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Heat: The major technical challenges we face in delivering decarbonised heat in the UK

Dr Andrew Smallbone

Durham Energy Institute

Oxford Energy Series– 18th January 2022

Talk overview

1. The challenge of heat in a net-zero world
2. The opportunity for hydrogen
3. A local hydrogen-enabled energy system
4. Summary
5. Net-zero research network

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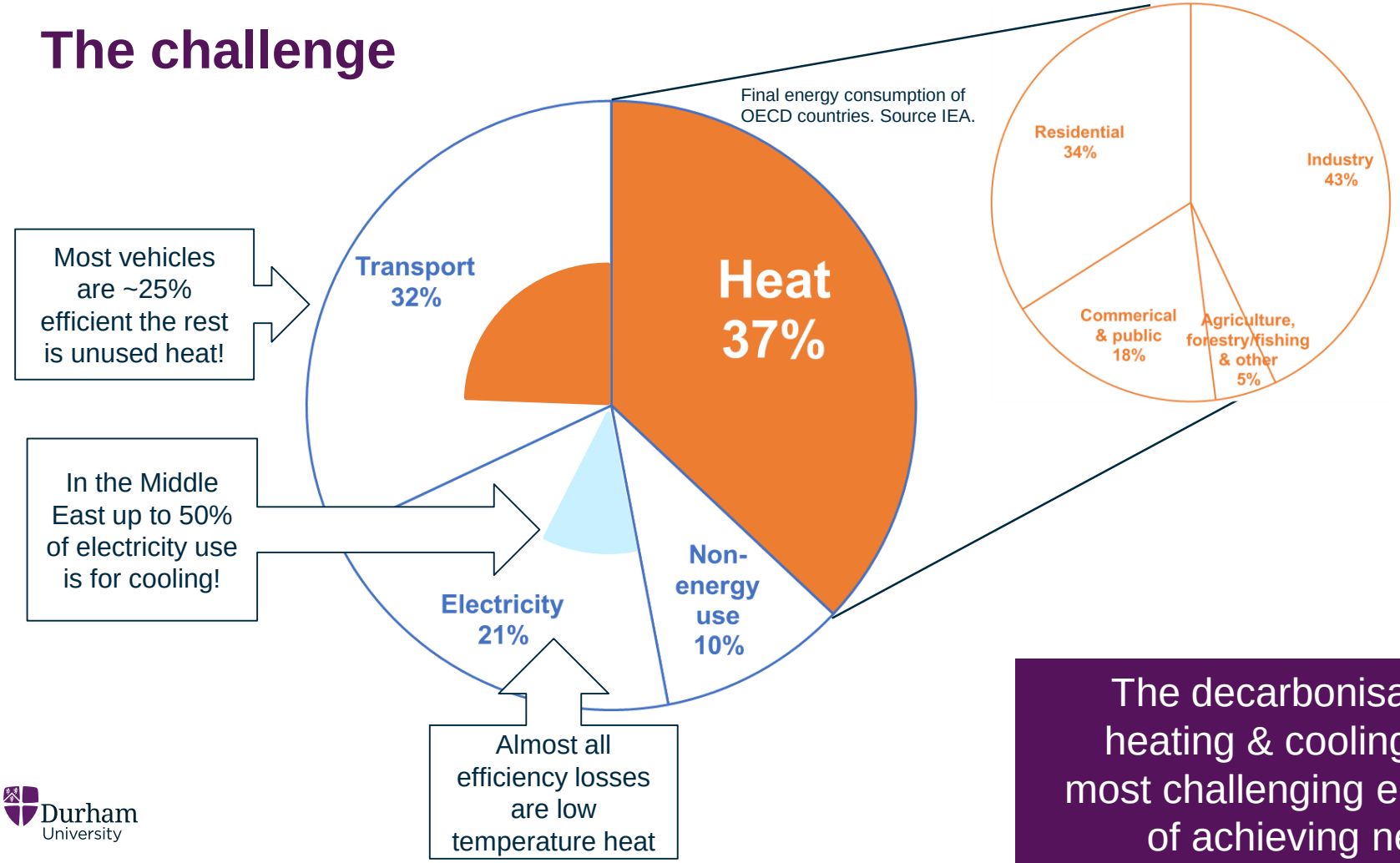
The challenge of heat

The challenge



The decarbonisation of heating & cooling is the most challenging element of achieving net-zero

