Energy 2050: Study Preview Slides

European Climate Foundation

About the study

- **How feasible is a genuinely zero carbon EU energy system (power, heat, road transport) by 2050** in light of the present-day context of low cost renewables, and new trends like sector coupling and smart electrification?
- Study examines energy system and macroeconomic implications of a set of electric (smart, efficient/not smart) – molecule (domestic/imported) constellations.
- Aims to provide an answer to questions such as:
  - What is future role of electrification (including heating in buildings and transport)
  - What are the system impacts of electrification (on supply, infrastructure, end use)
  - To what extent can "green molecules" contribute to supporting decarbonisation, particularly when electrification is challenging.

Approach

Scenario development

- Identify main system drivers
- Construct distinct Zero-2050 scenarios
- Identify representative country-archetypes

Energy demand

- End use-technology shares per country
- Hourly demand profiles for transport, heat, elec, H2

Whole energy system model

- Multiple vectors, fully integrated
- Hourly modelling of supply and demand to determine system adequacy in high vRES penetration.
- Flexibility (smart) technologies to reduce residual (net) demand.
- RES capacities minimize system cost (across generation, infrastructure), minimising curtailment
- Storage (various timescales, including seasonal)
- System capacities and costs

Macroeconomic assessment

- Investment
- Structural changes
- Jobs and social impact
- Disposable income
- Balance of trade

Scenarios: Four core, two additional gas scenarios, two sensitivities

Central case(Scenario A)

Intermediate efficiency savings; demand side flexibility (controlled EV charging, grid responsive electric heating), network battery storage to balance daily variation, seasonal energy store (H2)

Demand side failure (Scenario B)

Cost of no demand side engagement

Lower efficiency, no Demand Side Response

Demand side breakthrough(Scenario C)

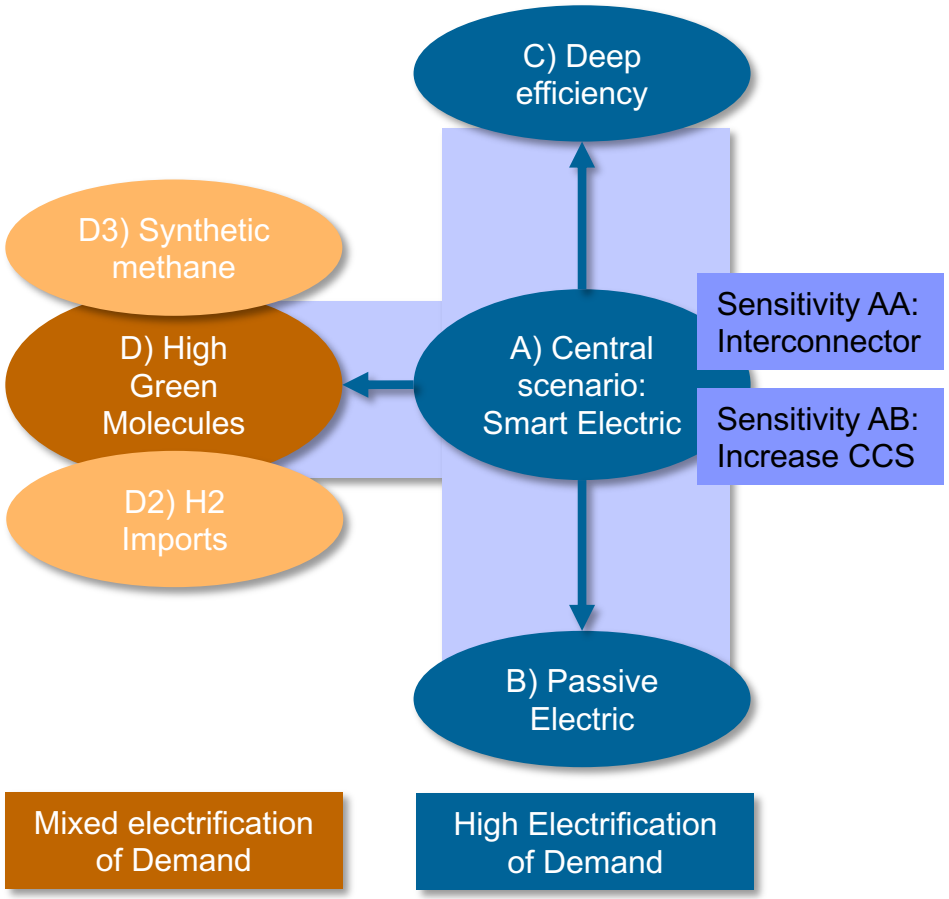
Whole system benefits of demand engagement

As (A) but deeper energy efficiency, and vehicle to grid

Molecules and electrons (Scenario D)

Role of gas in supporting electrification

As (A) but much greater use of hydrogen in demand applications transport and in the heating system



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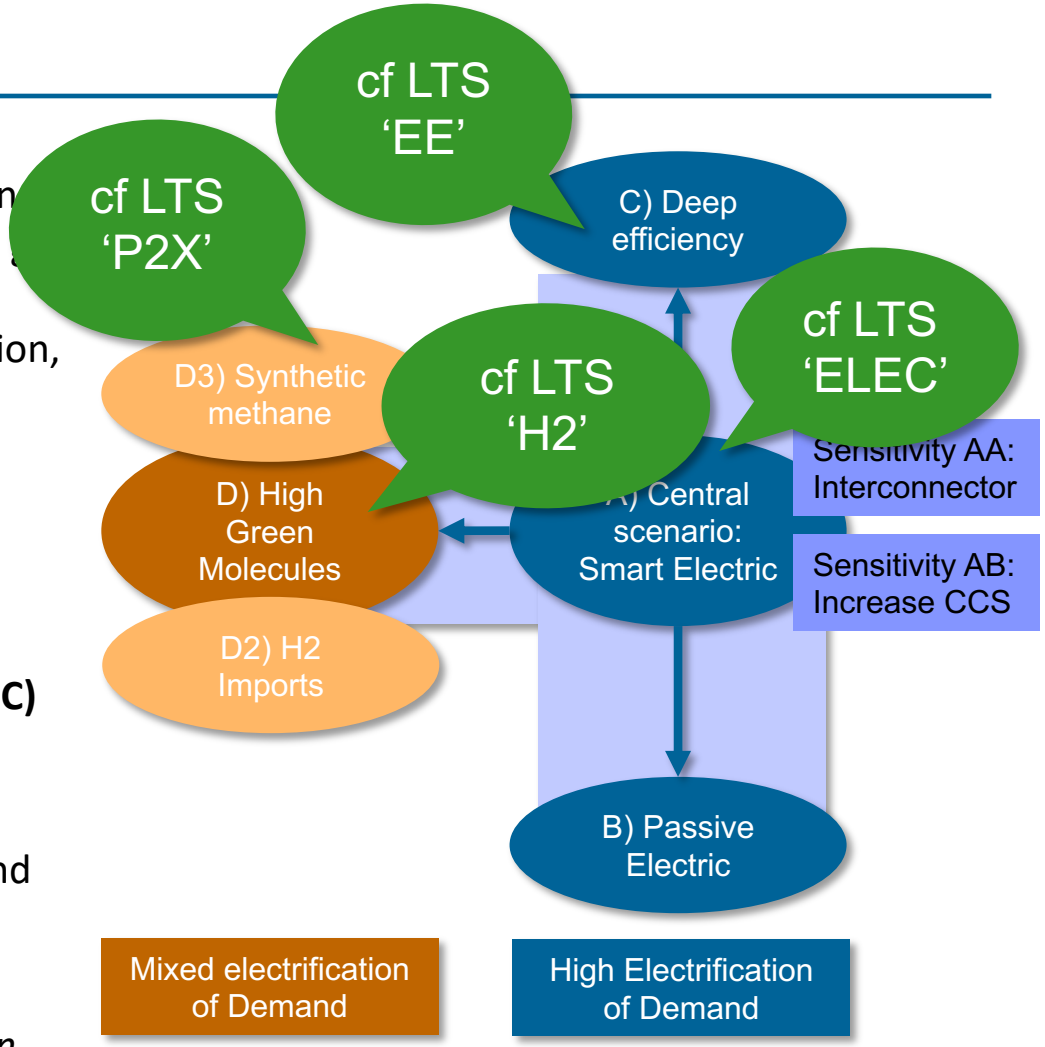

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Country archetypes based on key system drivers: renewable resource, and the extent of the gas network

- Sunny, high gas
- Sunny, med. gas
- Sunny, low gas
- Windy, high gas
- Windy, med. gas
- Windy, low gas

