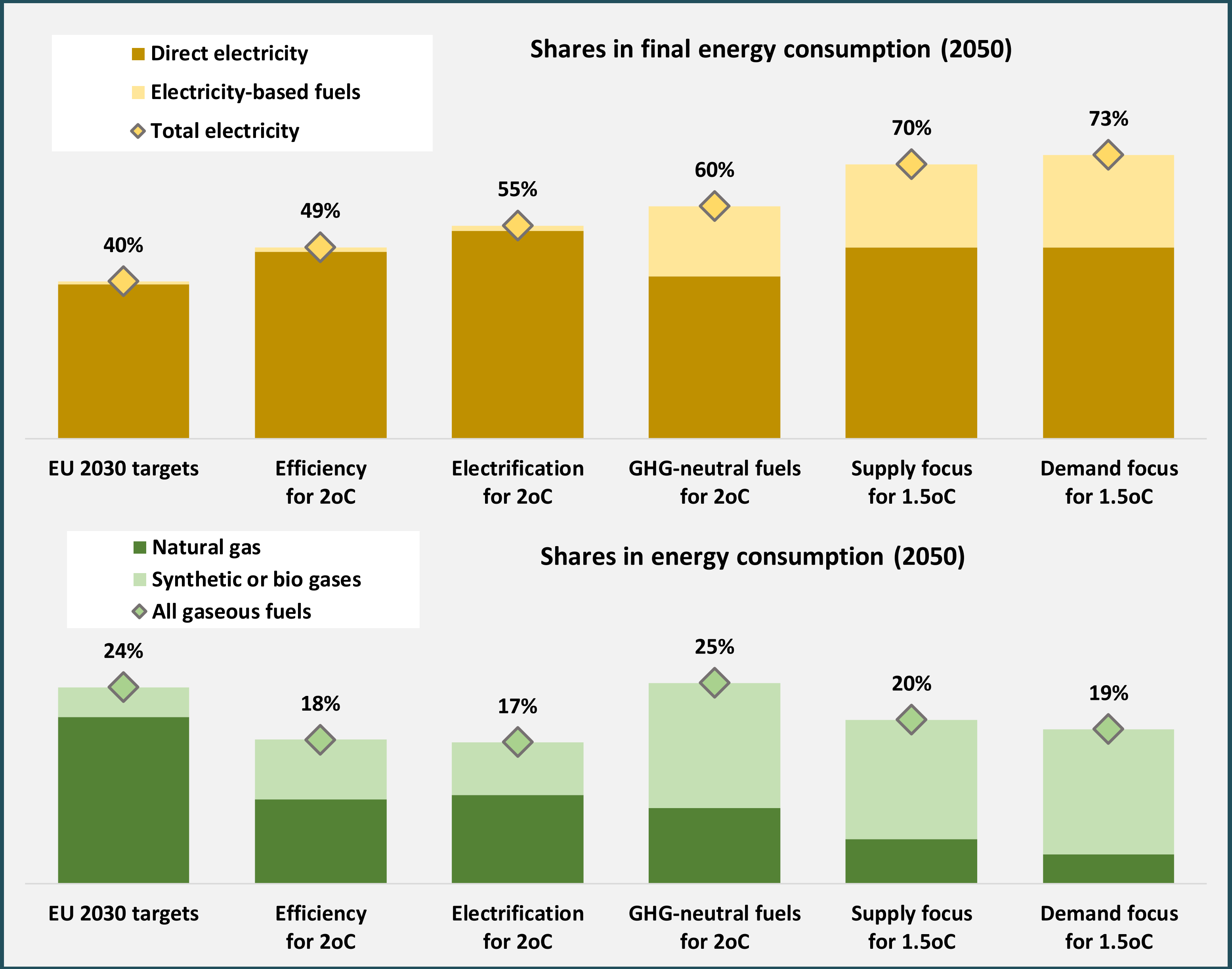


Carbon neutrality by 2050

A dynamic transition that

- Firstly develops No regret options ambitiously
- and in the longer-term achieves deep emission cuts via
- Disruptive changes