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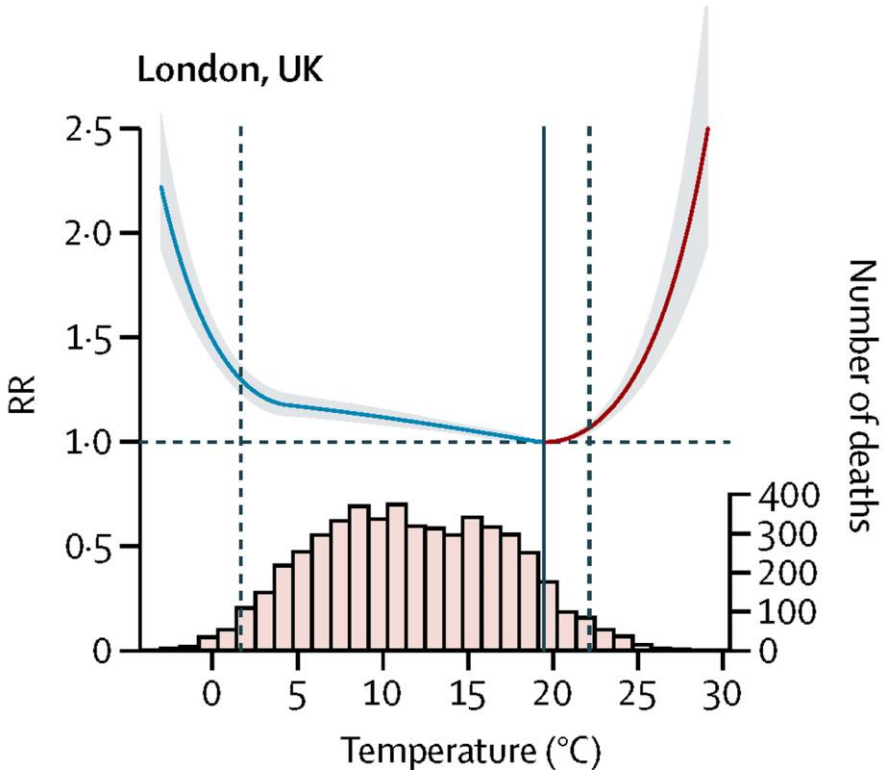
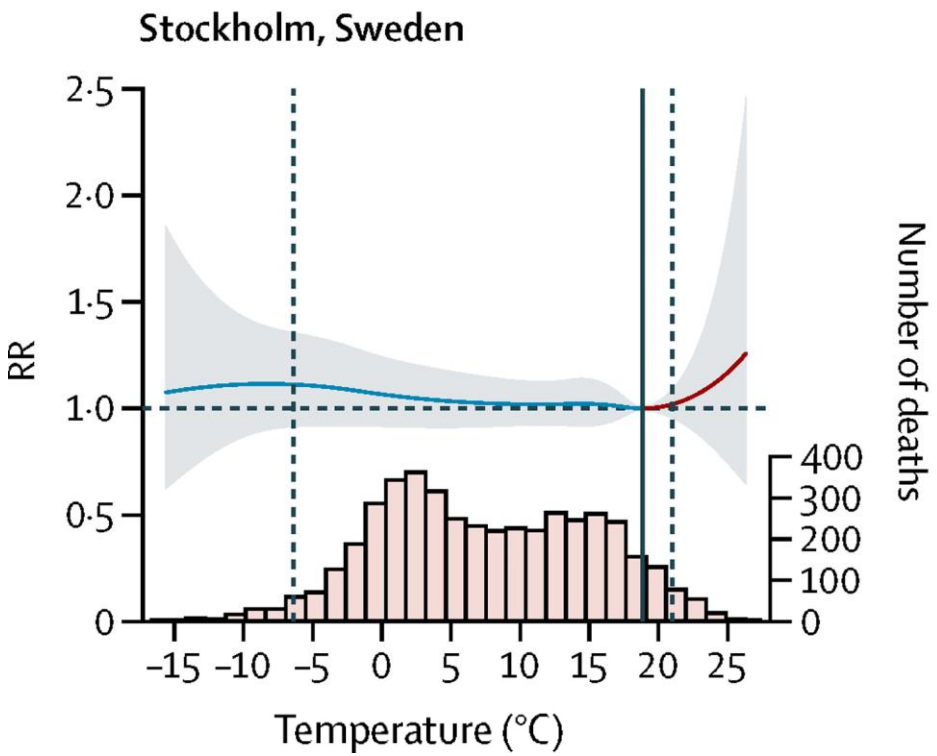
Heating is different – there's a direct link to mortality





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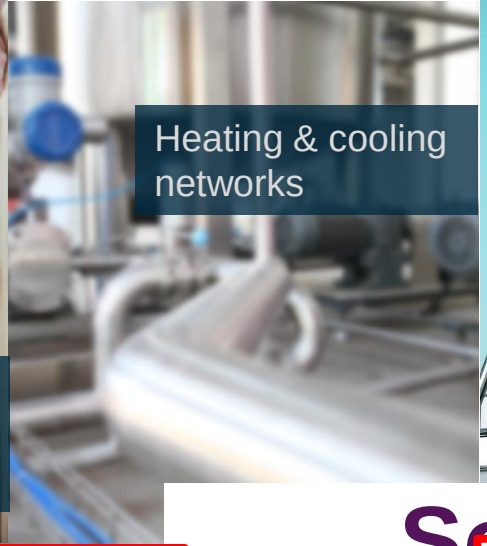
Source: Mortality risk attributable to high and low ambient temperature: a multicountry observational study. The Lancet, VOLUME 386, ISSUE 9991, P369-375, JULY 25, 2015. https://doi.org/10.1016/S0140-6736(14)62114-0