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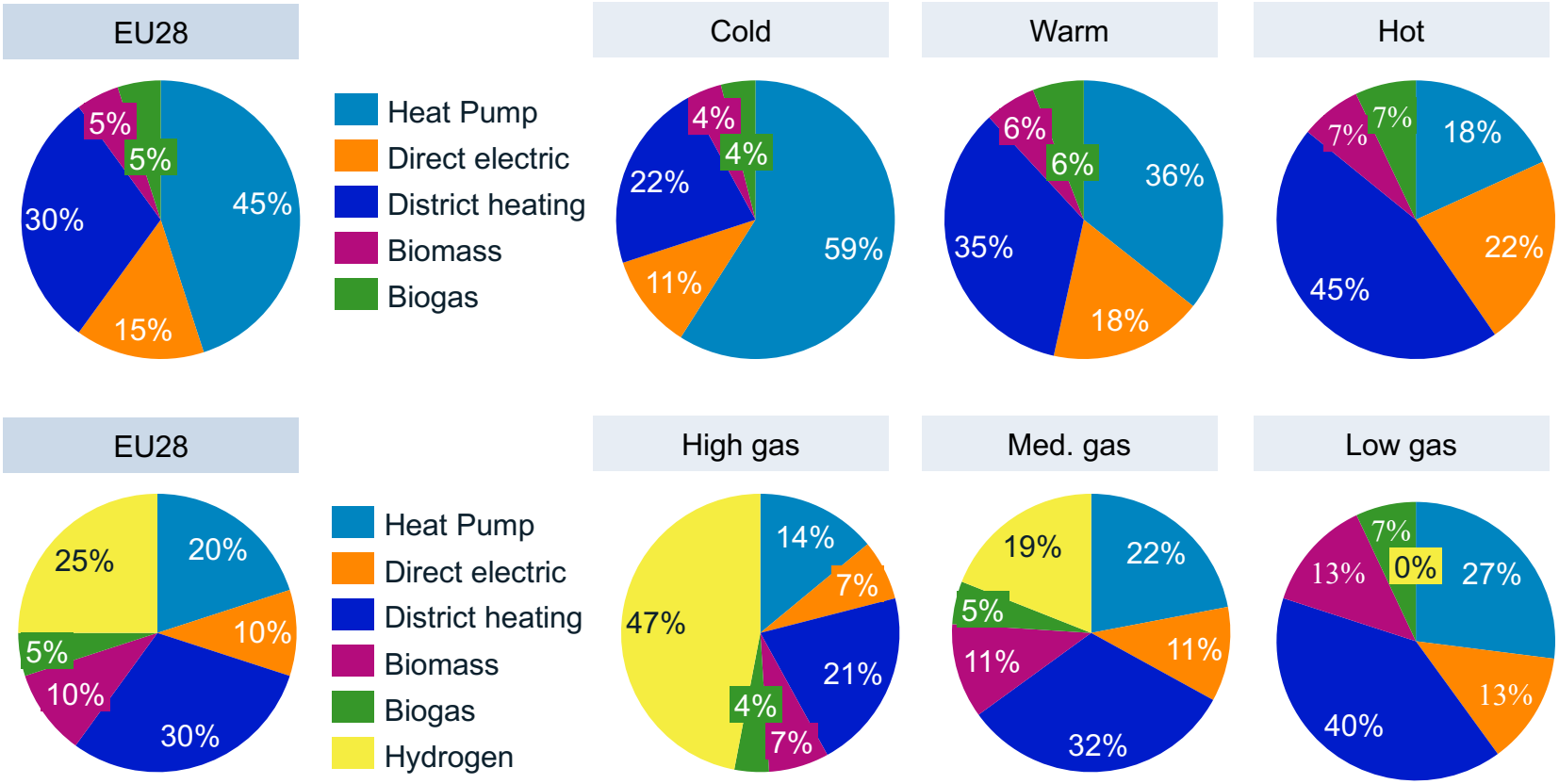
Distribution of heating technologies across EU28: Scenario A, B, C (top) and D(bottom)



Figures refer to the % of homes with each type of heating system

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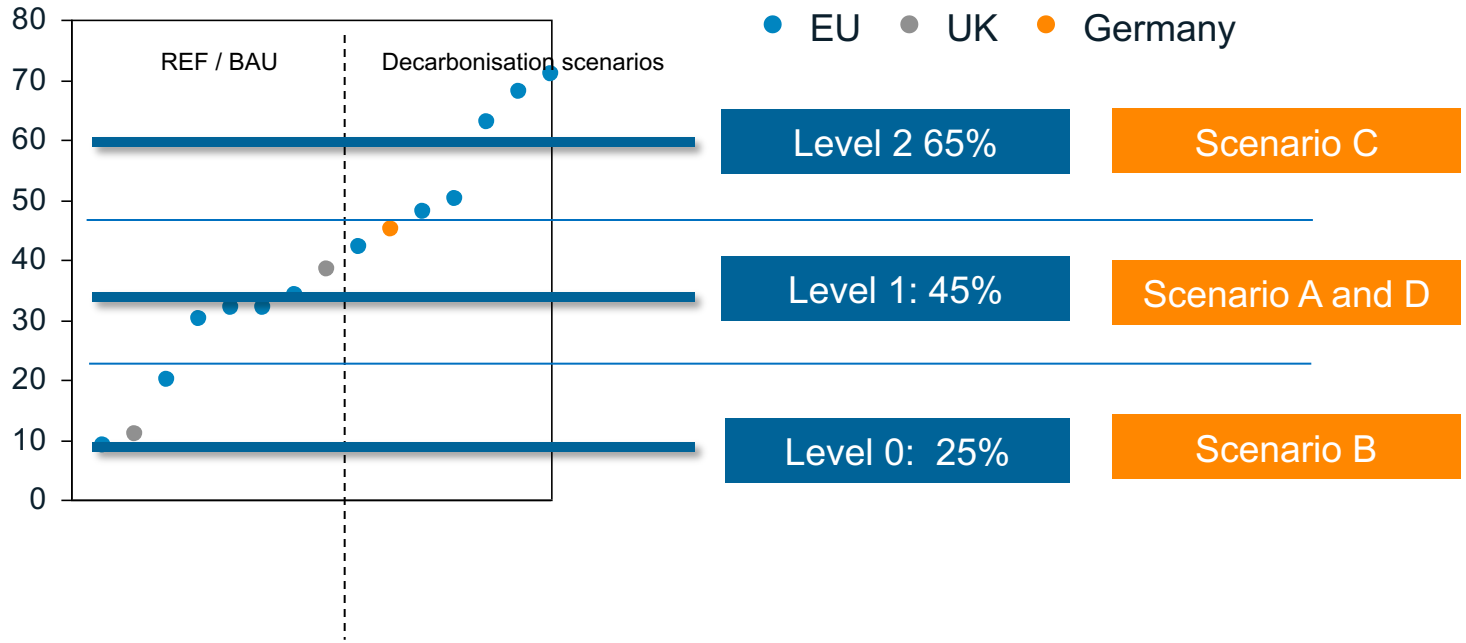
Reduction in final space heating demand due to energy efficiency measures reducing heat loss

Level of demand reduction, % (each dot is an individual reference)



Scenario C has significant demand reduction through retrofitting of energy efficiency measures in the majority of existing buildings

Note: Values shown here are for final space heating demand. They do not include heating technology efficiencies as they are already accounted for in the heating technology section

References: Aalborg University, BPIE, ECF, EPHA, European Commission, National Grid, Renewable Heating & Cooling (RHC-Platform)

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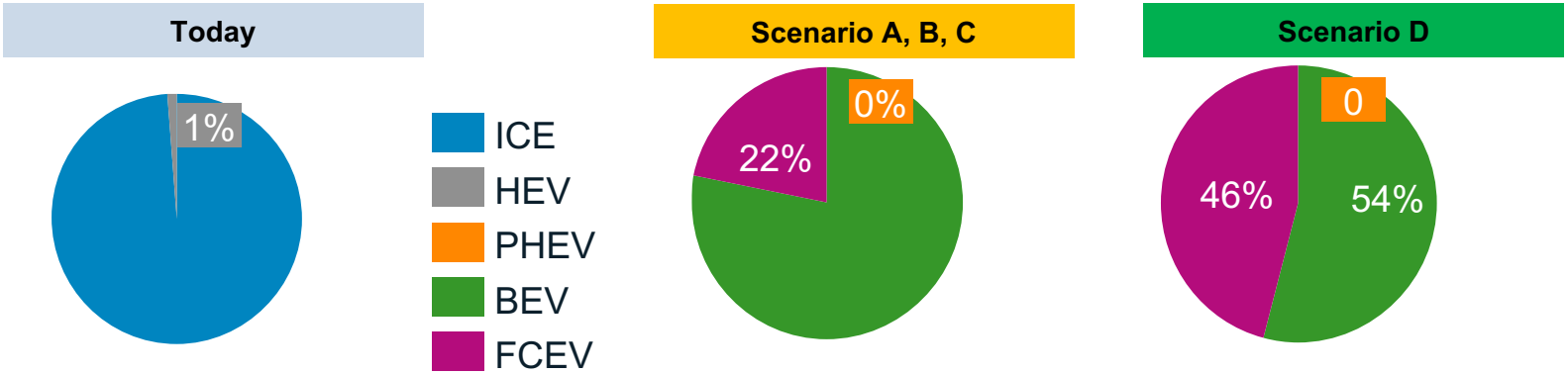
Passenger cars: Uptake based ECF study – Fuelling Europe's Future II



In all scenarios, the passenger car stock is comprised of 100% ultra low emission vehicles (ULEV) by 2050

A,B,C: Batt-electric dominates small and medium passenger cars.

