Mapping Synergies in the Freight Sector to Enhance the Success of Future Low Carbon Energy Systems

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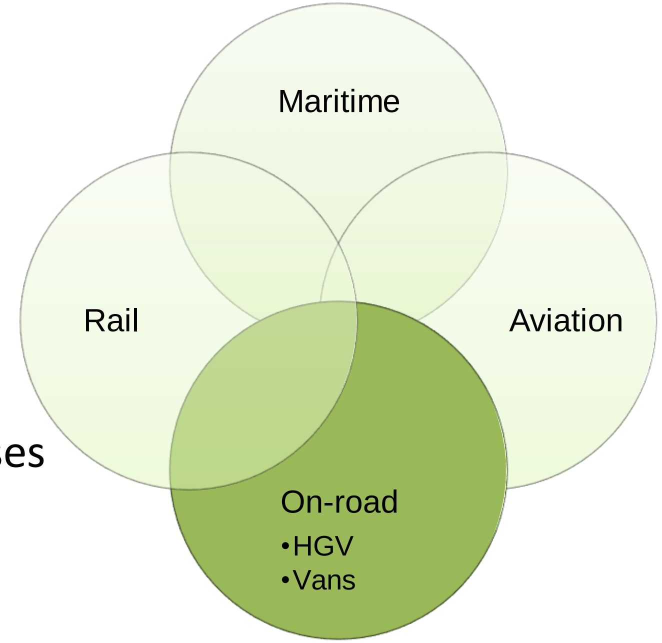
Multi-objective Optimisation

Security and reliability of supply as a function of energy demand
Whole system ideology leading to decreased costs, accelerating decarbonisation, and increased energy security
Identify and assess the severity of the evidence gaps in the future energy system for transport



Analysis Boundaries

Key issues will be analysed at 2030 and 2050
Current in-lab technologies, or more advanced technologies, will be included in the analyses
- Technology concepts will not be addressed

National viewpoint
First addressing on-road transport
Passenger vehicle sales will include a diminishing contribution from combustions engines until 2035
HGV sales will include a diminishing contribution from combustions engines until 2040

Energy System Analysis

Energy Generation → Distribution → Refuelling/Recharging Station → Use

Key Linchpins

Energy Generation
- SMR with CCS
- Electrolysis
- Curtailed Energy
- Energy Availability
- Renewable Energy Required

Distribution
- Use of pipeline infrastructure
- Infrastructure vkm requirements
- Grid Capacity
- Level of Decentralisation
- Hyper Hubs
- Industrial Cost

Refuelling/Recharging Station
- Hydrogen Refuelling Stations
- Consumer cost
- Recharging times
- Electric Road System

Use
- Niche Applications
- Vehicle Specifications
- Vehicle LCA
- Scaling up fuel cells and batteries

CO_2 reduction ability
Government subsidy timelines

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Energy Generation	Distribution	Refuelling/Recharging Station	Use
SMR with CCS	Use of pipeline infrastructure	Hydrogen Refuelling Stations	Niche Applications
Electrolysis	Infrastructure vkm requirements	Consumer cost	Vehicle Specifications
Curtailed Energy	Grid Capacity	Recharging times	Vehicle LCA
Energy Availability	Level of Decentralisation	Electric Road System	Scaling up fuel cells and batteries
Renewable Energy Required	Hyper Hubs		
	Industrial Cost		

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Hydrogen Energy System Analysis