Improving efficiency & insulation



Heating & cooling networks

Residential heating & cooling solutions

Heat from hydrogen

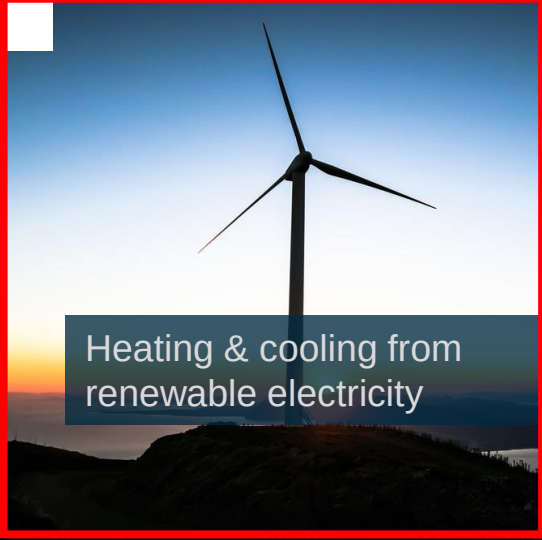
H_2

Solutions

Integrated energy systems

Drying

Industrial heating & cooling solutions



Heating & cooling from renewable electricity

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In the future - Will we heated by electricity or hydrogen?

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Nobody knows yet…

… probably both.

Energy system analysis shows that doing “both” is cheaper and more resilient.

Similar debate in transportation sector

Hydrogen’s role is yet to be written (novel and interesting)

- Early stage of any “demand” – nobody was asking for GWh scale until “net-zero”
- Embedded storage like fossil fuels
- Compatible with fossil-era technology
- Efficiencies & cost can improve significantly
- Certainly not perfect
- Main subject of this talk!

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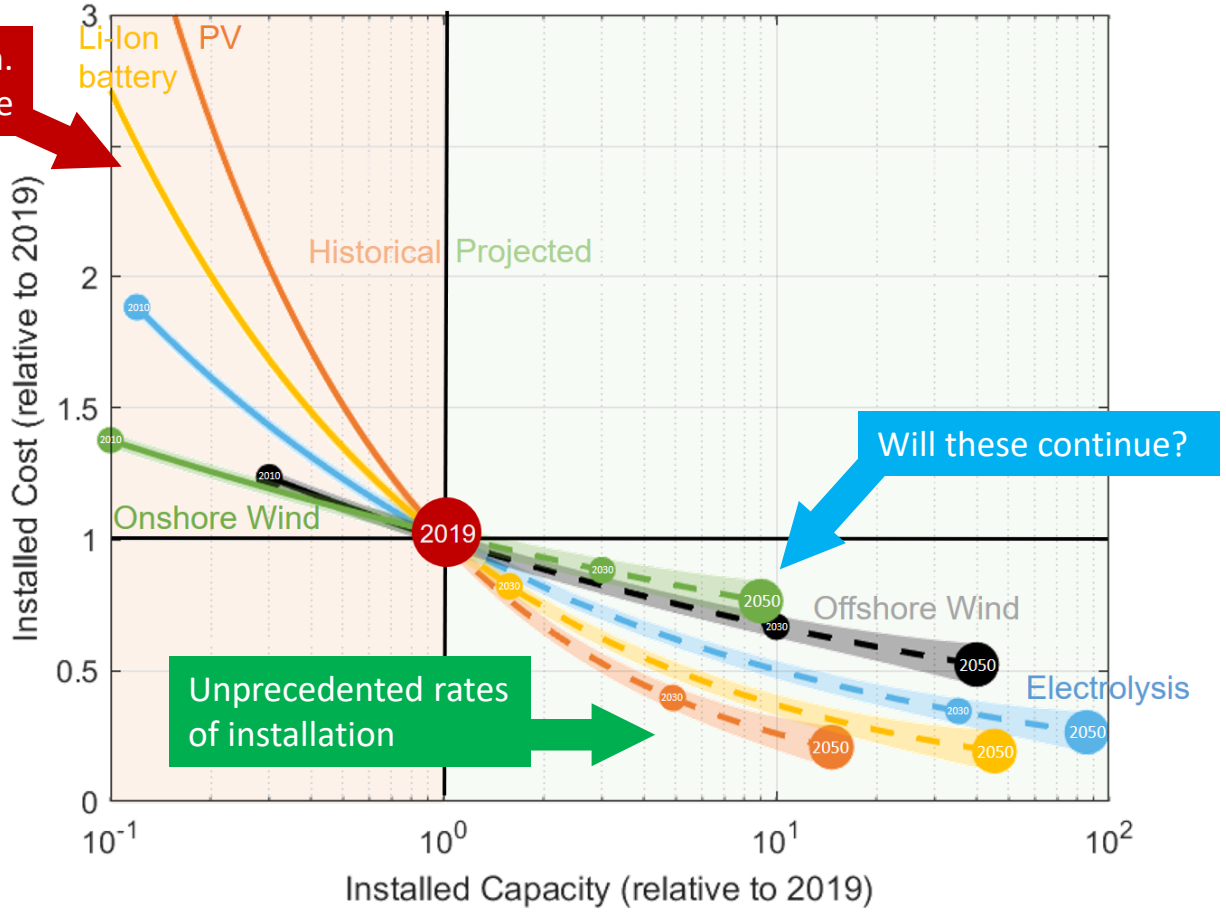
The opportunity for hydrogen

The world is changing fast!

