Value and Role of REsidential Whole System Integrated Resilience (REWIRE) Technologies in Supporting Low-Carbon Energy Future

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Strategic Innovation Fund: Round 3 Innovation Challenges

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  - Impact on the hydrogen production capacity and storage
  - Capacity factor of different hydrogen production technologies
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Context

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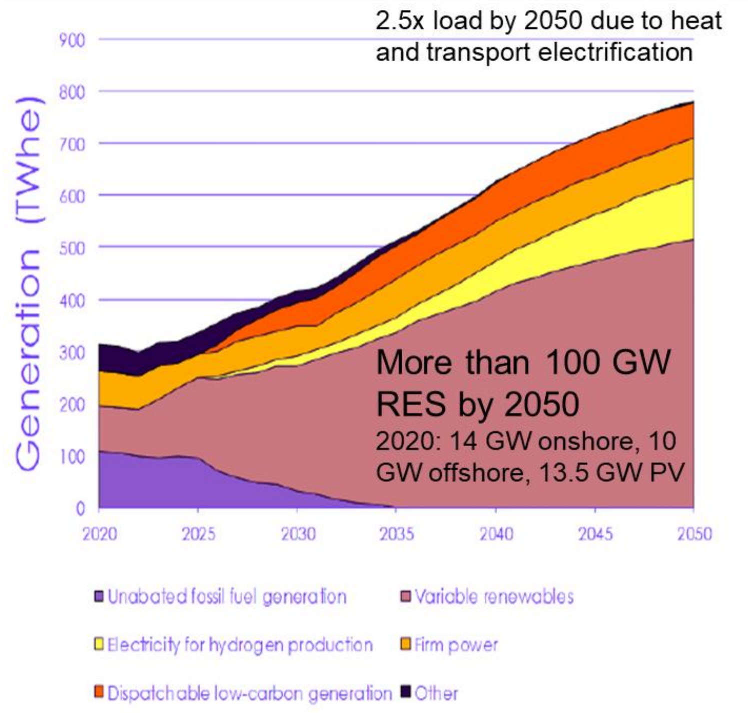
- Challenges:
  - Growing energy balancing challenges as the connected RES increase
  - Growing electrification due to heat and transport decarbonisation
  - Higher likelihood of extreme weather and infrastructure attacks
- Solution:
  - REWIRE is a domestic cross-vector storage system, exploiting reversible power-to-gas with integrated local hydrogen storage.



Source: CCC analysis.
Notes: Chart reflects UK electricity generation. Additional capacity is available through interconnection. Unabated fossil fuel generation includes coal and gas. Variable renewables include wind and solar. Firm power includes nuclear. Dispatchable low-carbon generation includes gas CCS, BECCS and hydrogen.

Objective

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- Evaluate the system benefits of the REWIRE solutions to support the transition to a net-zero emission energy system in the context of
  - Benefits of flexibility services
    - Savings in CAPEX and OPEX of energy system
    - Utilisation of existing gas infrastructure for transporting and storing hydrogen.
  - Benefits of domestic multi-energy concept in enhancing resilience of supply

Case study description

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- Energy system background
  - 2050 Net-zero "Leading the Way"
  - Hydrogen pathway
- Rewire technologies evaluated
  - Domestic electrolyser+ fuel-cell + hydrogen storage Rating: 5kW charging and discharging, and 40kWh.
  - Efficiency
    - Electrolyser: 68%
    - Fuel cell: 60%
    - Hydrogen storage: ~100%
- Cases:
  - Counterfactual: no Rewire technologies
  - Around 10% domestic (15 GW) with 8 h domestic hydrogen storage
- Key analysis
  - Gross system benefits (£/year per unit installed)
  - System implication

Whole-system modelling critical for capturing technology, spatial and temporal diversity, investment and operation decision interactions in multi-energy low carbon systems

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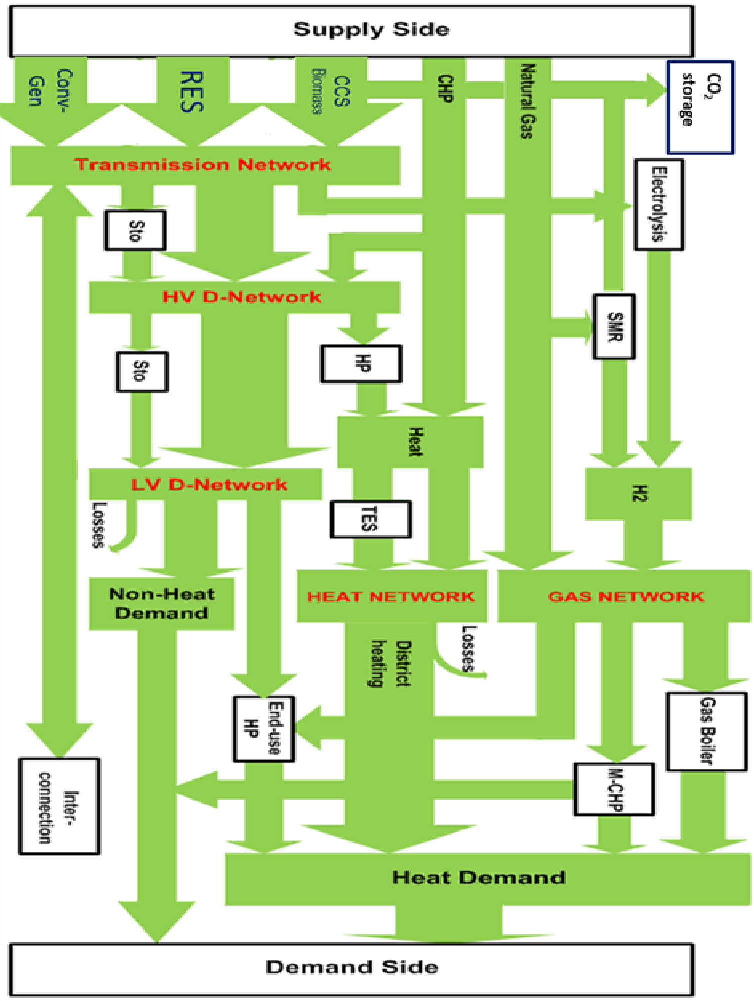