Key Linchpins

Energy Generation

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Use

Level of Decentralisation

Electrolysis

Curtailed Energy

Use of pipeline infrastructure

Hyper Hubs

Hydrogen Refuelling Stations

Scaling up fuel cells and batteries

Energy Storage

Hydrogen Energy System Analysis

Energy Generation

↓

Use

Key Linchpins

Level of Decentralisation

Electrolysis

Curtailed Energy

Use of pipeline infrastructure

Hyper Hubs

Hydrogen Refuelling Stations

Scaling up fuel cells and batteries

Energy Storage

	Risk Level			
Barriers	Low	Moderate	High	Unknown
Technological readiness	Can be purchased on a consumer/industrial level - optimised solutions	In commercial operation - solutions still need optimisation for full scale up	Very few examples of technology in place or still under theoretical development	
Scalability	Can increase load to meet demand	Can increase energy output with a few modifications	New infrastructure would be needed to meet changing demand	
Geographical	No geographical dependence	Relational geographical dependence (level of decentralisation)	Completely geographically dependent	
Consumer Engagement	Consumer engagement is beneficial but not required	Consumer engagement and external engagement required	Relies completely on consumer engagement	
Resource	Not limited by natural resources		Limited by natural resources	
System Logistics	Can operate logistics independently		Requires coordination of logistical planning	
Disruption to daily life	No disruption	Moderate daily changes	Energy system redesign	
Resilience	Able to adapt to energy changes	Can adapt but will influence cost, and other factors	Change influences system's ability to adequately supply energy	
Reduce CO_2 emission	Can achieve CO_2 emissions reduction goals alone	Can aid in CO_2 reduction goals	Cannot aid in CO_2 reduction goals	
Consumer cost	Consumer cost will decrease	Consumer cost will remain unchanged	Consumer cost will increase	
Industrial cost	Distributing energy will be less than current	Distributing will cost the same as current operations	Distributing energy will cost more than current	
National cost	Government funding needed until 2030	Government funding needed until 2050	Government funding needed beyond 2050	

Hydrogen Energy System Analysis

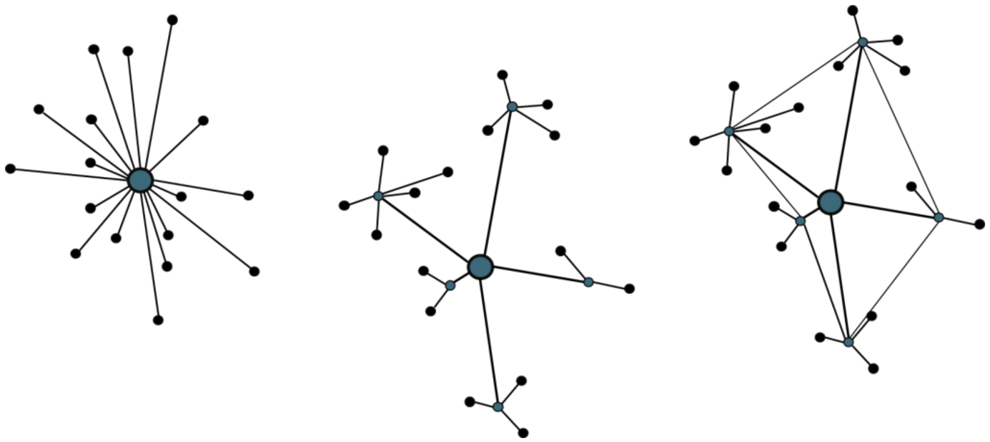
Risk Level: Low | Moderate | High | Unknown

Key Linchpins

Energy Generation → Use

Key Linchpins	Tech. Readiness	Scalability	Geographical	Consumer Engagement	Resource Requirements	System Logistics	Resilience	Reduce CO_2	Consumer Cost	Industrial Cost	National Cost
Level of Decentralisation	Moderate	Moderate	Low	Low	Unknown	Moderate	Low	Unknown	Unknown	Unknown	Unknown
Electrolysis	Moderate	Moderate	Moderate	Low	High	High	Moderate	Moderate	Unknown	Unknown	Unknown
Curtailed Energy	High	High	High	Low	High	High	Moderate	Moderate	Unknown	Unknown	Unknown
Use of pipeline infrastructure	Moderate	Unknown	High		Low	High	Moderate	Unknown	Unknown	Unknown	Unknown
Hyper Hubs	Moderate	Moderate	High		Low	High		Low	Unknown	Unknown	Unknown
Hydrogen Refuelling Stations	High	Moderate	Moderate	Low	Moderate	Moderate	Low			High	Unknown
Scaling up fuel cells and batteries	Moderate	Unknown	Low		High	Moderate	Unknown	Low	Moderate	Moderate	Unknown
Energy Storage	Moderate	Low	High		High	High	Low	Moderate		Unknown	Unknown

Scaling Up Unknowns



- What level of decentralisation will there be?
- How will a profit be made on a national/industrial level while keeping costs as low as possible for the consumer?
- Will these decisions change how the consumer interacts with the energy system?
- To what degree will freight move to rail/maritime?

Project Deliverables

- Start to determine the requirement differences in scaling up these technologies in a centralised/decentralised system

- Identify and assess the severity of the evidence gaps in the future energy system for transport

- Populating DfT interactive energy system diagram with peer reviewed manuscripts, reviews, reports, policies, evidence gaps, key energy hurdles, timelines, etc.