Most renewable tech. follows a leaning rate



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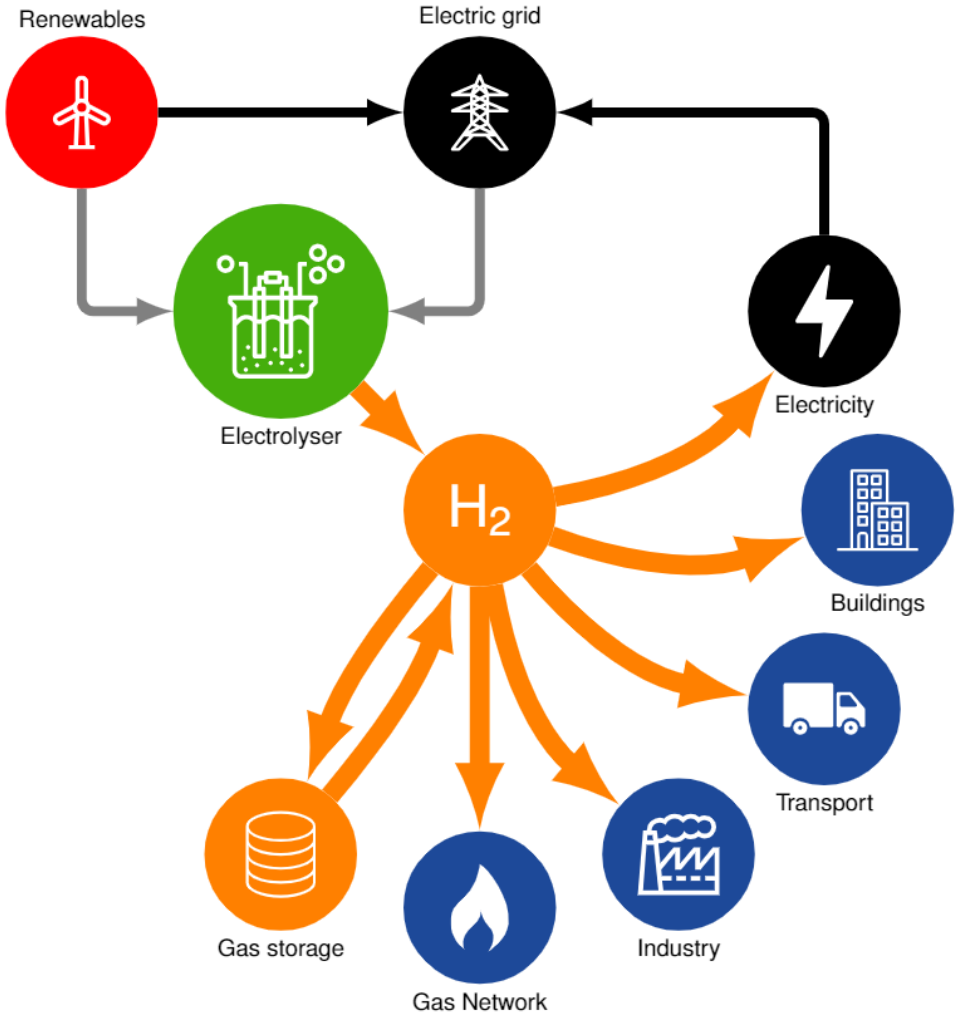
What about Hydrogen?

What about hydrogen?

- Many pathways lead to hydrogen
- Green is probably best
- Electrolysis brings more flexibility & resilience to all energy networks
- Huge potential demand
- Cost savings mass manufacture, supply chains & cheap renewables
- Many consider it to be cheapest from ~2030 onwards



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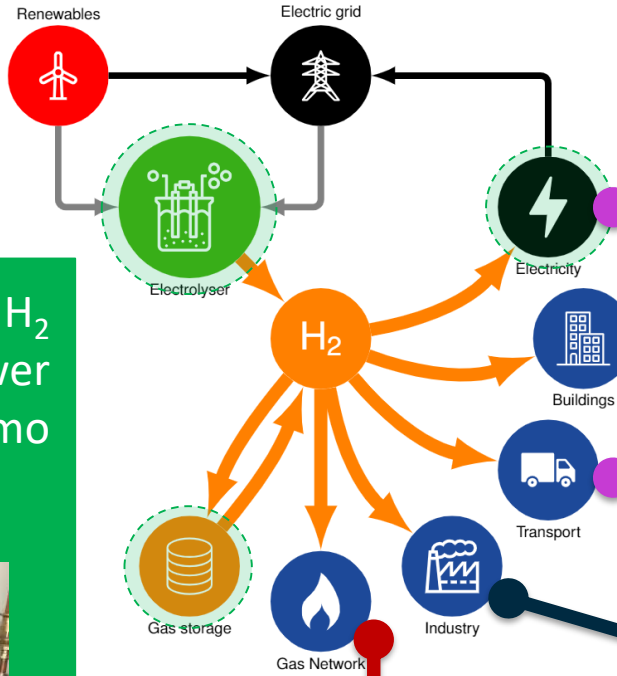
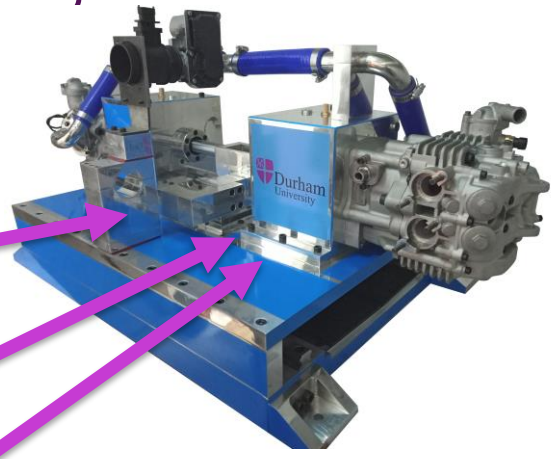
Hydrogen for heat laboratory at Durham University