D: All large and 50% of medium passenger cars are FCEV

ICE – Internal combustion engine HEV – Hybrid electric vehicle PHEV – Plug-in hybrid electric vehicle
BEV – Battery electric vehicle FCEV – Fuel cell electric vehicle (Hydrogen)

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Scenarios: sectoral consumption breakdown

Scenarios A-B-C

Heating provided by heat pumps, direct electric, and district heating.

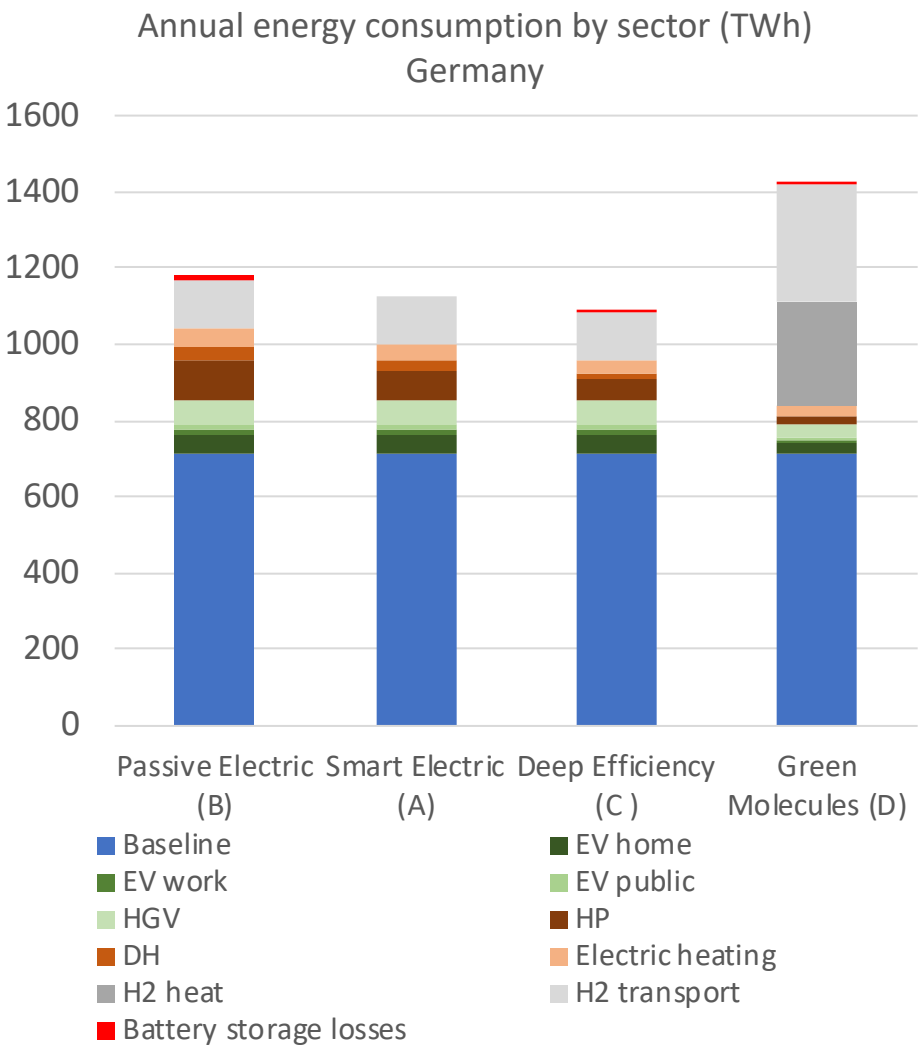
80% of passenger cars and 60% HGV are battery electric.

Scenario D

High Gas regions: Hydrogen + biogas supplies nearly all homes on gas network.

In other regions, Heat pumps and district heating dominate

50% of passenger cars and 60% HGV are fuel cell.



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Energy System Outputs

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clarity from complexity

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Main themes emerging from the analysis

System benefit of deep efficiency

- Reduces fuel consumption but also lowers heating system cost, reduces peak system load, contributing to lowest overall system cost.

Flexibility and smartness vital to support decarbonisation

- Demand side must be “active” to respond to variable RES output and limit curtailment of green energy and reduce network investments. Failure to “activate” demand leads to highest overall system cost.

Infrastructure and “green gas”

- Decarbonising gas system does reduce investment in electricity infrastructures. But significant additional electricity infrastructure investment is inevitable in all scenarios. On-cost of using gas infrastructure could be very significant.

Long-term and seasonal storage

- Diurnal storage will become widespread, mainly benefitting PV.
- Heating season demands dominates seasonal energy storage requirements. Challenging to develop longer-duration storage as cycling (utilisation) reduces.

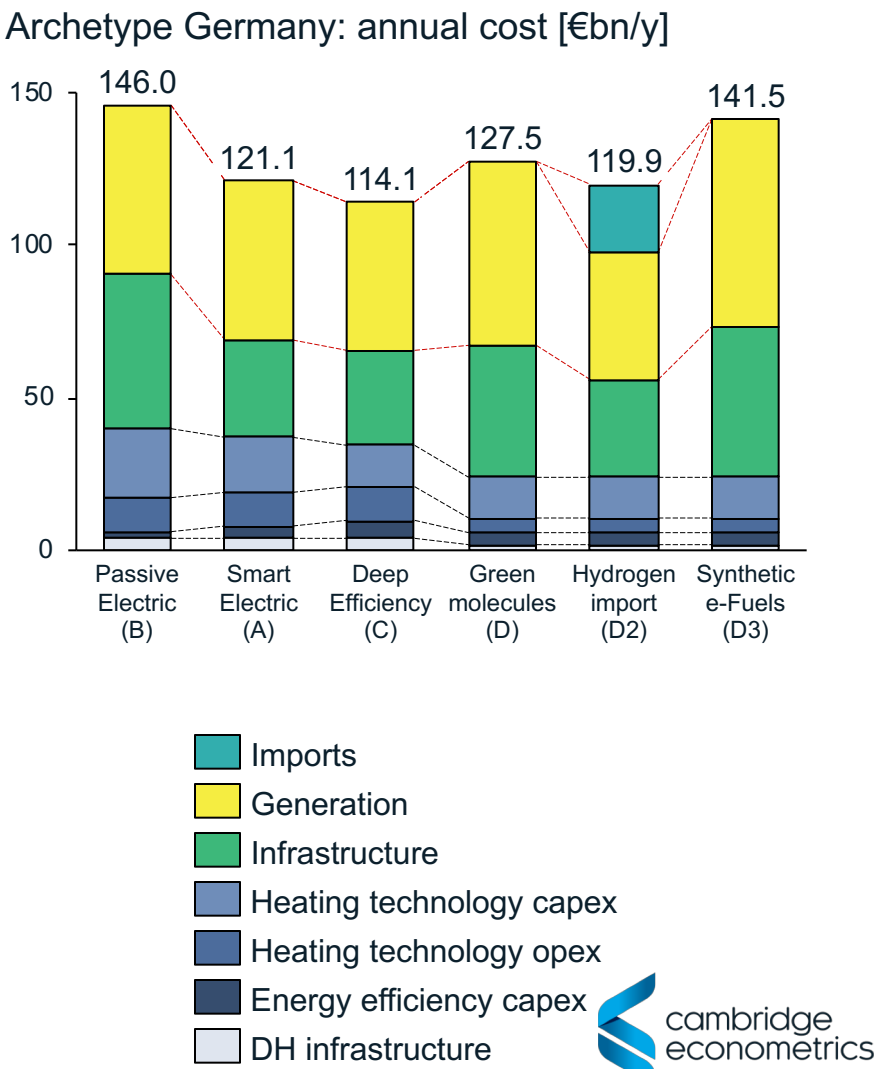
Deep Energy Efficiency programmes generate system savings and lowest overall system cost

Deep energy efficiency (thermal fabric) measures require a high investment within households.