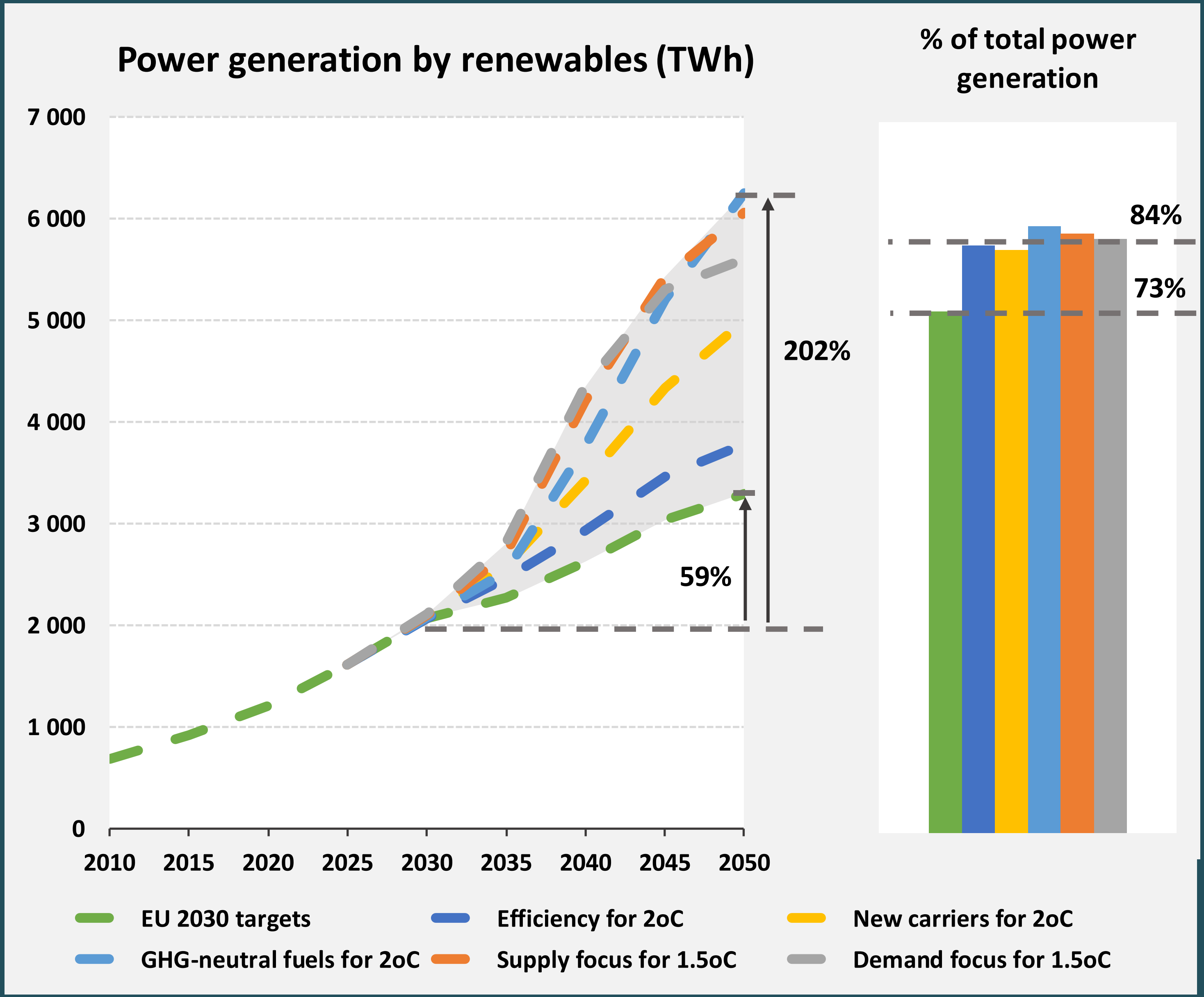
Electricity and Gas shares – EU28



Source: Primes model – E3MLab

- Electricity dominates energy supply both directly in final demand and as feedstock for H2 and e-fuels
- The dominant role of electricity is common feature of all 1.5°C strategies irrespective of the focus
- The share of gaseous fuels slightly decreases over time, with natural gas dropping dramatically, especially in the 1.5°C strategies
- Independence from natural gas and oil imports is an impressive game changer