Providing a Home Base for Future Research

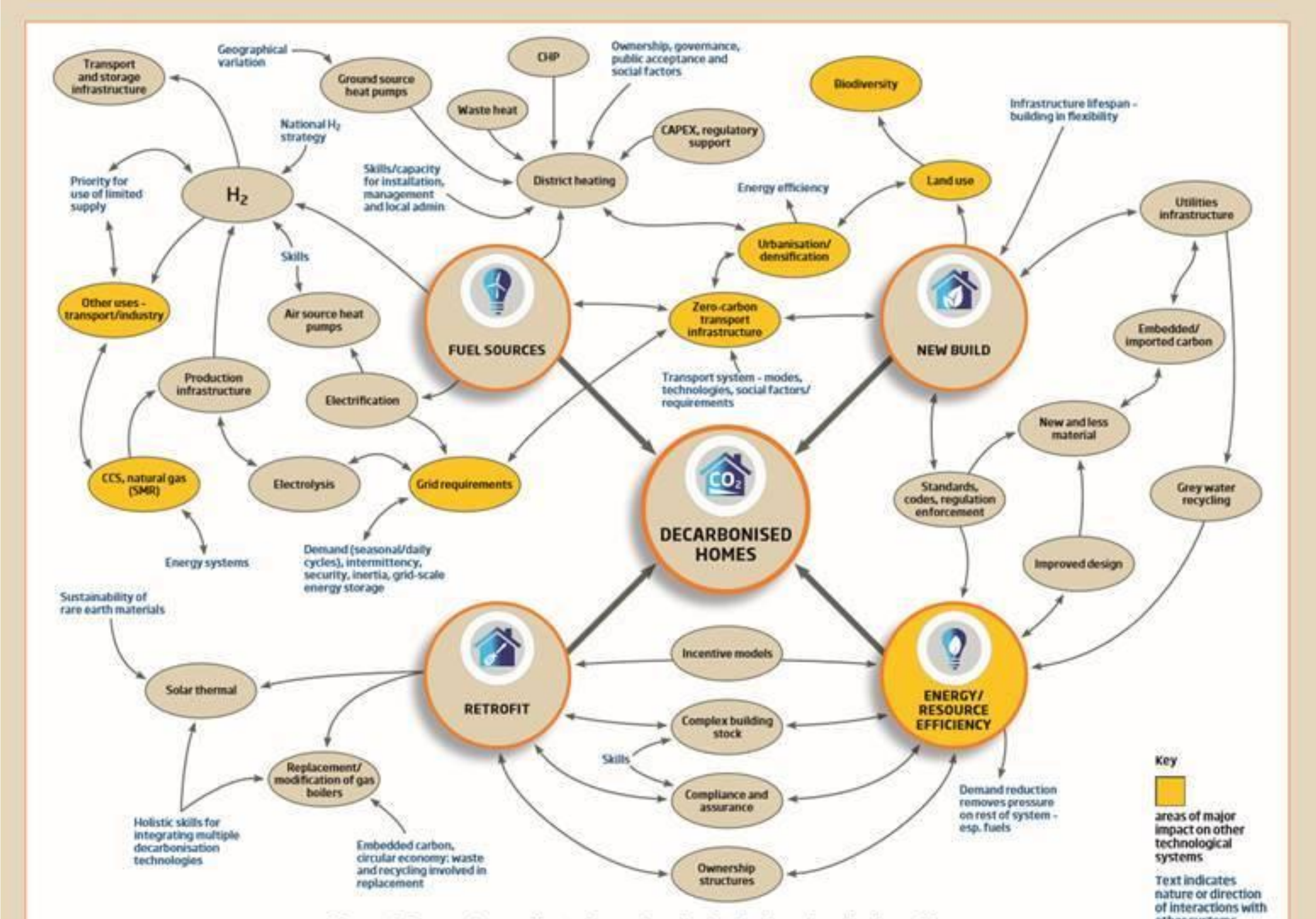