Hydrogen for heat laboratory in Belmont, Durham

North East
Local Enterprise Partnership

Power to H_2 to power demo



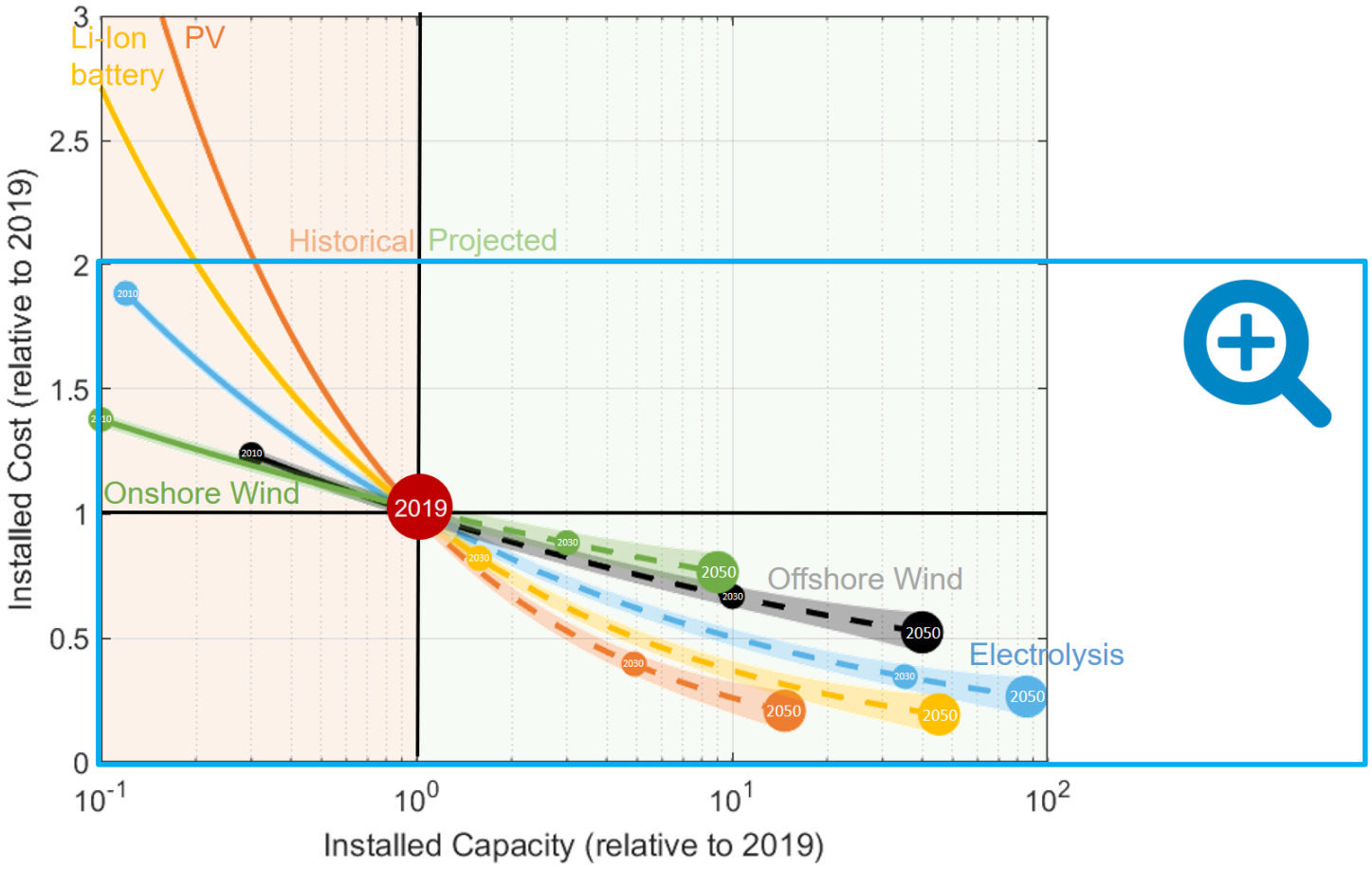


FutureGrid (100% H_2 trial in NTS)

IDRIC

The UK Industrial Decarbonisation Research and Innovation Centre – Teesside Cluster transition to net-zero

What about hydrogen?