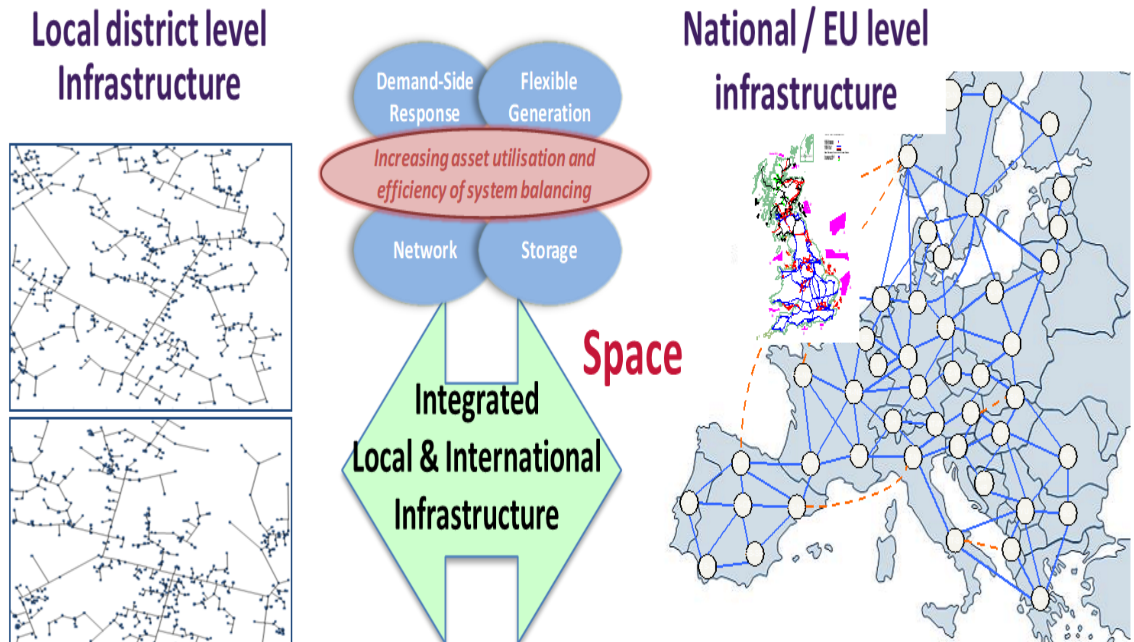

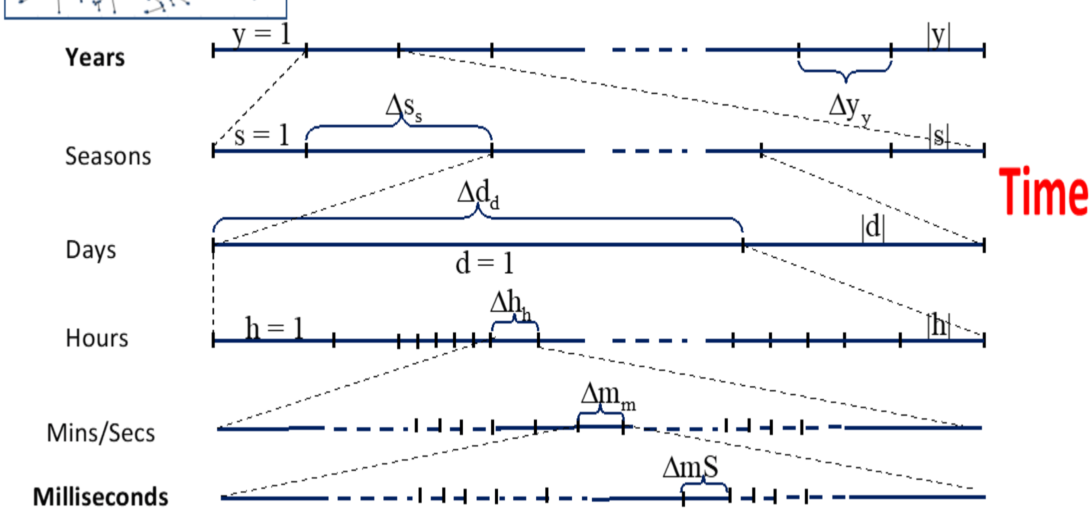

IWES – *Integrated, Whole-Energy System model*

IWES in a nutshell

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Formulated as a least-cost optimisation problem to determine investment and operation of multi-energy systems involving electricity, gas (including hydrogen), heating, and CCUS systems to meet the carbon target while maintaining system security.

Input data

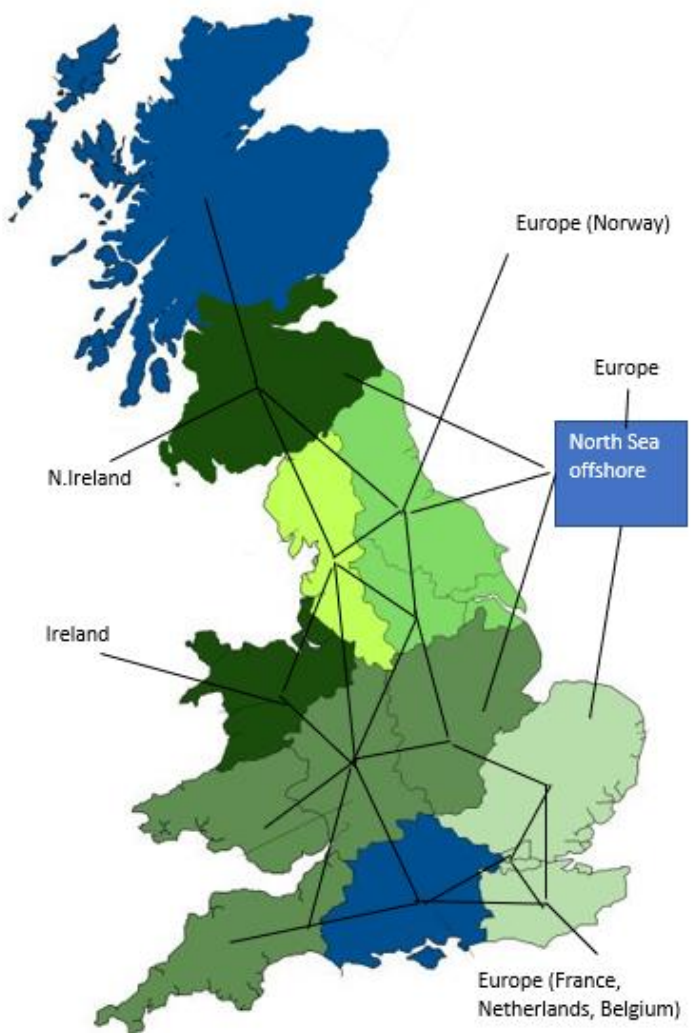
- Load profiles: electricity, space heating and hot water, transport for both domestic and non-domestic
- Technologies
  - ❖ Power generation (e.g. RES, nuclear, hydro,biomass, geothermal, CHP, H_2 power, CCGT/OCGT with and without CCS)
  - ❖ Network (transmission onshore and offshore, distribution, interconnector)
  - ❖ H2 production (methane reformer, electrolysis, bioenergy)
  - ❖ H2 network
  - ❖ Heating technologies (ASHP, G/ WSHP, CHP, solar thermal, NG and H2 boilers, hybrids, district heating)
  - ❖ Energy storage (electricity, heat, hydrogen)
  - ❖ CCUS (carbon storage, DACCS, CCUS)
  - ❖ Demand response
- CAPEX, OPEX
- Other constraints: e.g. emissions

Output data

- Optimised multi-energy infrastructure
- Coordinated multi-energy operation
- CAPEX and OPEX
- Fuel usage
- Carbon captured and emission performance
- Energy exchange and capacity sharing across regions
- Flexibility deployment considering sector coupling