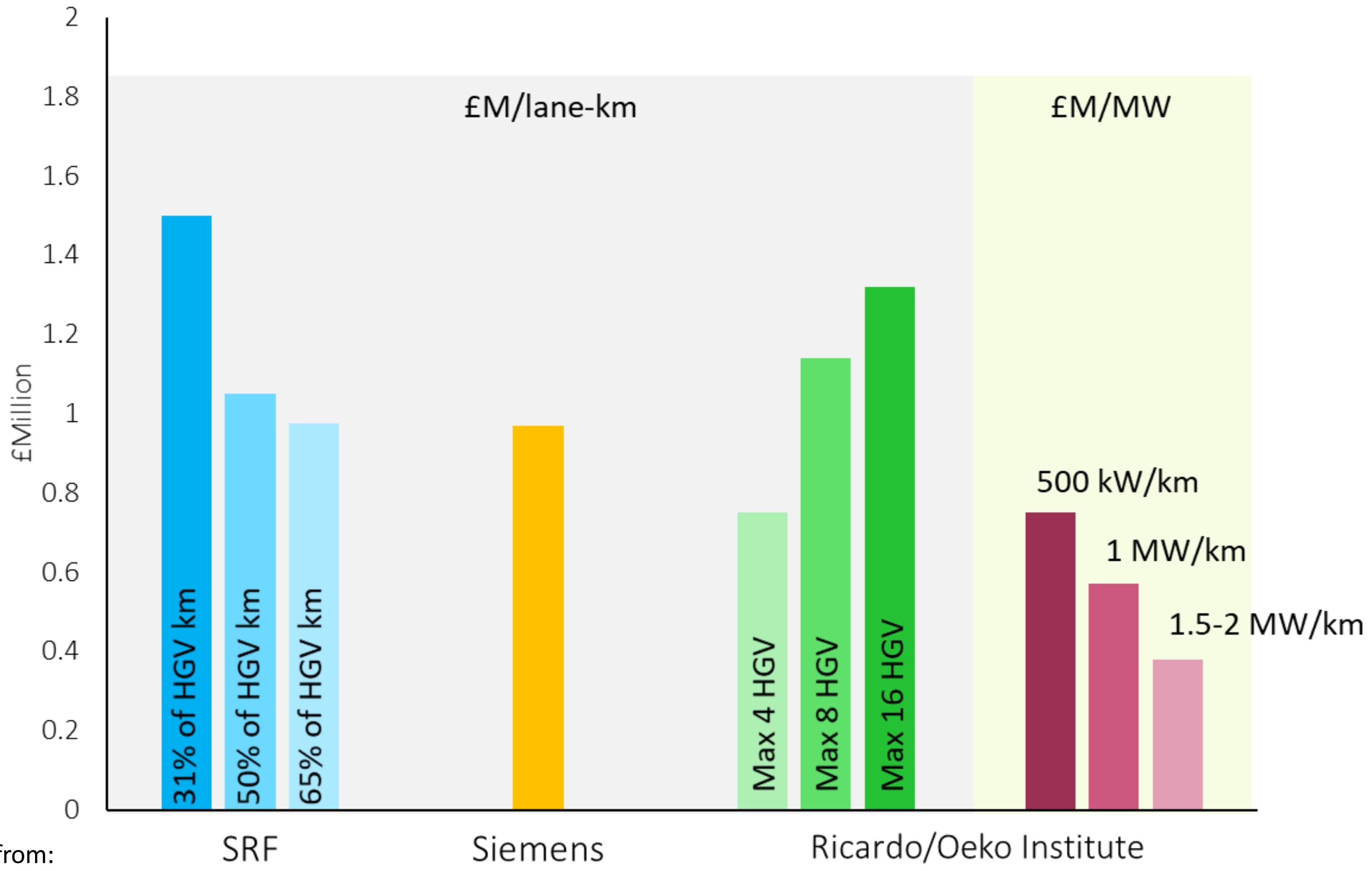