Renewables in Power Generation – EU28



Source: Primes model – E3MLab

- All strategy variants foresee renewables up to 85% by 2050 (70% for variable RES), much above the 30% in 2015 and 55% in 2030.
- RES increase at the same pace as total demand for electricity, including for production of H2 and e-fuels
- The GHG-neutral fuels strategy doubles RES compared to the efficiency strategy. The new carriers strategy increase RES by 50%.
- The 1.5°C need very high RES irrespective of the demand or supply focus

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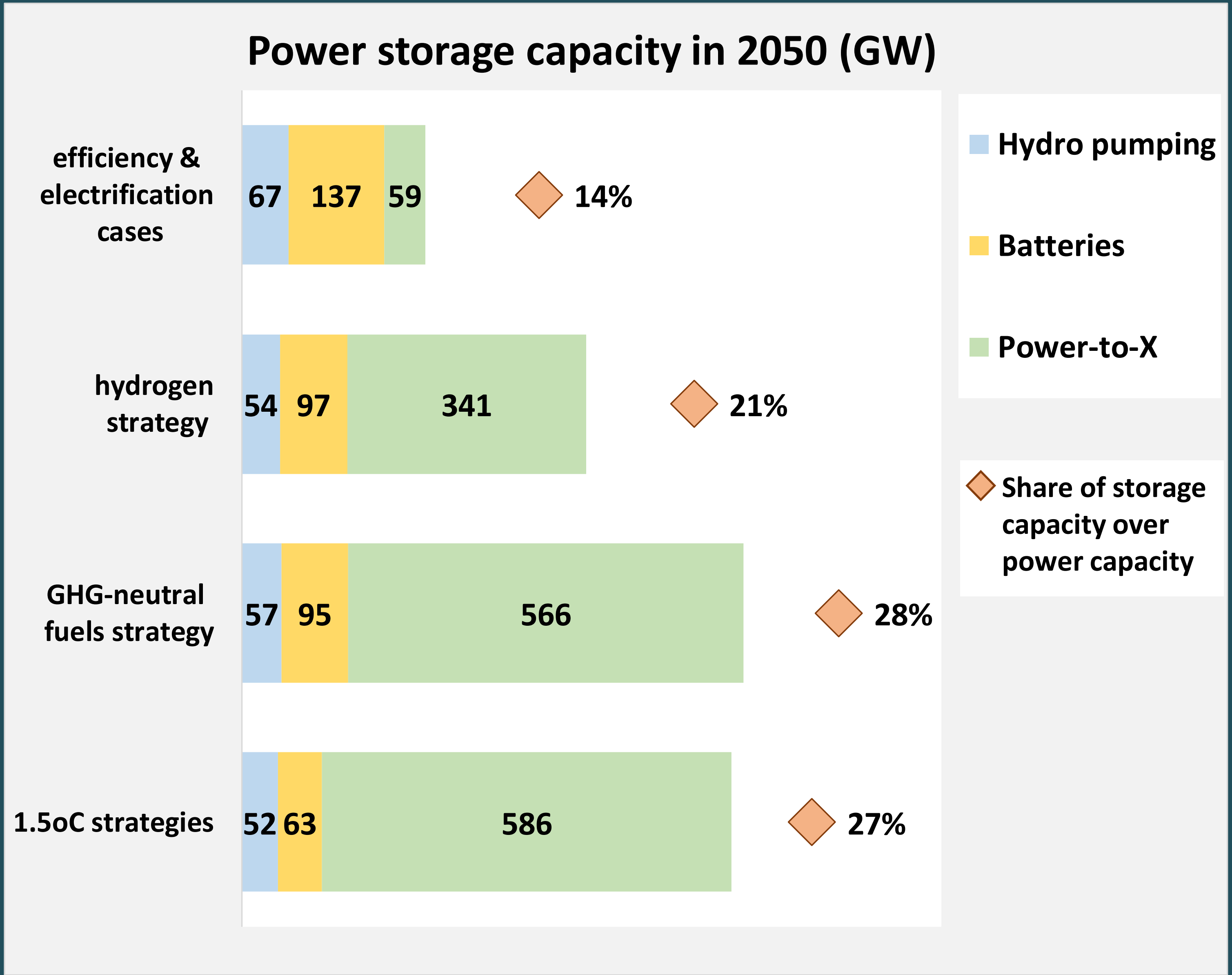
Electricity storage outlook – EU28