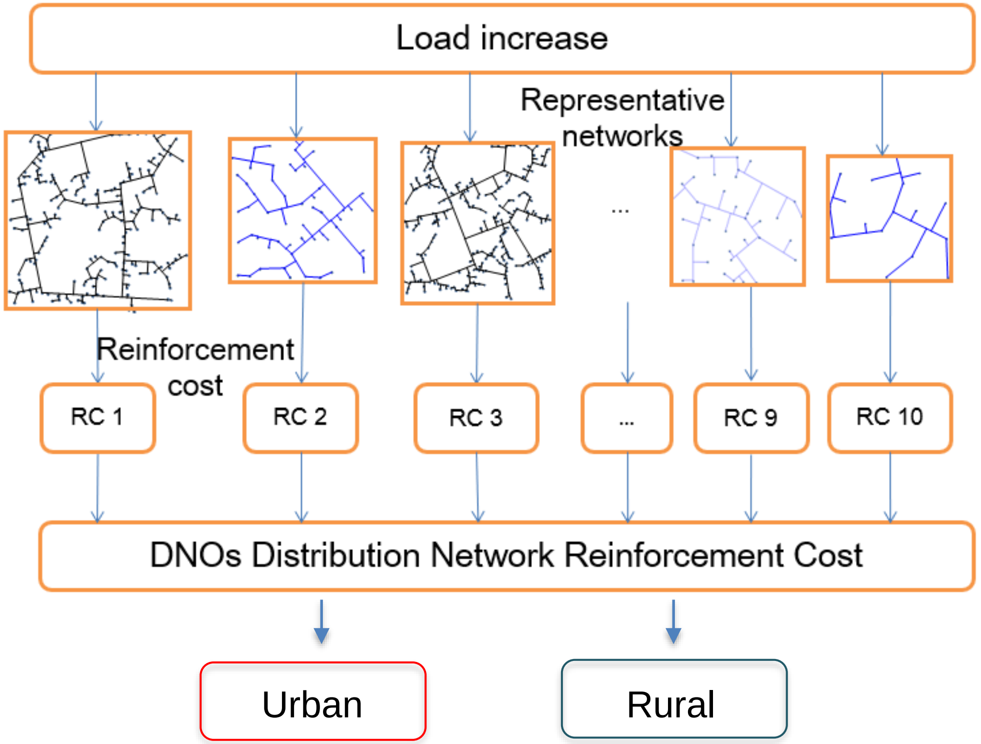
Electricity Network

Transmission system



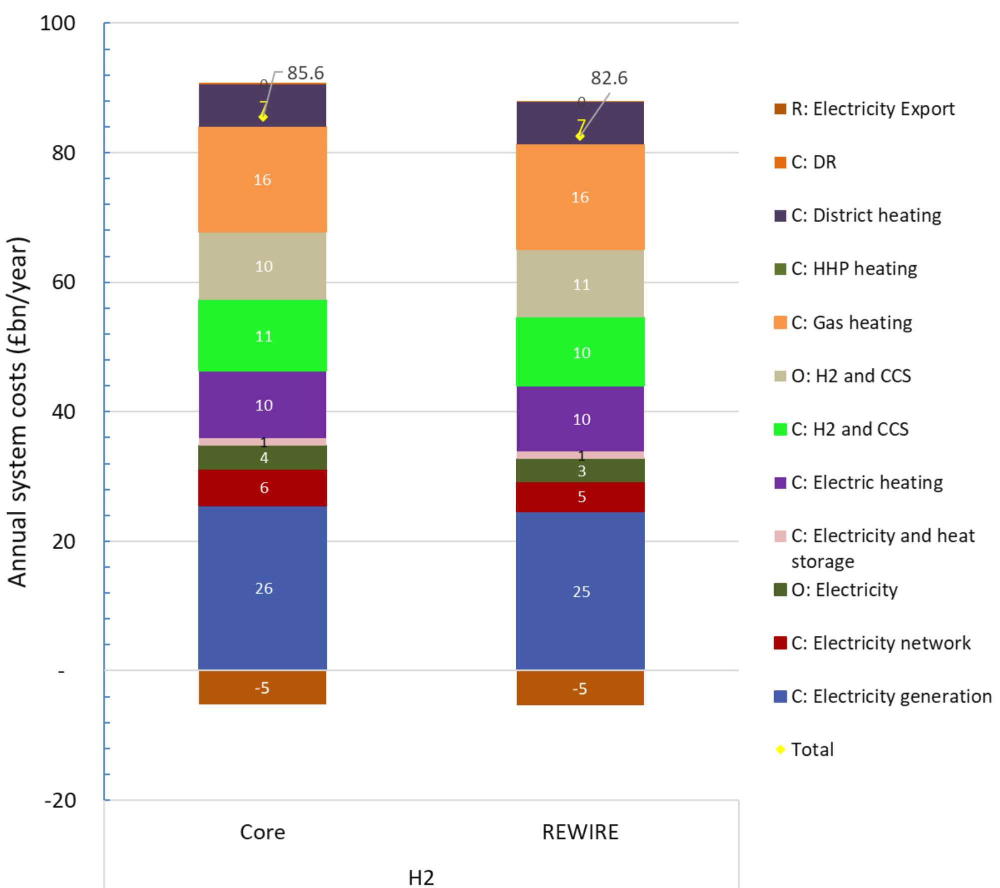
Distribution system

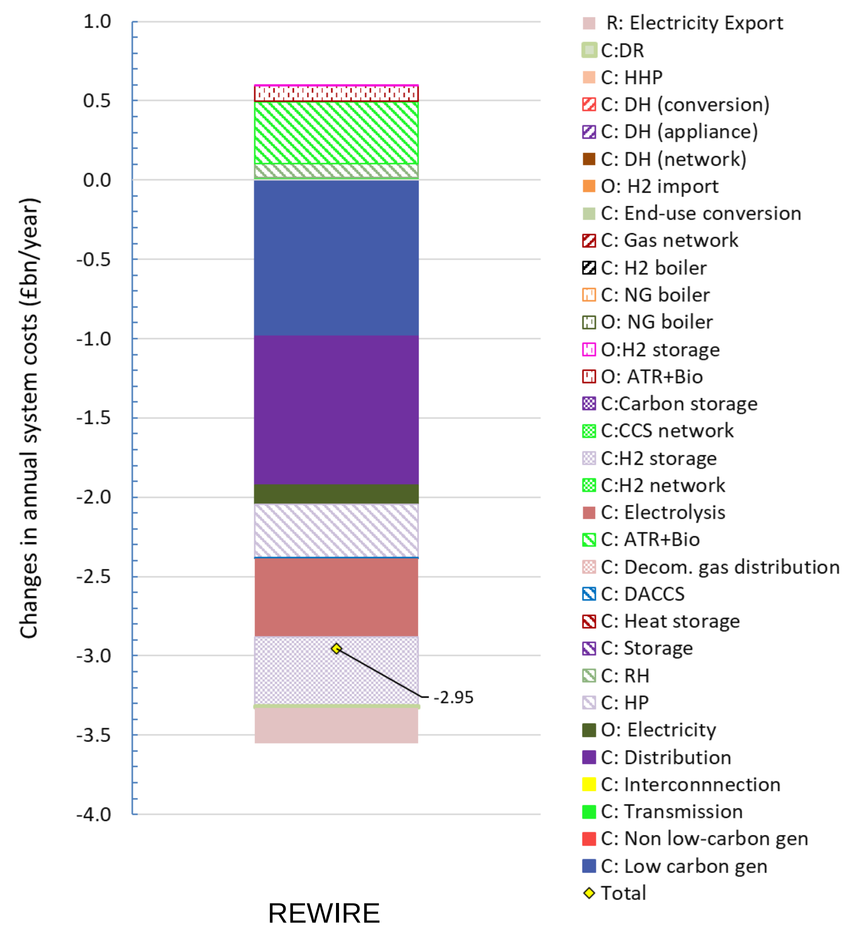
Cost curves approach



Each distribution region consists of urban and rural systems.

Gross system benefits of REWIRE technologies





Gross system benefits of 15 GW REWIRE is £2.95B/year, i.e. **£197/kW per year**

While main savings are in the reduction in low-carbon generation, distribution cost, hp, and large-scale electrolysers and hydrogen storage, and higher export of electricity.
Additional costs include the cost of ATR+CCS, resistive heating, and OPEX of hydrogen storage