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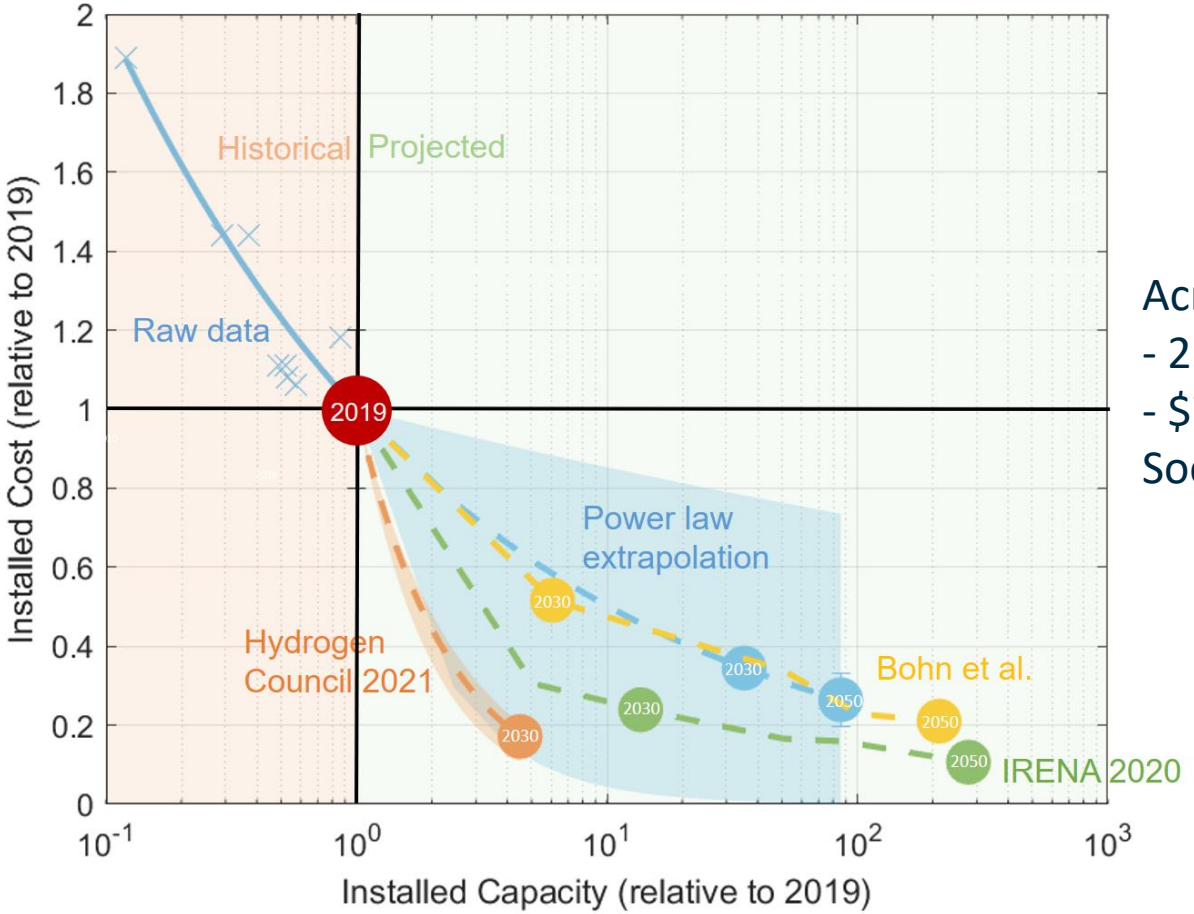
Uncertainty with hydrogen electrolysis



Across 30 major nations
- 228 large-scale hydrogen projects
- $70bn value

Society is betting big on hydrogen

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An evidence based exploration of the cost reductions associated with green hydrogen production