Figure 1: Synergies and interdependencies in the decarbonisation of homes

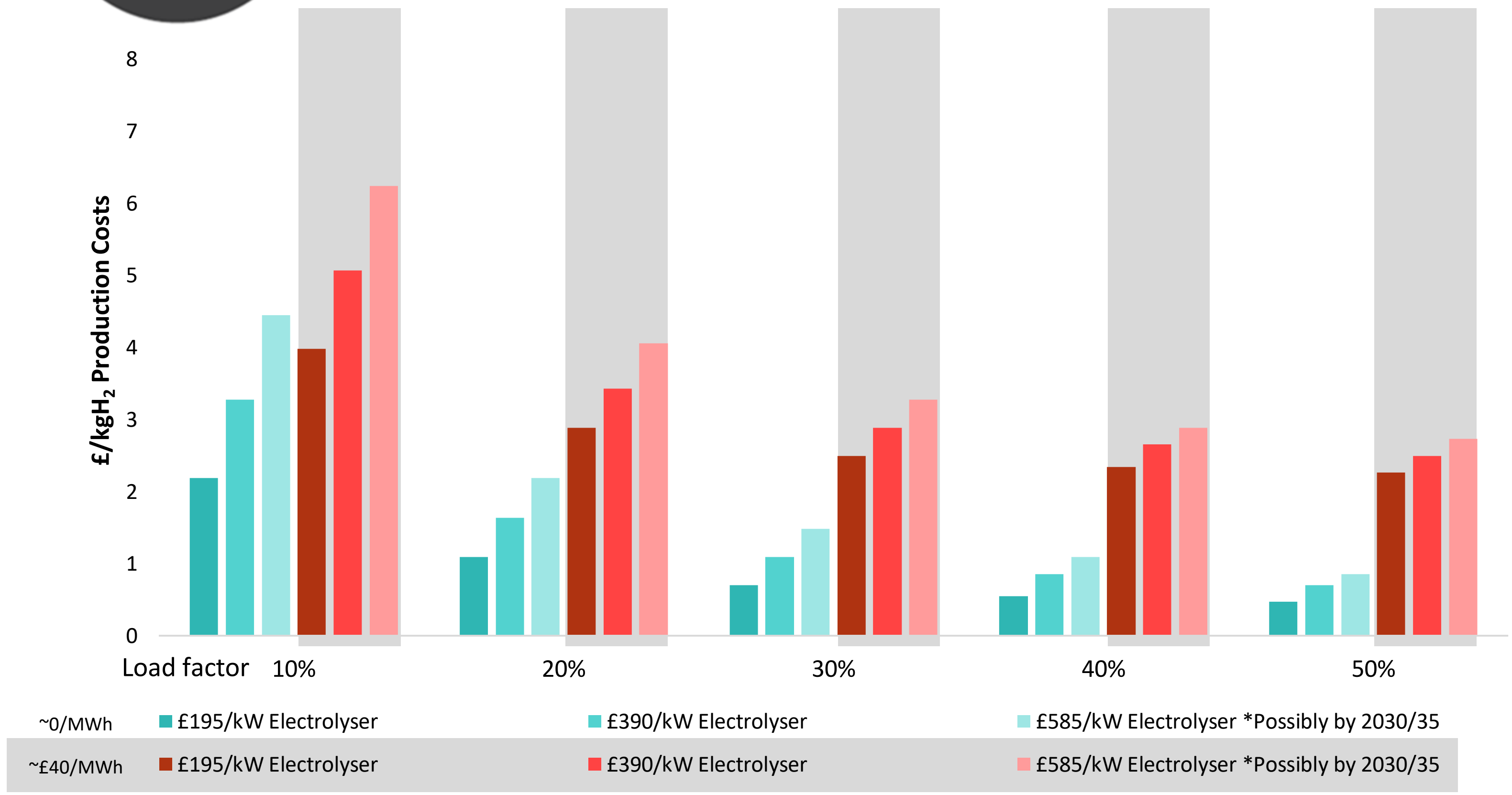
Flow chart created by DfT

Electric Vehicle Pathway

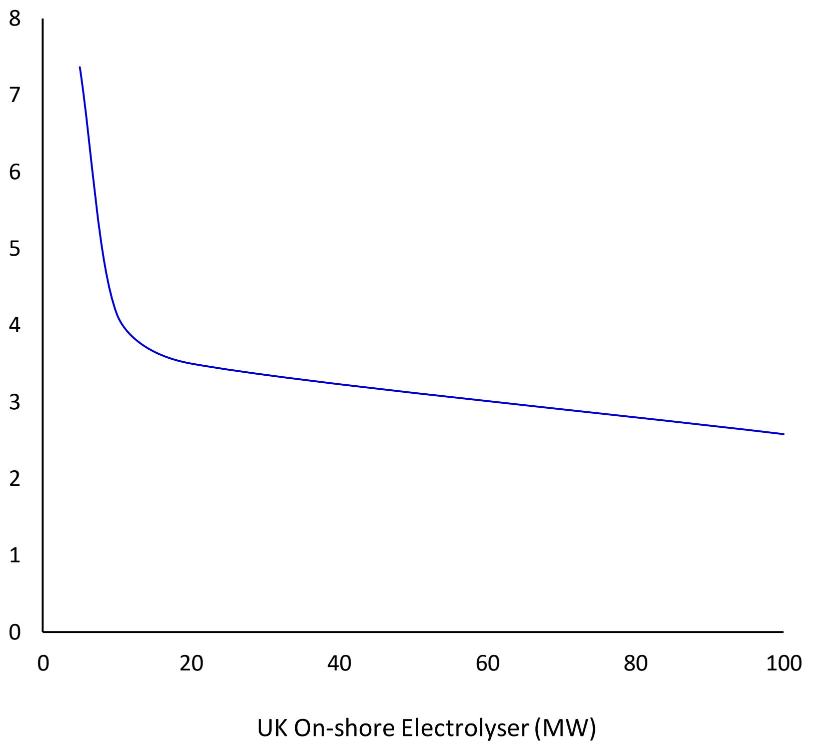


Adapted from:

"Green" Hydrogen Production



Adapted from Hydrogen Council 2020 - McKinsey



Adapted from IHS Markit 2020

- Mass production reduces costs for hydrogen
- H_2 for niche applications will cost more
- Degree of centralisation matters
- Requires the most renewable energy

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