Impact of REWIRE on annual electricity demand

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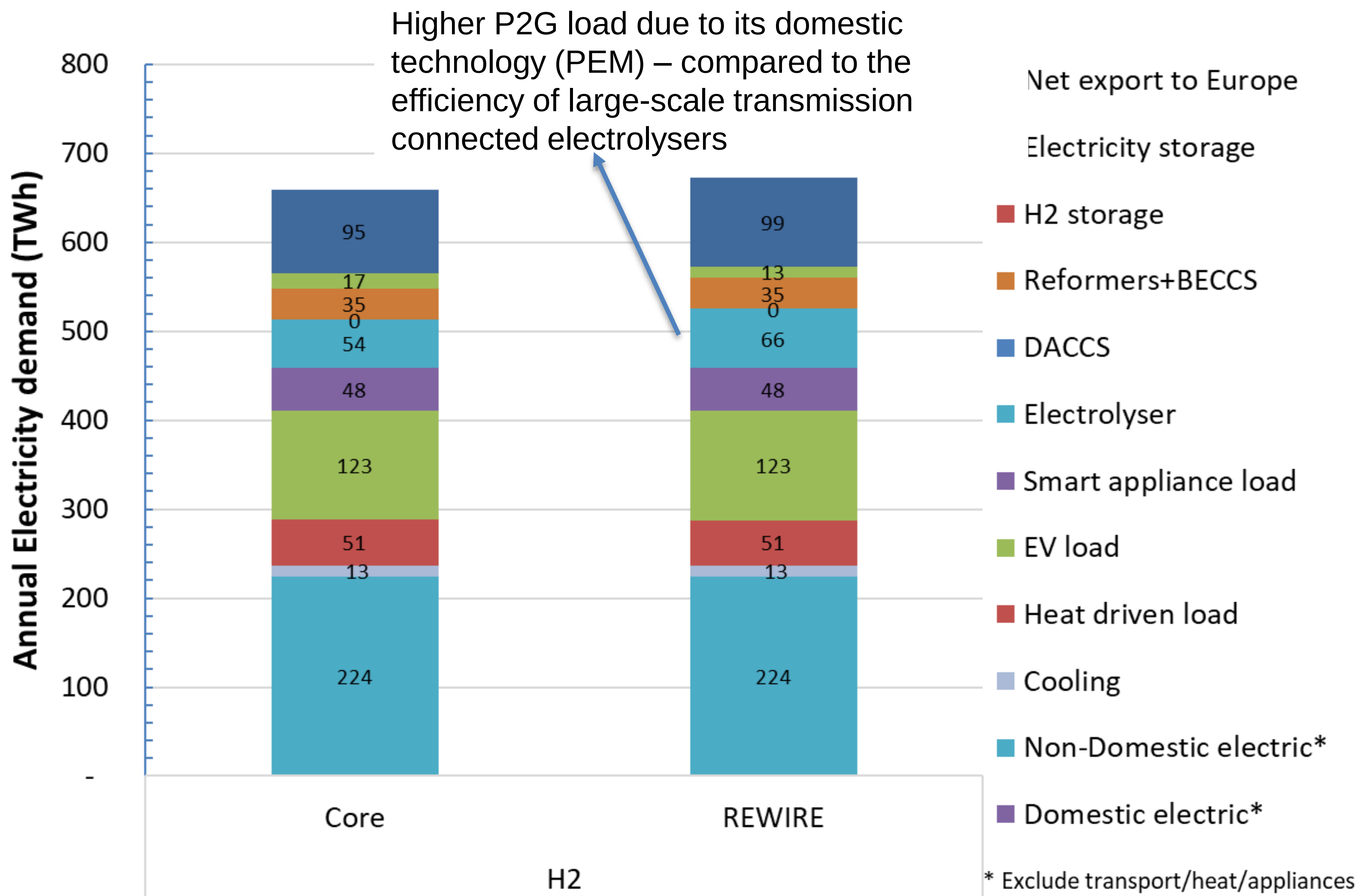
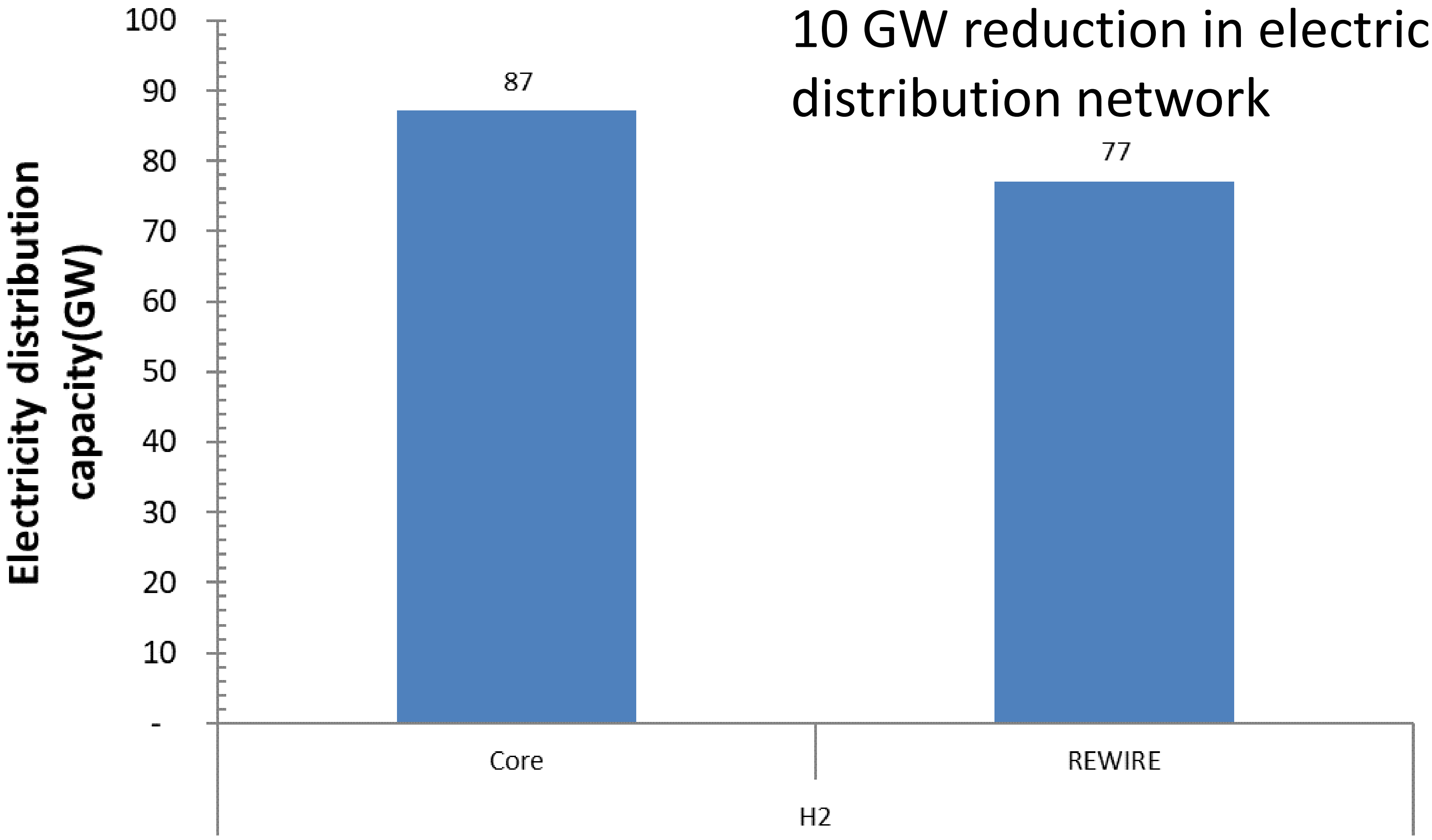


Improving the efficiency of domestic electrolysers is important to reduce increase annual electricity demand because of REWIRE technology.

Impact of REWIRE on electricity distribution capacity need



Fuel cell integrated in REWIRE can reduce electricity peak demand and acts as local back-up to improve energy security at domestic premises.