Techno-economic model

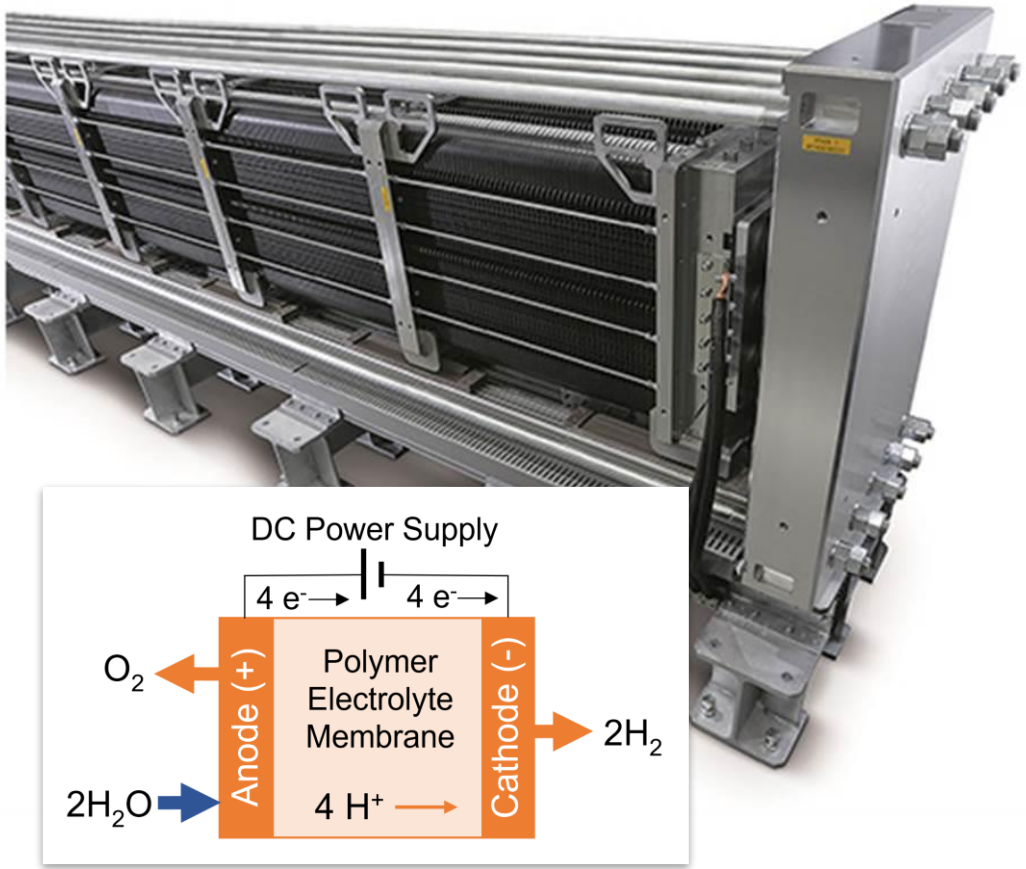


Image: https://www.dieselgasturbine.com/7009711.article

Model of a 200kW electrolyser system

1. Technical model

- Efficiency
- Energy consumption
- Sizes

2. Economic model

- Component by component
- Cost and supply chain

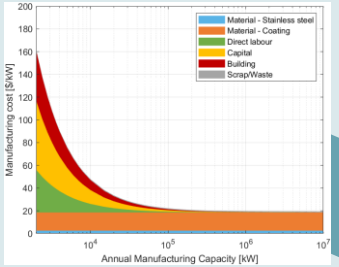
3. Manufacturing model

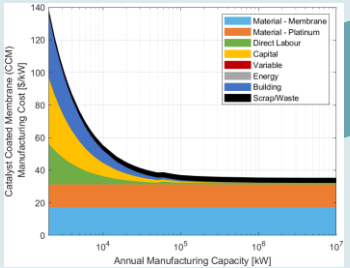
- Component by component
- Raw materials
- Production line incl. staff
- from 10/year to 1000/year

CAPEX at mass-scale manufacture

RAW MATERIALS

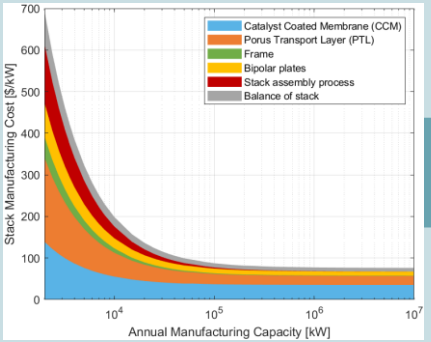
Sub-components





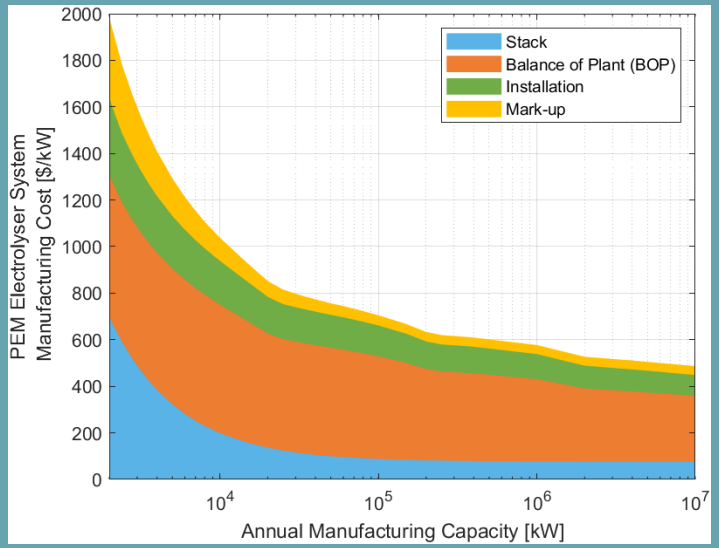
Labour, Energy, Buildings, Waste, Capital

Components



Catalyst coated membrane
Porous Transport layer
Frame
Stack assembly
Balance of stack