Relative to scenario (A), this cost is offset by a lower investment required in heat pumps.

This investment allows savings in infrastructure and in power generation.

These savings translate into reduced fuel costs to consumers.



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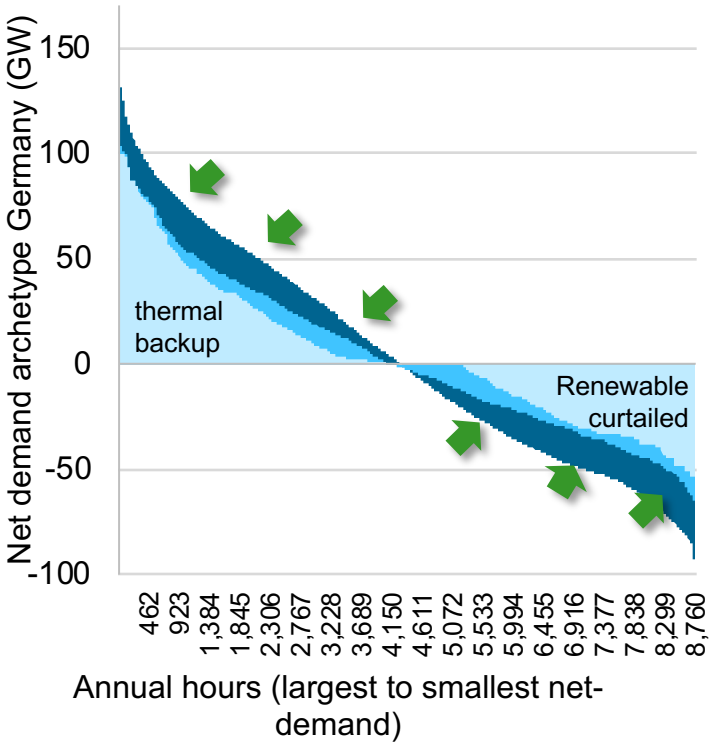
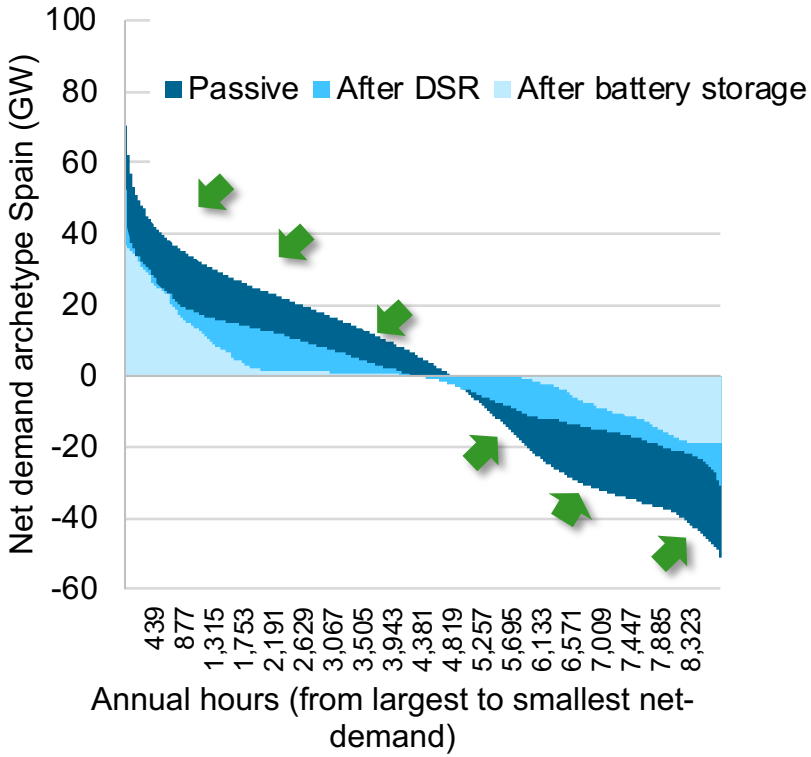
Flexibility: Daily flexibility and multi-day storage: enabling a zero carbon energy system based on (variable) RES





Germany, scenario C:

Thermal backup reduced by 38%: 162GWpeak to 100GWpeak

Net demand is reduced by 44%: from 408TWh to 229 TWh

Spain, scenario C:

Thermal backup reduced by 54%: 78GWpeak to 36GWpeak

Net demand is reduced by 68%: from 109TWh to 34 TWh

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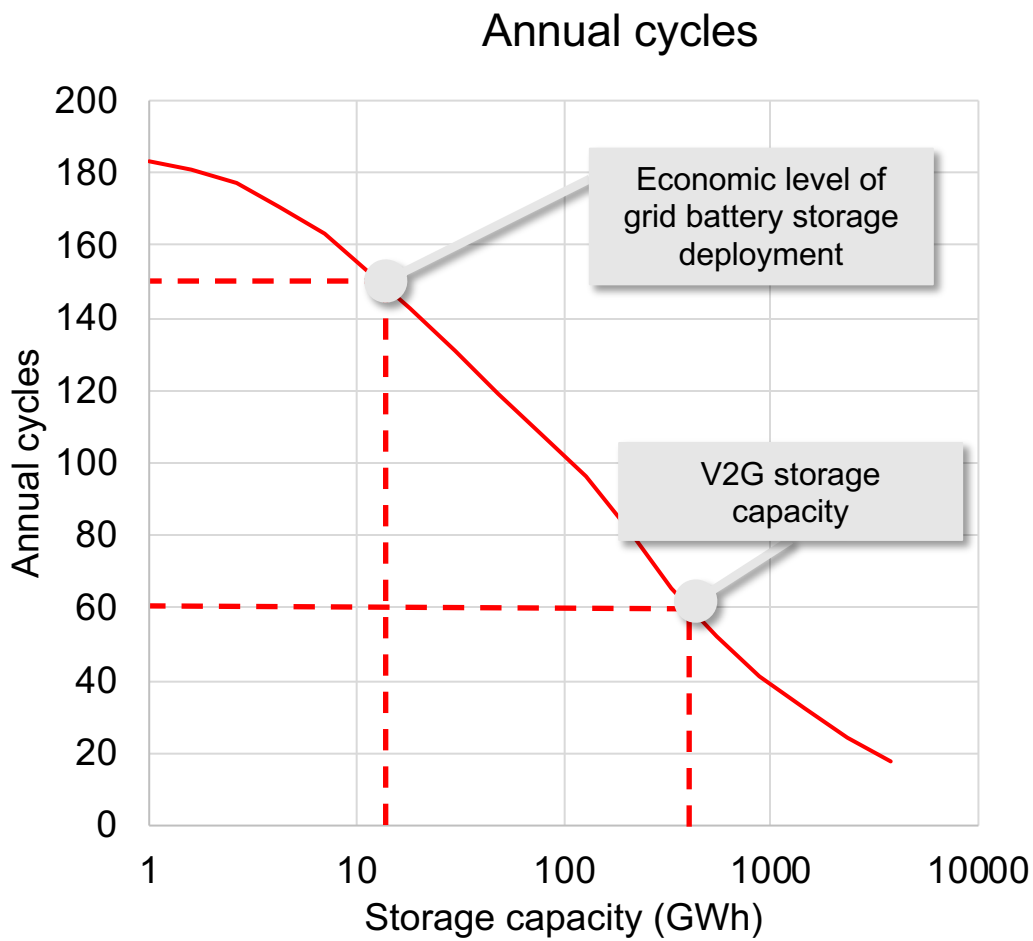
Flexibility: Utilisation of Vehicle-to-grid using the 2050 EV fleet would replace grid battery storage

Electricity storage with a (typical) duration of a few days, has a vital role in matching supply with demand over this time period.

Longer duration reduces curtailment, but annual cycling of the battery reduces.

The cumulative storage capacity contained in the 2050 EV fleet, is approximately 15 times that of the economic threshold of grid batteries.

Compared to grid batteries, V2G (as per scenario C) could reduce RES curtailment by a factor of 6.