Impact of REWIRE on the optimal power generation portfolio

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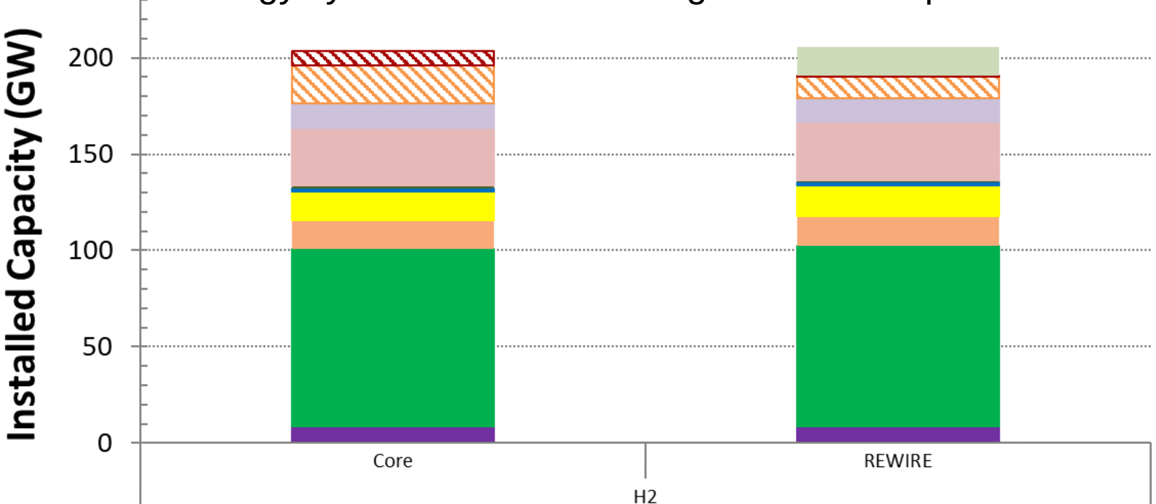
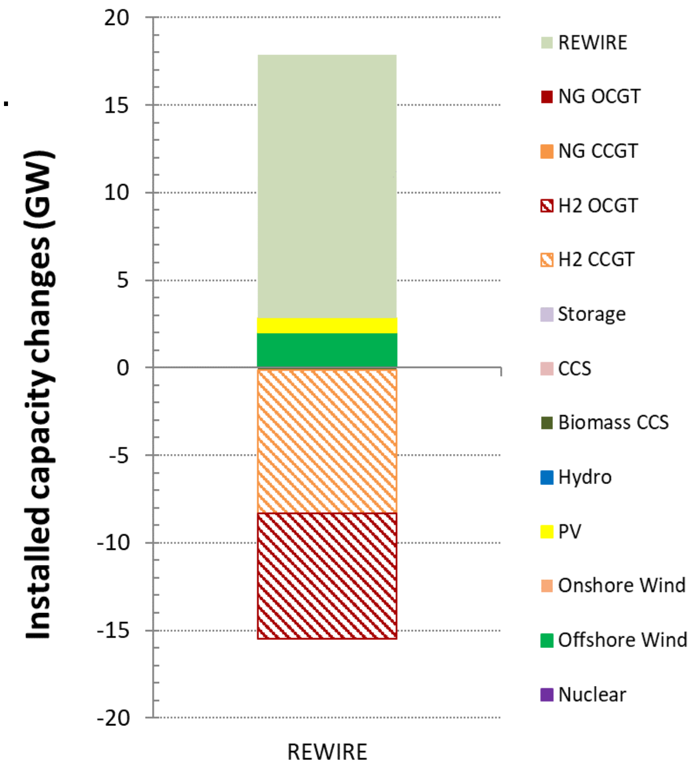
Low-carbon dispatchable generators such as gas CCS and hydrogen power generation are used for balancing and providing firm capacity to meet peak demand and support energy system resilience during low-RES output conditions.

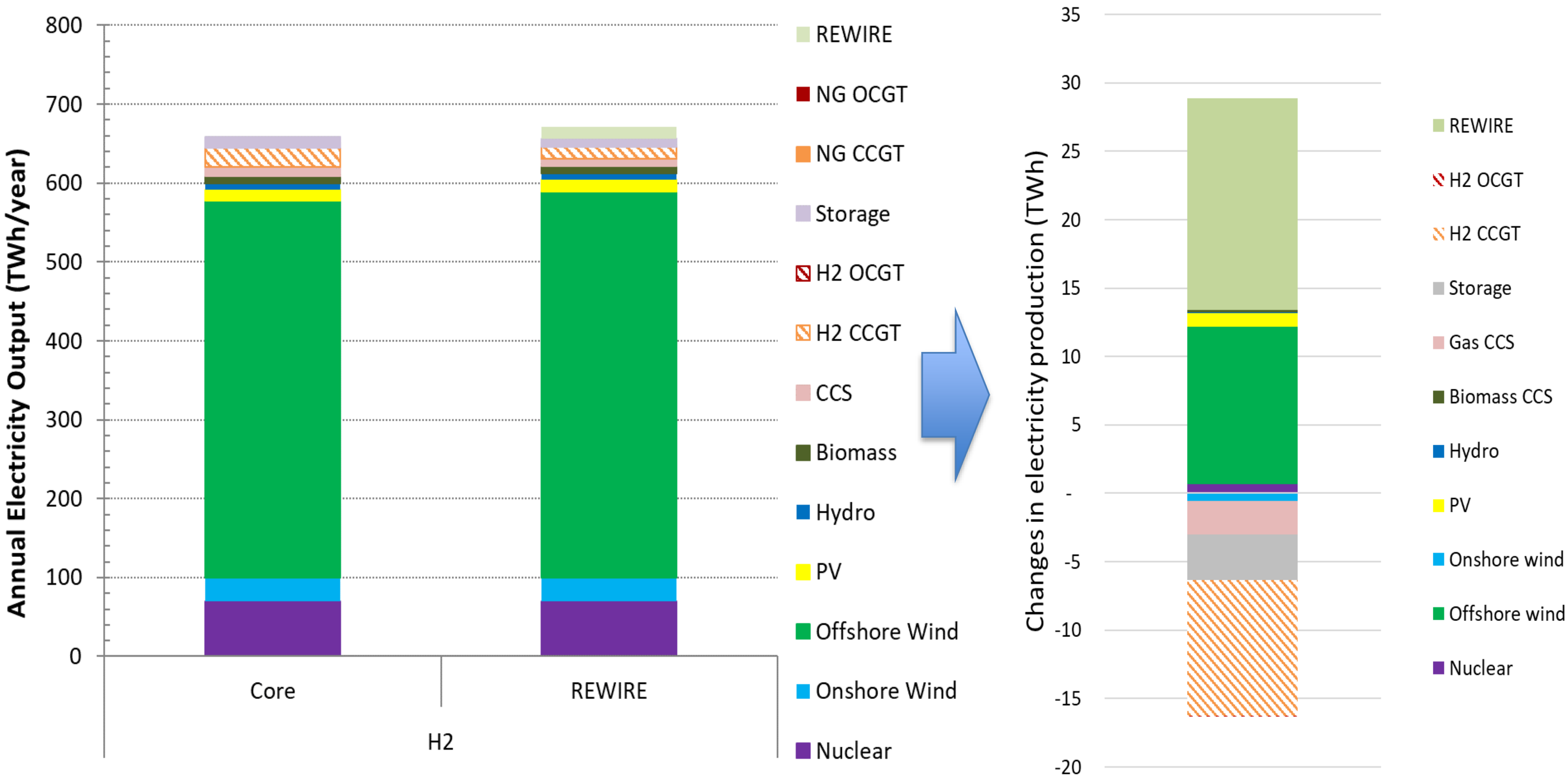


	H2 Core	H2 REWIRE
REWIRE	0	15
H2 OCGT	7.6	0.4
H2 CCGT	19.2	11.1
Storage	12.7	12.7
CCS	29.9	29.9
Biomass CCS	1.6	1.4
Hydro	1.5	1.5
PV	15.2	16.1
Onshore Wind	15.0	15.0
Offshore Wind	91.8	93.7
Nuclear	8.9	8.9



REWIRE can displace capacity of large-scale hydrogen generation while improving energy security of domestic customers because it is local.

Impact of REWIRE on the electricity production



REWIRE displaces large-scale hydrogen power generation capacity and output. It also reduces electricity storage and gas CCS usage. It enables more integration of RES as the alternative.