Source: Primes model – E3MLab

Storage and interconnections, rather than gas plants, provide the large flexibility and reserve needs of the system due to RES

Mainly batteries (various scales and system levels) provide storage in the efficiency and electrification variants

Large chemical storage in variants with H2 and e-fuels, enable maximum exploitation of renewables despite the significant increase on total electricity generation

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Climate-neutral gas (production)

Hydrogen

From steam reforming of natural gas or naphtha
- Efficient and well-established
- Not climate-neutral unless CCS
- But underground storage of CO_2 unavailable

From electrolysis
- High Learning potential exists
- Condition is climate-neutral electricity
- Synergy between RES and Power-to-H_2
- Economics depend on electricity price

Distribution issues
- Up to 15%vol (5% energy) injection
- Significant investment to adapt the gas system and the end-user appliances
- Storage of hydrogen, still not mature

Climate-neutral methane

Biogases-biomethane
- Important role in a clean system
- Competitive costs (anaerobic digestion from waste)
- Not on a scale to substitute for natural gas

Synthetic methane
- 1.5 to 3 times more expensive than natural gas
- learning potential exists (methanation)
- Depends on hydrogen and the costs of electrolysis
- Depends on CO_2 capture - from the air (not mature), biogenic sources (upgrade to biomethane, CC of biomass plants, biomass gasification)

No disruption
- Gas infrastructure
- Stock of appliances

Actors and incentives

Investment strategy

- Steam reforming with CCS only in niche applications
- Electrolysis location issue: centralized versus local hubs

Drivers

- Standards (max CO_2 emission factor of gas, or blending mandates) are the only possible driver
- Guarantees of Origin
- Technical norms to complete

Actors

- Active role of Distribution Operators (not TSOs) in the blending and for the norms
- Dispersed injection points implies diverse climate-neutral gas producers and traders
- Later to see centralized production facilities involving power companies

Market for climate-neutral gas

Hydrogen direct consumption, cases in industry (e.g. iron and steel), heavy duty transport (fuel cell trains, buses and trucks) and hubs

More likely to inject H_2 up to 15%vol, adding also large amounts of biogas rather than distributing hydrogen at a large scale

Small scale LNG using climate-neutral gas may enable new markets (shipping, transport etc.).

However, heat pump electricity is likely to substitute for gas in heat demand

Infrastructure

Current topology does not fit	•No injection at borders •Limited role of high pressure
New topology has to accommodate	•Various injection points at different pressure levels (most likely not on high-pressure) •The composition of the blend will vary by location and over time
Security of Supply issues	•not all countries have the clean resources •No emergency gas •Different location of storage
Interoperability	•Different calorific values •Different blends
Local or regional grids	•Different prices to consumers •Different operators
Storage facilities	•Link to local operators •New investment required

Market and regulation aspects

Market

Today gas is priced and sold on its energy content but measured for the volume of gas

The calorific value cannot be standardized as the blend composition varies

Charging on flow weighted average calorific value will be difficult

Competition

The dispersion of blending and the implied decentralization of markets has consequences on the degree of competition –

likely to see market power in local markets

Operators

Local direct hydrogen applications require a new type of operator for the infrastructure, otherwise there will be no competition among suppliers

Gas balancing (and emergencies) can be handled only locally (at a distribution of local hub levels, new considerations of uninterruptible supply need to apply

The entire regulatory system of third party access has to change

Climate-neutral gas (strategy)

Barriers

- Overpriced
- Technologies not yet mature
- Coordination failure (value chain dependence)
- Regulatory uncertainty (infrastructure and standards)
- Spatial planning (locational issues)
- Infrastructure and system management restructuring

Strategic advantages

- Lack of alternatives
- Storability improving security
- Maintaining infrastructure
- Maintaining equipment
- Strengthened acceptance
- Potentially global trade
- Import independence