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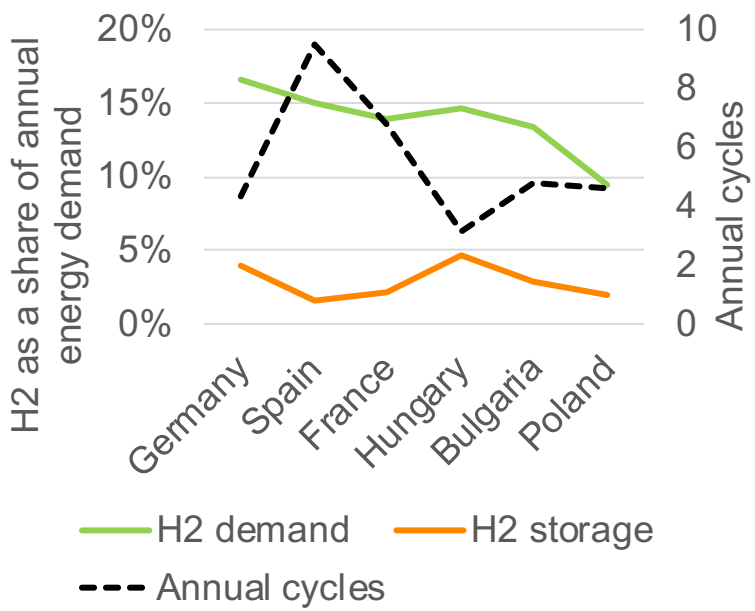
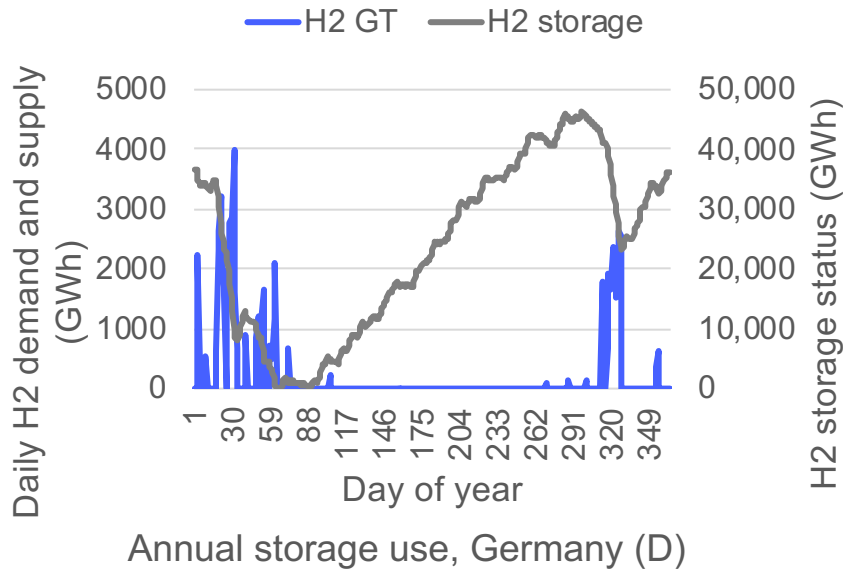
Seasonal Storage: Required to address long-term deficits of RES supply and seasonal peaks in demand.





Long-term energy supply/demand deficit requires dispatchable energy to fill the gap: biofuel resource helps but is limited.

Size of seasonal store varies significantly depending mainly on seasonality of supply and demand. Spain and Bulgaria use hydro and interconnectors to deal with supply gap; Germany and Hungary have largest seasonal stores

Seasonal energy stores discharge very few times per year, and so the must be very cost effective – and many times cheaper than storage today.

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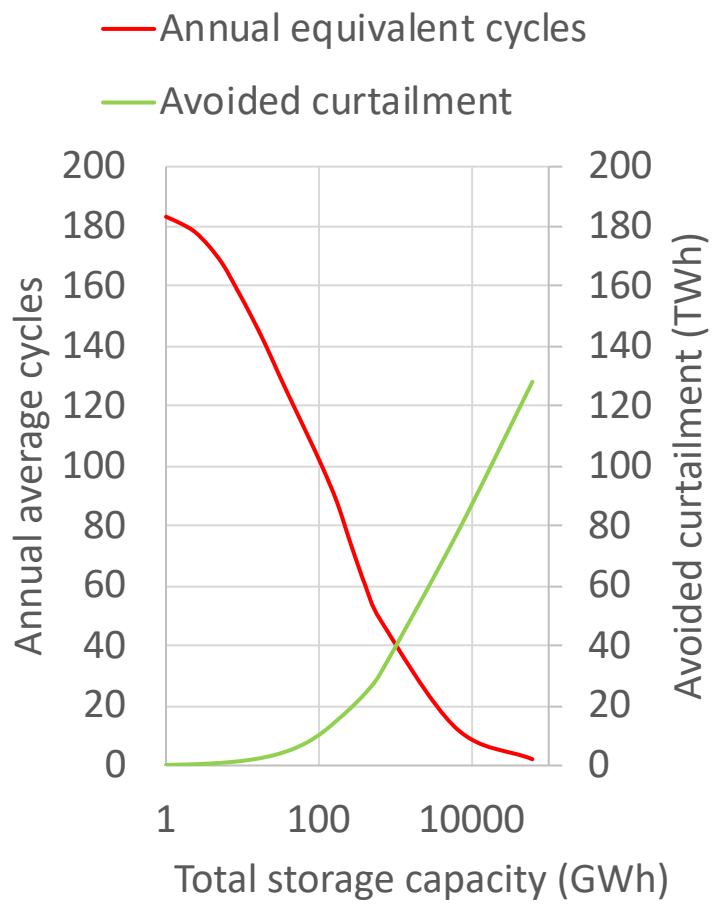
Technology competition: increased deployment of flexibility (DSM and storage) leads to lower marginal value

The “first” GWh of storage deployed is utilised intensively to match supply and demand. Further GWh of storage are utilised progressively less intensively.

Earlier battery deployments will be more expensive than subsequent deployments. This may inhibit the initial investments necessary to allow costs to reduce.

As batteries reduce in costs, their capabilities will need to increase in order for these newer batteries to access markets distinct from earlier deployments.

System demand will have to increase in line with flexibility deployment (e.g. increase market for flexibility by introducing additional RES)



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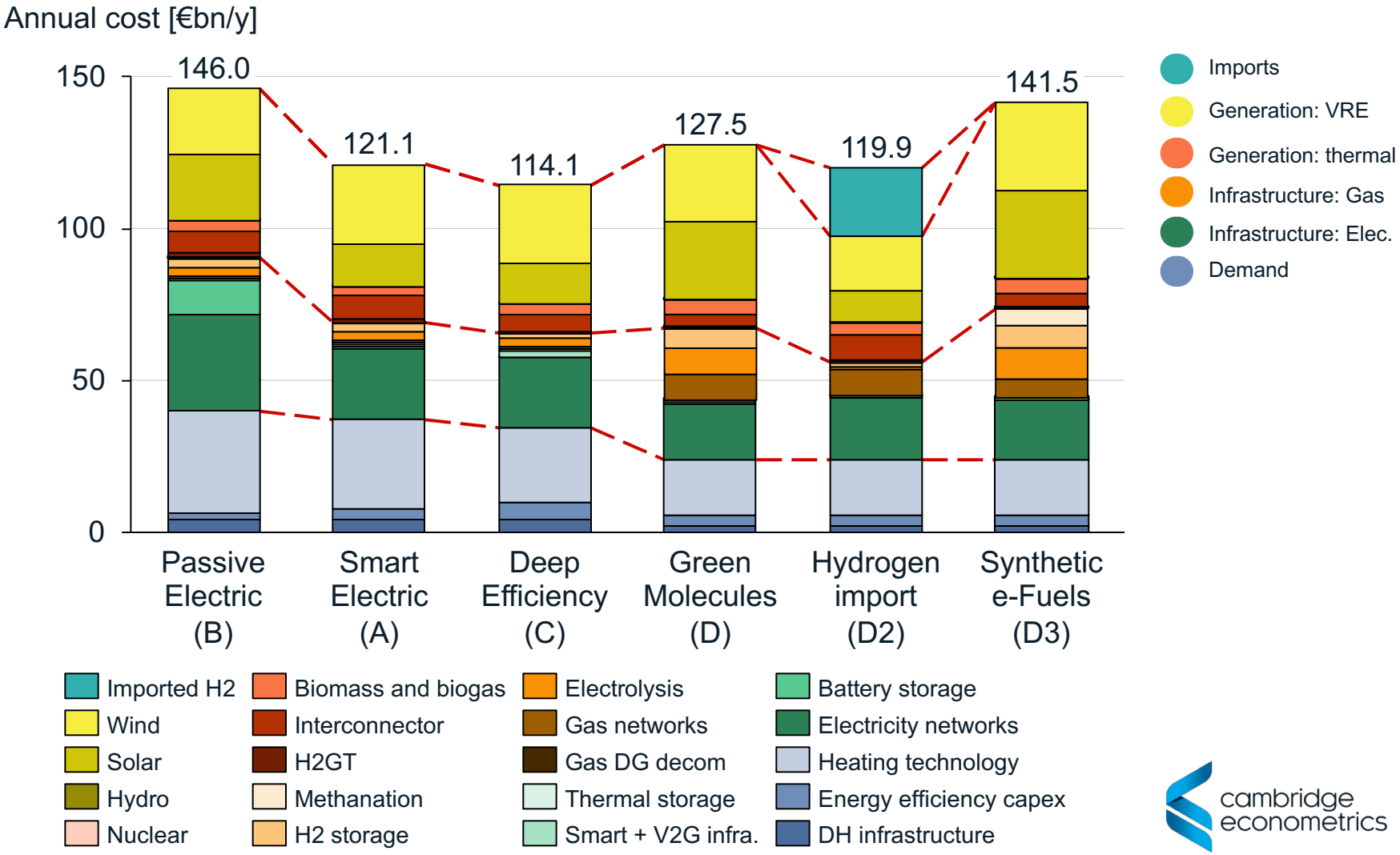
Green Gas: A largely electrified future is feasible at slightly lower cost than a largely gas future