Impact of REWIRE on the demand and supply of hydrogen

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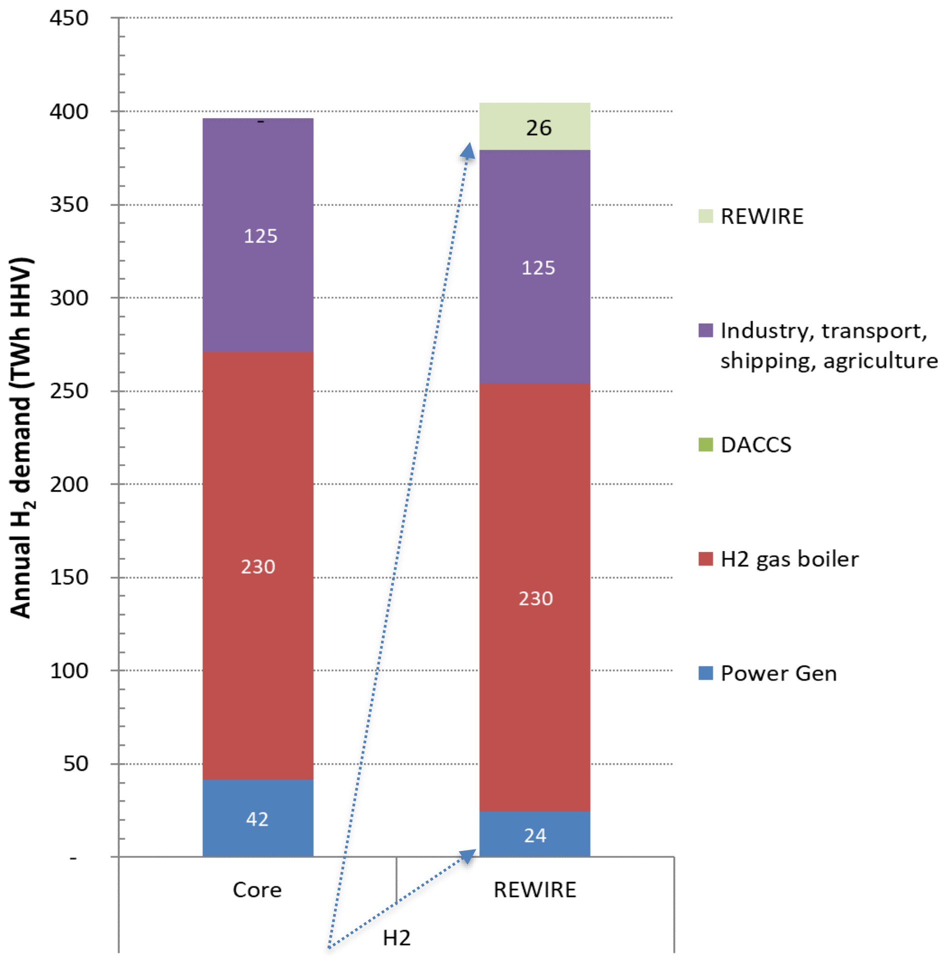
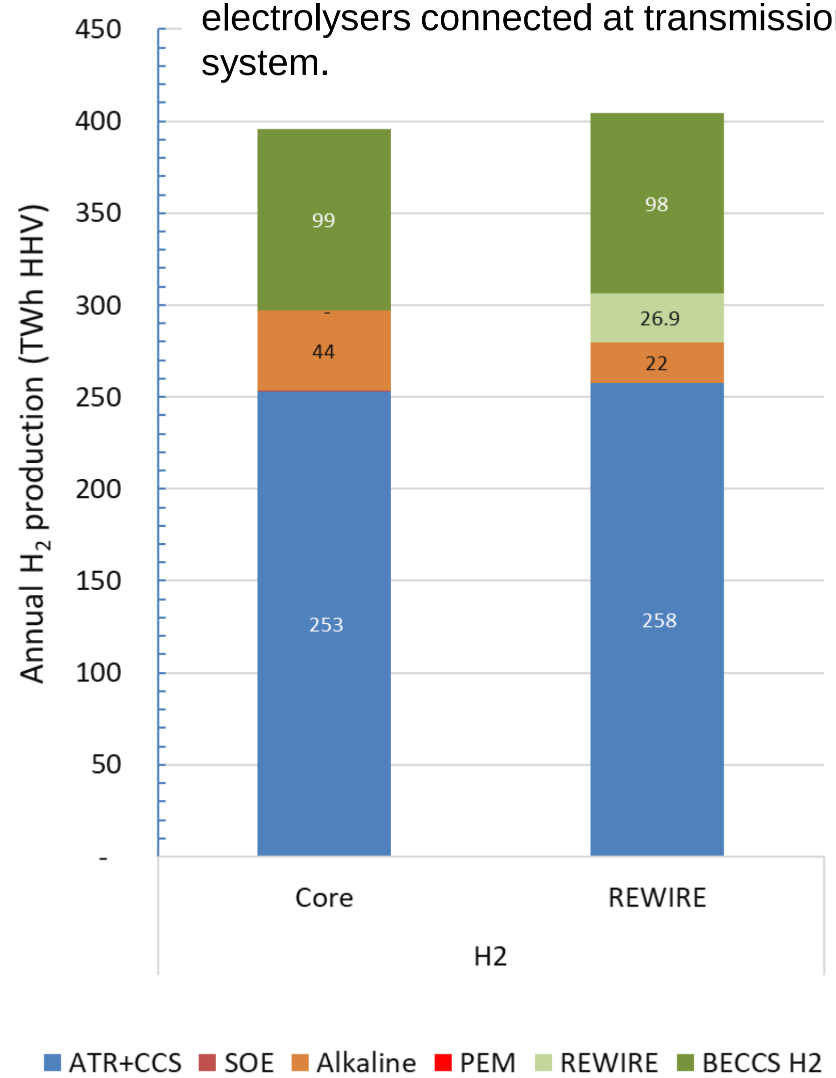
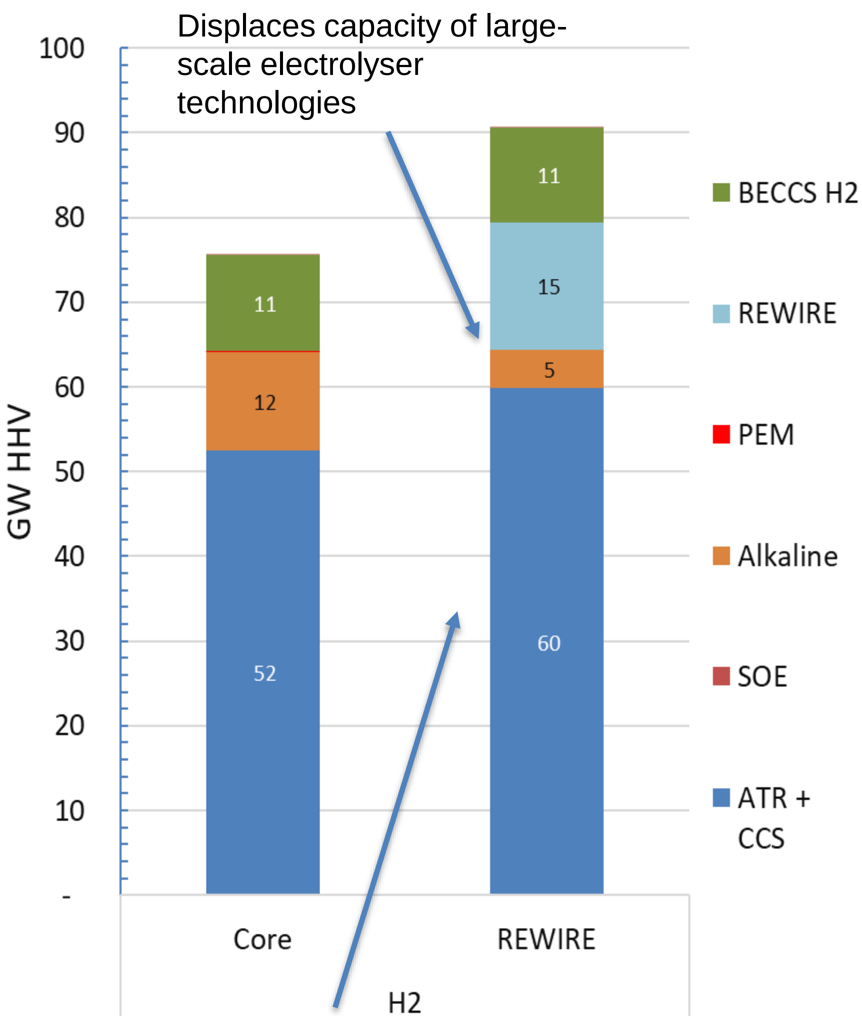


Trade-off between hydrogen consumed for large-scale power generation or domestic fuel cell.