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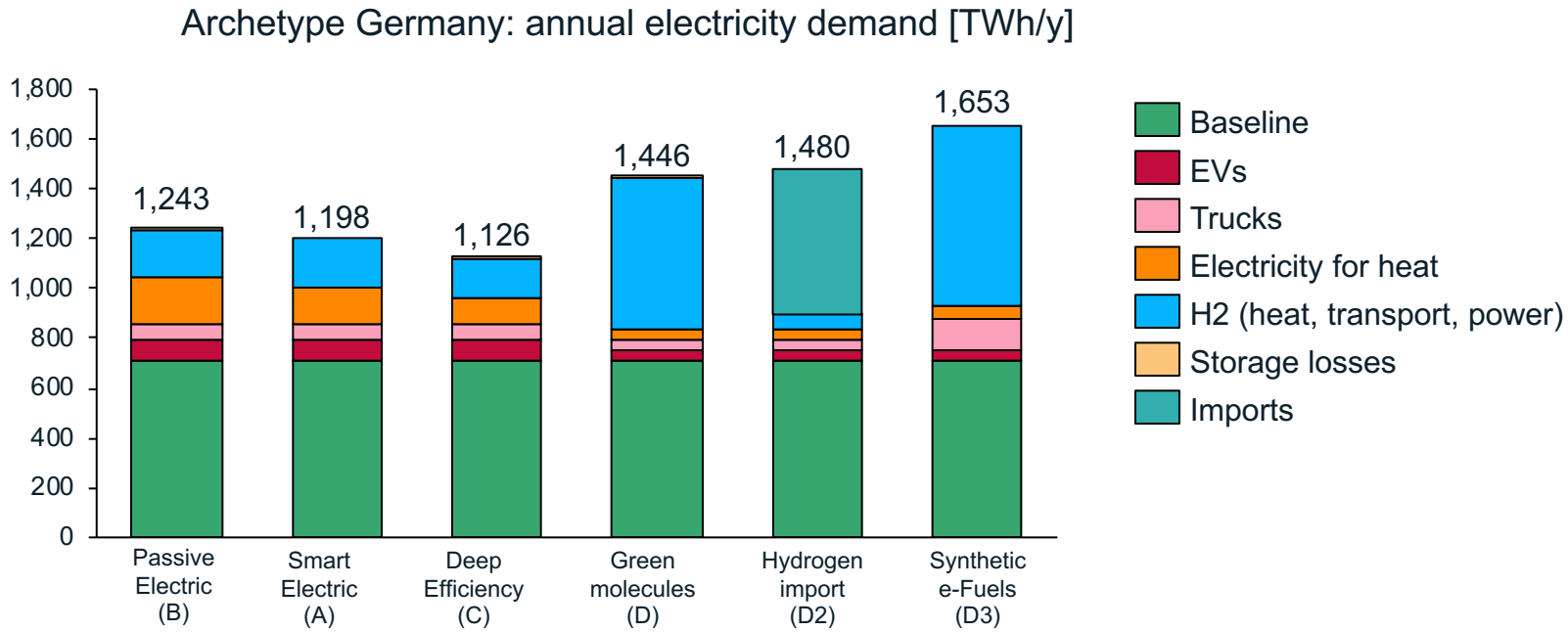
Green Gas: Carbon-neutral gas is a scarce resource, deployment at scale significantly increases electricity supply



Relative to scenario A, additional demand due to:

- Losses in production of H2 (70% efficiency)
- Lower efficiency of fuel cell compared to EV battery
- Lower efficiency of H2-boiler compared to HP

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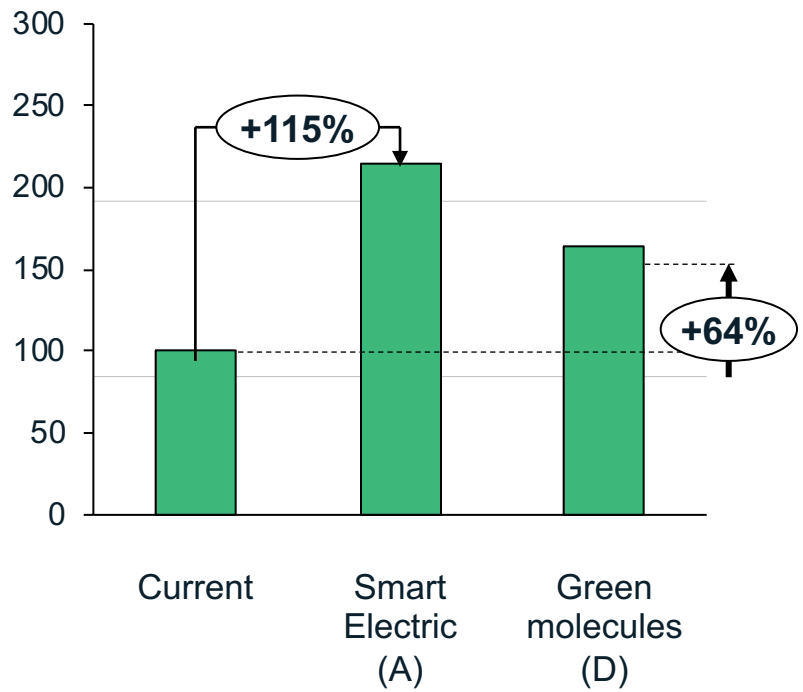
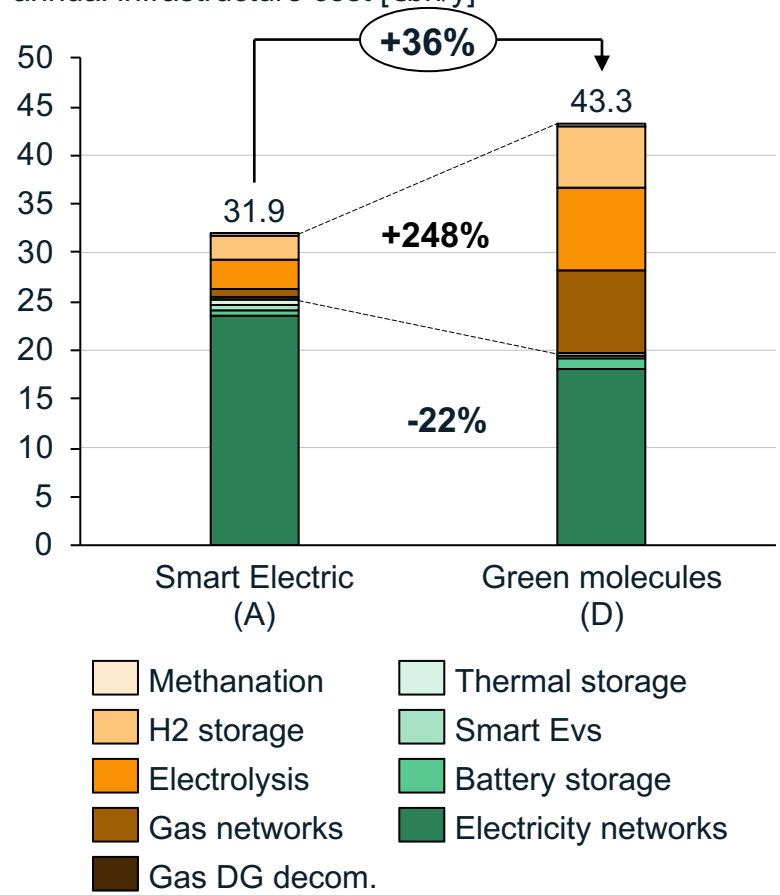
Carbon-neutral gas saves on electricity infrastructure costs - but these benefits are outweighed by additional gas infrastructure costs and additional generation costs

Archetype Germany: electricity grid capacity relative to current peak demand (%)



Archetype Germany: annual infrastructure cost [€bn/y]



Optimised system:

Expansion in electricity distribution network reduces curtailment and generation GW.

H2 end use takes pressure off of DN, but with additional infrastructure requirements

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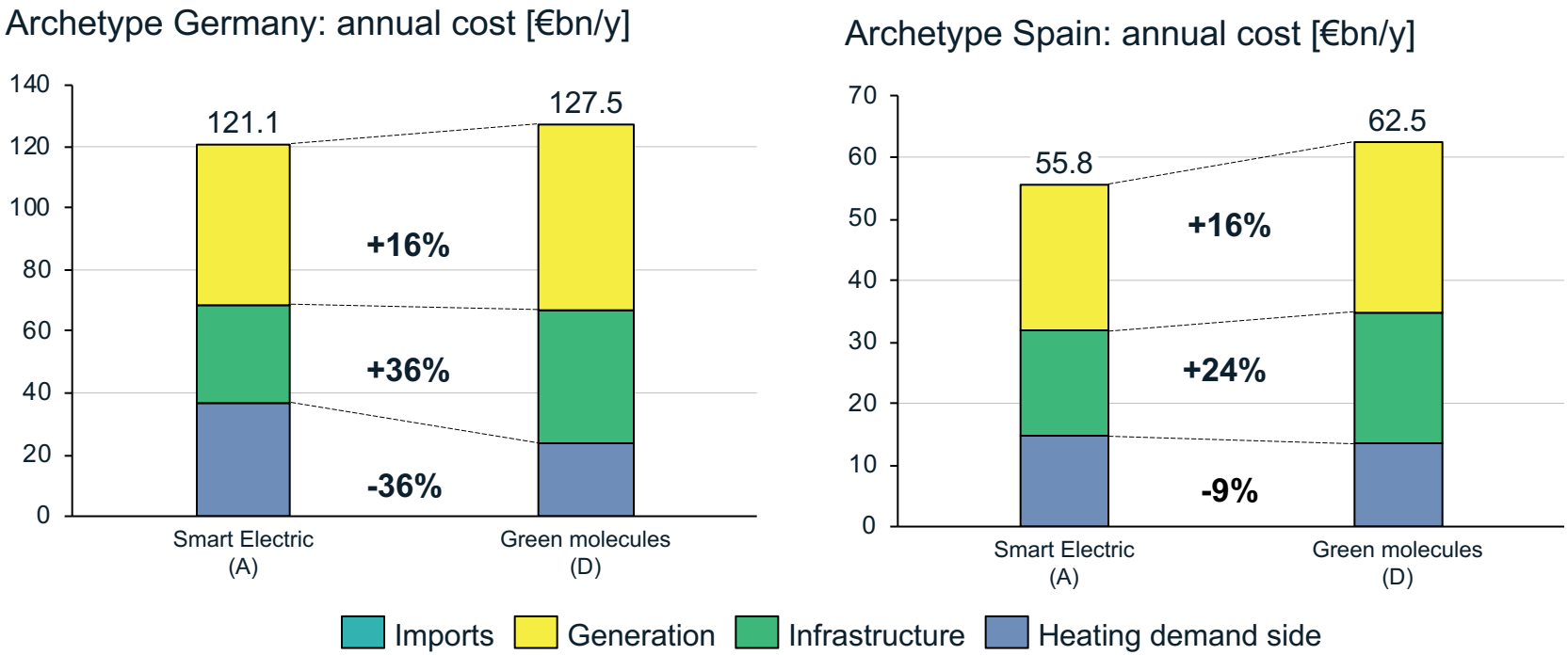
Maximising the use of carbon-neutral gas for heating shifts investment from consumers to generation and infrastructure, where it might be easier to unlock



- Scenario D: greater use of hydrogen boilers for heating where there is a widespread gas distribution network.
- Significant reduction in residential capex+non fuel opex could make these investments easier to deploy
- Overall increase infrastructure and generation costs will result in higher fuel bills.

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Macroeconomic Results

Richard Lewney
Jamie Pirie

Cambridge Econometrics

Overview

- The logic of the macroeconomic impacts
- Scenarios and expected impacts
- Macroeconomic impacts for EU28
- Summary of macroeconomic messages

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The logic of the macroeconomic impacts

- Net increase in annualised energy costs
  - spending diverted from household consumption to investment
- Where the equipment and fuel is produced
  - potential substitution of European production for imports
- Substantial structural change
  - from carbon-intensive to low-carbon sectors
- Jobs and social impact
  - potential for more European production and jobs
  - oil refining has low employment intensity; 'other' sectors have higher employment intensity
  - structural change implies winners/losers/retraining need
  - higher energy prices – can poor households adapt?

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Scenarios and expected impacts

Archetypes, €bn (2015 prices)	A (Smart electric)	B (Passive electric)	C (Demand side breakthrough)	D (High green molecules)	D2 (Hydrogen imports)	D3 (Synthetic methane)
Annual spend on energy efficiency measures	11	6	16	11	11	11
Annual spend on demand side heating technology	56	61	51	50	50	50
Annual spend on supply side energy supply, storage and infrastructure	220	270	215	261	181	294
Total annual spend on energy technology	286	337	282	322	241	355

Smart technology and/or energy efficiency keep energy system costs down. (Energy efficiency requires more consumer buy-in.)

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Largest investment stimulus

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Smallest investment stimulus. Overall cost including value of imported hydrogen is similar to A and C

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Macroeconomic results in 2050 of Scenario A relative to REF2016

EU28 Member States	A (Smart electric)
GDP (%)	2.1%
Employment ('000)	1754
Investment (%)	3.6%
Real household disposable income (%)	1.4%
Balance of trade as % of GDP (pp)	0.3%

Net impact of higher energy costs and lower imports is positive: higher production and more jobs

Investment-led

Real income grows by less than GDP (higher energy costs)

Reduced oil & gas imports

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Macroeconomic results in 2050 of all scenarios relative to REF2016

EU28 Member States	A (Smart electric)	B (Passive electric)	C (Demand side breakthrough)	D (High green molecules)	D2 (Hydrogen imports)	D3 (Synthetic methane)
GDP (%)	2.1%	2.0%	2.1%	2.2%	0.7%	2.6%
Employment (000s)	1754	1214	1852	1215	1355	892
Investment (%)	3.6%	5.5%	3.5%	6.6%	1.6%	9.8%
Real household disposable income (%)	1.4%	0.4%	1.5%	0.4%	0.8%	-0.3%
Balance of trade as % of GDP (pp)	0.3%	0.4%	0.3%	0.3%	-0.2%	0.3%

Best real income and jobs impact (less costly and cut imports)

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Macroeconomic results in 2050 of all scenarios relative to REF2016

EU28 Member States	A (Smart electric)	B (Passive electric)	C (Demand side breakthrough)	D (High green molecules)	D2 (Hydrogen imports)	D3 (Synthetic methane)
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Low cost but no import saving

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Macroeconomic results in 2050 of all scenarios relative to REF2016

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Higher investment and cost

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Balance of trade as % of GDP (pp)	0.3%	0.4%	0.3%	0.3%	-0.2%	0.3%

Biggest diversion from household income & consumption. Boosts GDP but jobs lost in labour-intensive consumer services.