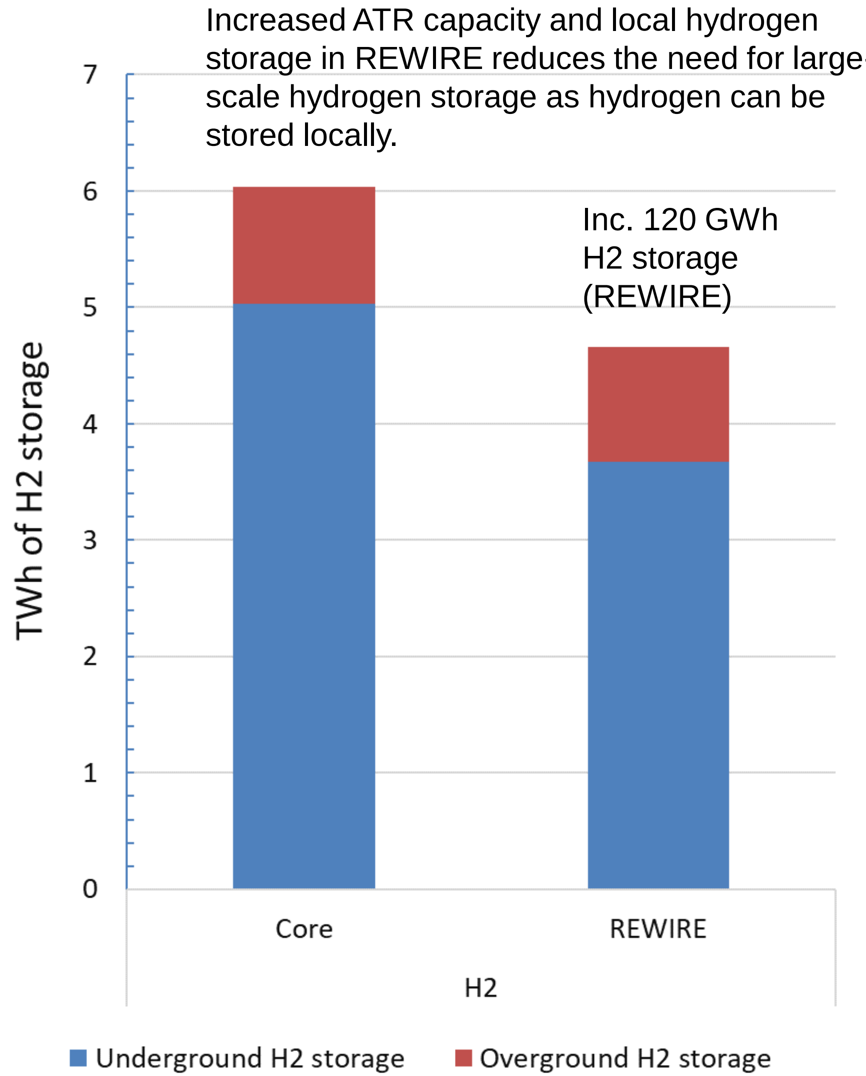
Domestic electrolyser in REWIRE displaces production from large-scale electrolysers connected at transmission system.



Impact of REWIRE on the hydrogen production capacity and storage



Increased ATR capacity to produce hydrogen when distribution capacity is constrained.



Increased ATR capacity reduces H2 storage requirement

Capacity factor of different hydrogen production technologies

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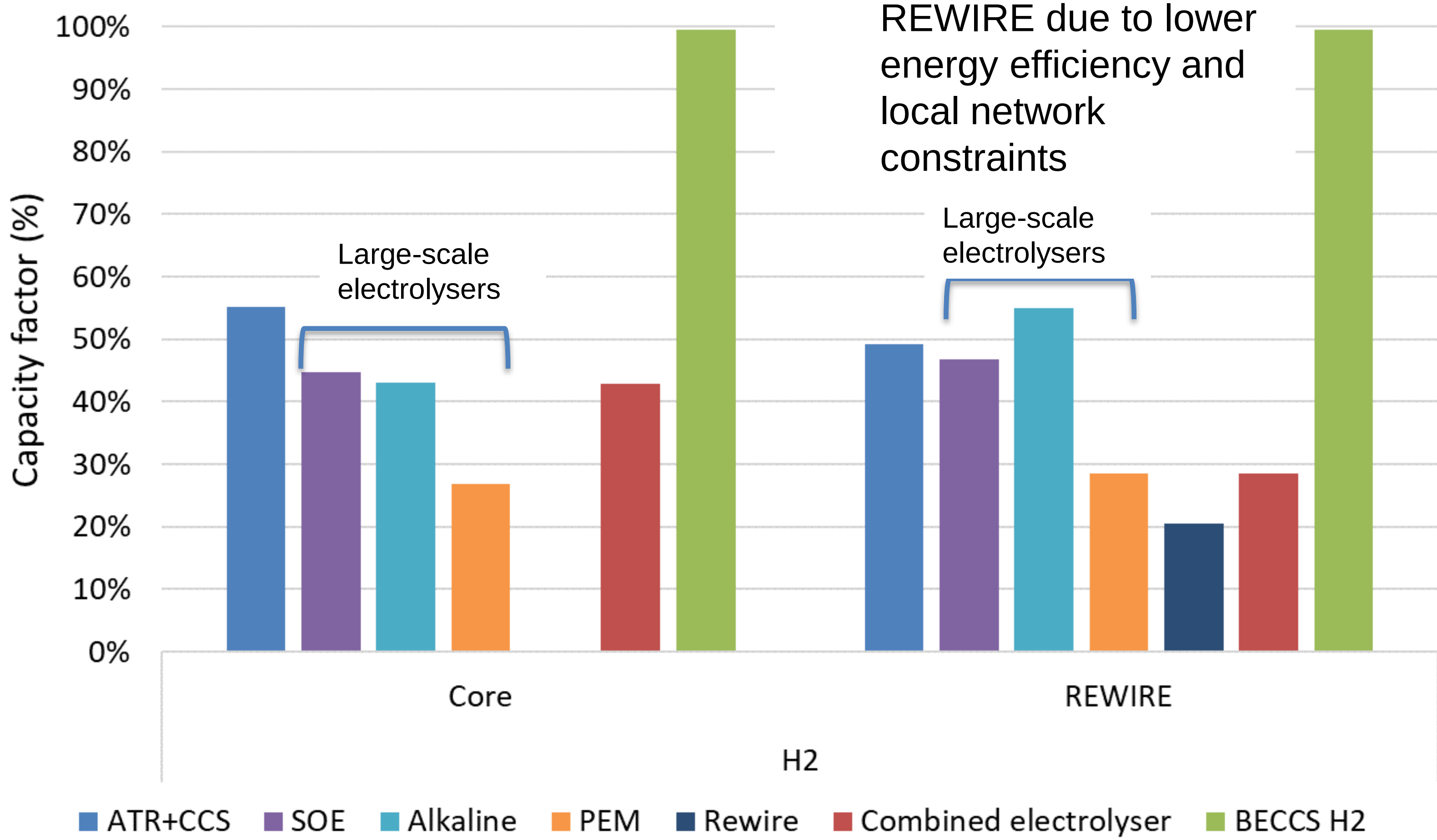
Low-capacity factor of REWIRE due to lower energy efficiency and local network constraints



Impact of REWIRE on other flexibility technologies

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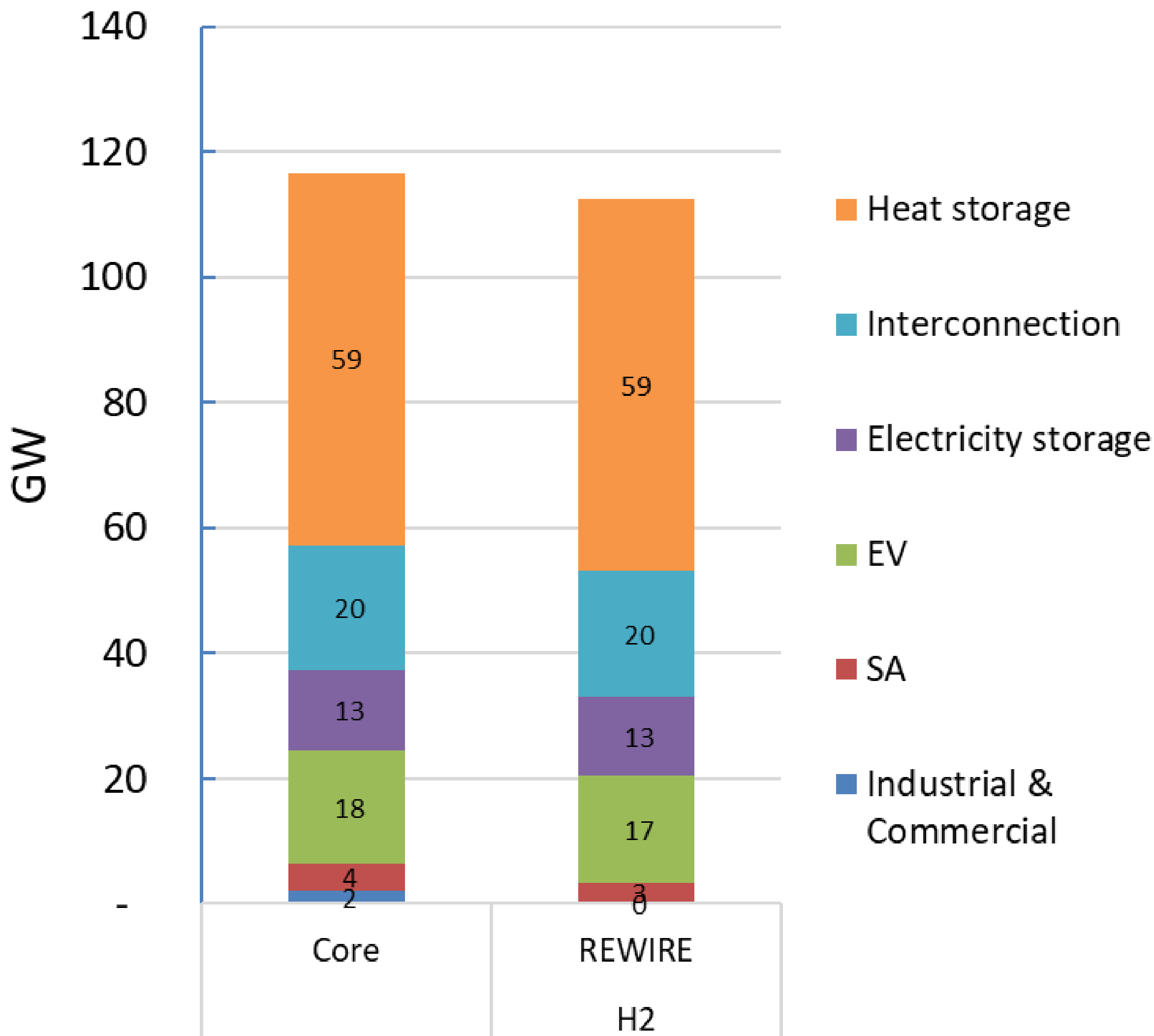

REWIRE improves system flexibility and therefore reduces the need of other distributed flexibility resources, e.g. demand response technologies.

Conclusions

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- Gross system benefits of 15 GW REWIRE is £2.95B/year, i.e. **£197/kW per year**
  - With 30 years lifetime, the accumulated system benefits > £5900/kW
  - Main savings: low-carbon generation, distribution cost, hp, and large-scale electrolysers and hydrogen storage
- REWIRE
  - Has a capacity value and displaces firm capacity provided by H2 generation
  - Enables/needs some more investment in wind and PV
  - Displaces output from H2 CCGT, electricity storage, and gas CCS --
  - Support distribution network (reduce the need for distribution capacity)
  - Displaces capacity and output of large-scale electrolyser technologies
  - Improve system flexibility and therefore reduces the need of other distributed flexibility resources
- Challenges
  - Low-capacity factor of REWIRE indicates lower energy efficiency
    - Assuming high-end characteristics of the technology
  - Integration of electricity and hydrogen system

APPENDIX

LAVO

An integrated solution, when combined with rooftop solar can power an average Australian home for 2 days.

Key Parts [1]:
- PEM Fuel cell – converts stored hydrogen energy to electrical power
- DC-DC converter – Regulates power output from fuel cell
- Battery – traditional Lithium-ion battery to enable fast response time
- Hybrid inverter (not included [2]) – Manages electrical flow between solar, house and LAVO
- Electrolyser – Converts excess solar energy to hydrogen
- Water purifier – De-mineralises tap water for electrolyser use
- LAVO Hydride – patented metal hydride hydrogen storage solution

- Cost: £18,800 [2]
- Outdoor installation required [2]
- Annual professional maintenance probable [2]

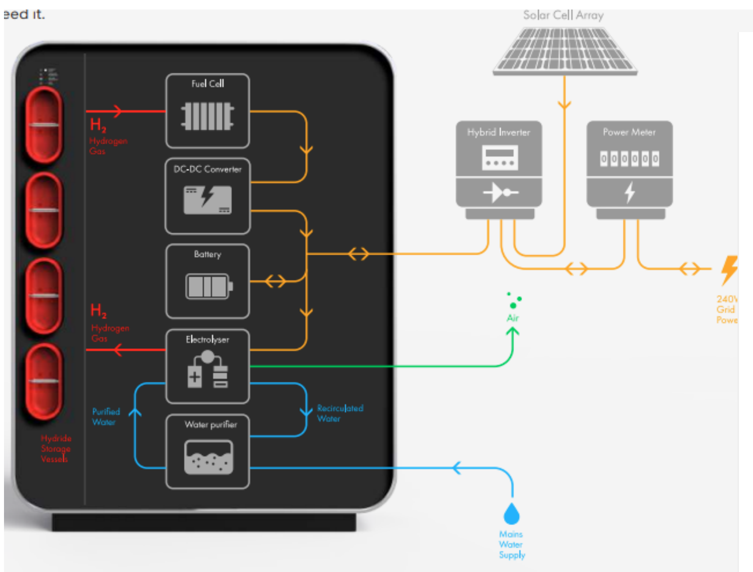

Figure 1: LAVO set-up [1]

Mechanical

Dimensions (HxWxD)	1680 x 1240 x 400 mm
Weight	196 kg
Hydride Vessels	4 vessels
Max System Pressure	35 bar_g
Vessel Weight	32 kg
Total Installed Weight	324 kg
Mounting	Floor Mount / Outdoors

Environmental

Operational Temperature Range	-10° to +50° C
Recommended Temperature Range	5° to 45° C
Environmental Humidity Range	3 to 100% RH
Maximum Elevation	2000 m
Noise Level	< 45 dB
Enclosure Protection Rating	IP54

Performance

Usable Capacity	40 kWh
Real Power, max continuous	5 kW (charge and discharge)
Nominal Voltage	48 V DC
Output Voltage Range	45 – 53 V DC
Hydride Cycles	< 20,000
Warranty	10 years
Lifetime	30 years

Connections

Water Supply	Portable Mains Water / LAVO™ water purification unit
Communication	Local WiFi / Ethernet / 4G / 5G

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