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Comparison of macro results with Long Term Strategy

- Similar GDP impact
  - E3ME, 1.5 degree, ‘global action’: 2.19% in LTS
- Emphasis on
  - potential higher cost of hydrogen, demand-side failure and (especially) synthetic methane options
  - in these cases higher investment, lower household income and spending, fewer jobs
  - structural change in jobs
  - importance of European competitiveness in clean technologies

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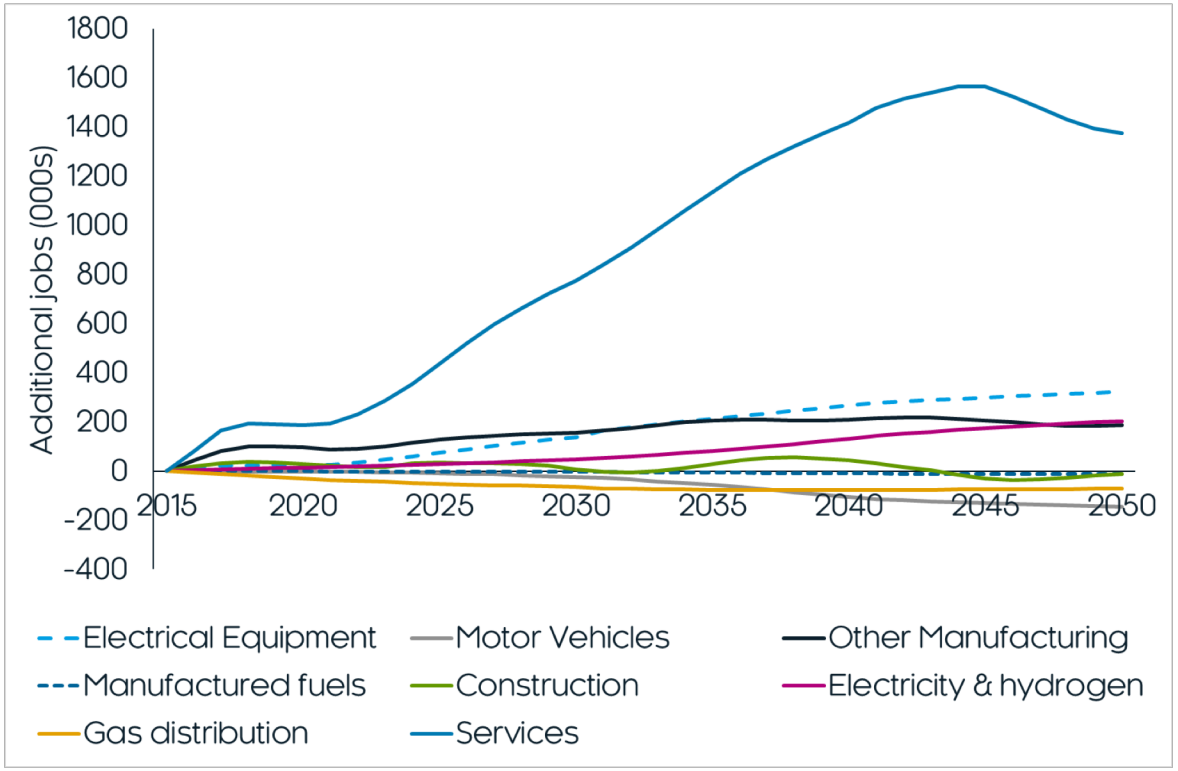
Structural changes in EU28 employment across sectors – Scenario A



- Jobs lost in oil refining and gas distribution.
- More jobs in electricity and equipment.
- Jobs transferred from motor vehicles to electrical equipment and other manufacturing.
- More jobs in labour-intensive consumer services.

Note: Difference between Scenario A and REF2016.

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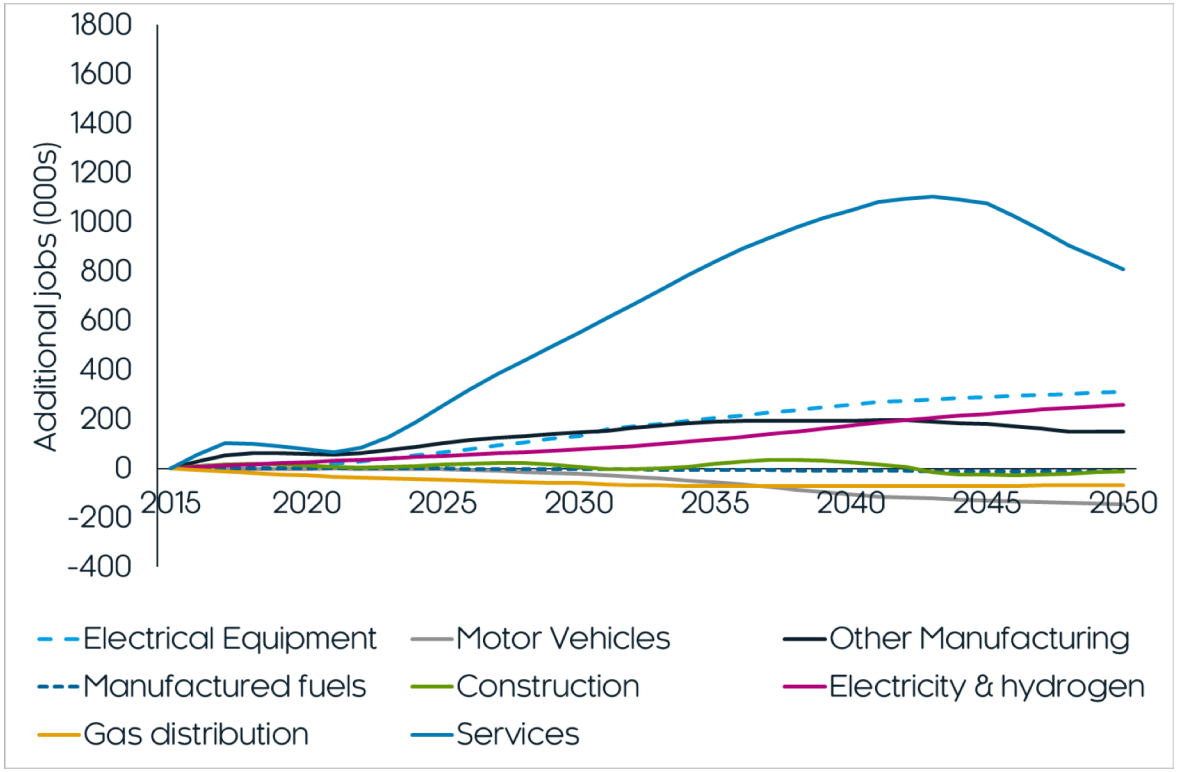
Structural changes in EU28 employment across sectors – Scenario D



Note: Difference between Scenario D and REF2016.

- Jobs lost in oil refining and natural gas distribution. More in electricity & hydrogen and equipment.
- Jobs transferred from motor vehicles to electrical equipment and other manufacturing.
- Boost to labour-intensive consumer services is less (higher energy costs).

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Summary of macroeconomic messages

- Energy costs are higher than baseline, but the GDP impact is still positive
  - because of the benefit of reducing oil imports (and substituting European production)
- Scenarios A-D have similar GDP impacts, but
  - scenario B (Passive electric) and D (High green molecules) are more costly (more investment and less consumer spending) so households benefit less

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Summary of macroeconomic messages, *contd.*

- Scenario E (hydrogen imports) is less costly
  - but less benefit from reduced imports smaller GDP impact
- Scenario F (synthetic methane) is the most costly
  - involves substantial investment (which boosts GDP) but costs households more (so that real income is actually lower than baseline in this scenario)

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Summary of macroeconomic messages, *contd.*

- The positive GDP impacts are also reflected in positive jobs impacts, but there is substantial structural change among sectors
  - jobs lost in oil refining and gas distribution
  - more jobs in electricity and equipment
  - jobs transferred from motor vehicles to electrical equipment and other manufacturing
  - more jobs in labour-intensive consumer services

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Key messages

- **Zero-carbon energy system by 2050 is feasible in different constellations and beneficial from a macro-economic point of view**
- What is needed to achieve this is a step-change in efficiency, smart flexibility and seasonal storage solutions (such as green H)
- Of the different pathways studied (high E vs high M), **deep efficiency, high electrification provide the most attractive pathway in terms of total energy system cost and macroeconomic benefits**
  - Relying on green molecules, i.e. green Hydrogen, at scale not an easier solution than electrification – would still require supersizing electricity infrastructure
- But, green molecules can play an important role to complement green electrons
  - In the absence of further innovation breakthroughs, green Hydrogen could be brought in at limited and cost-efficient scale to provide critical value as a seasonal storage of energy in regions with colder climates

Next Steps

- Feb – March: bilateral meetings with policy makers and stakeholders
- **Report launch: Thu, 14 March, 16:00 – 18:00 @ The Office.**