PEM Electrolysis System



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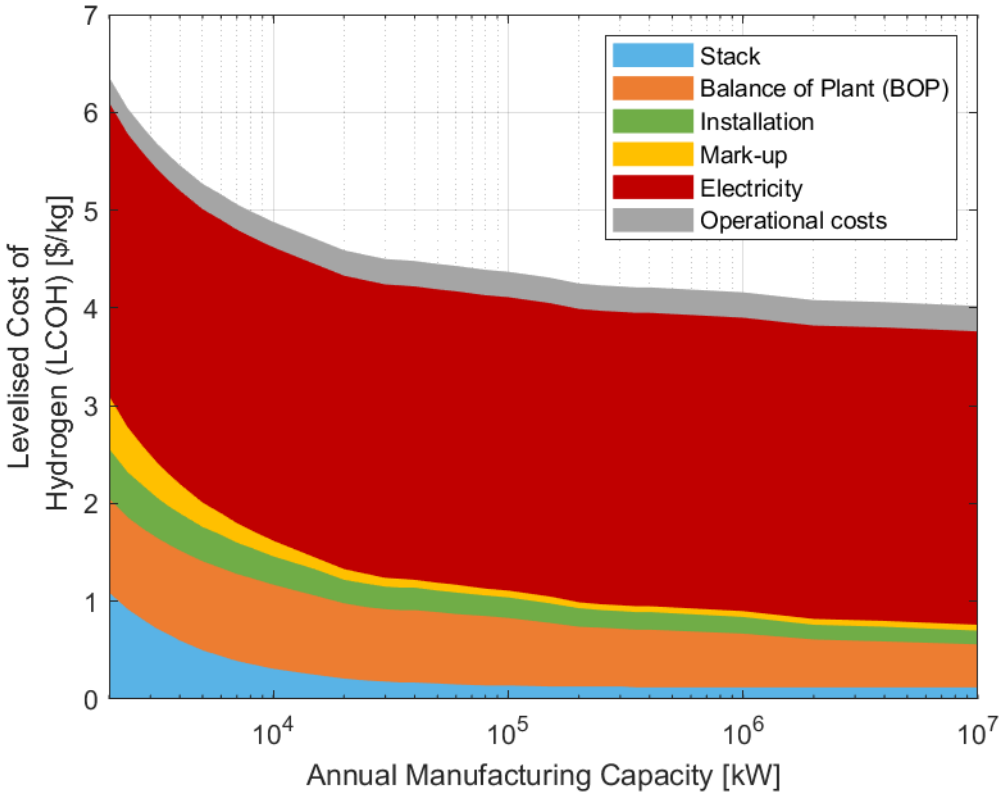
A levelised cost of hydrogen (LCOH)

Methodology yields a CAPEX

Further assumptions
- Future electricity prices
- System capacity
- Operational costs

Levelised cost of hydrogen per kg.

1 litre of gasoline ~ 1kg H2



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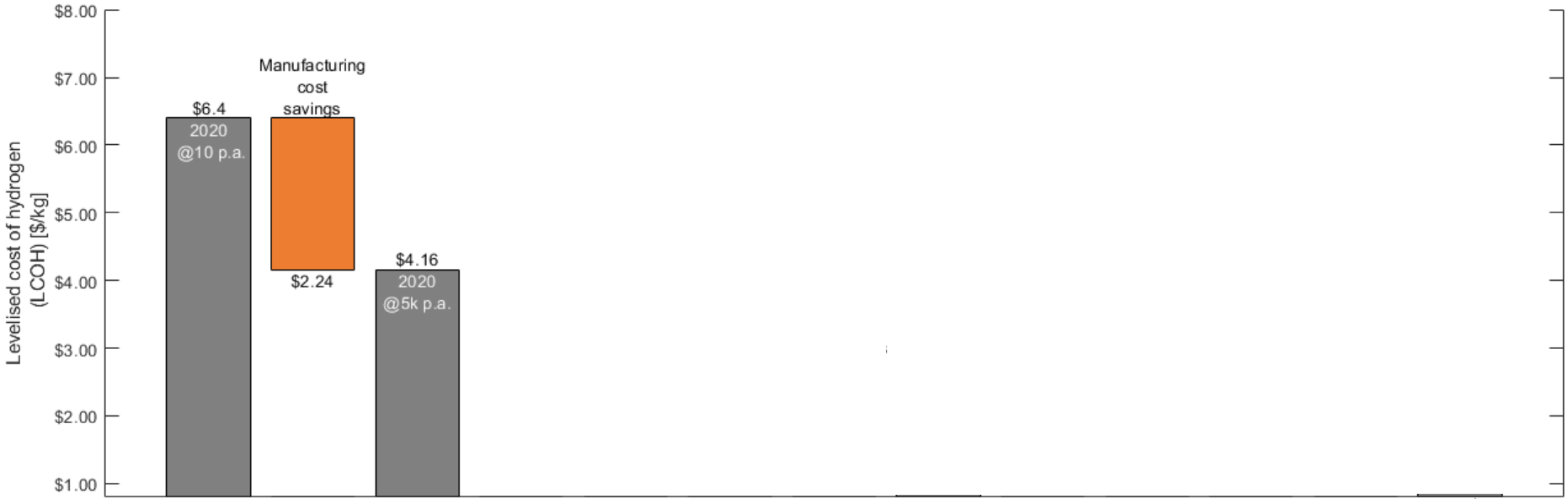
Toward *x*100 scale-up of green hydrogen



*x*10 scale-up

Further *x*10 scale-up

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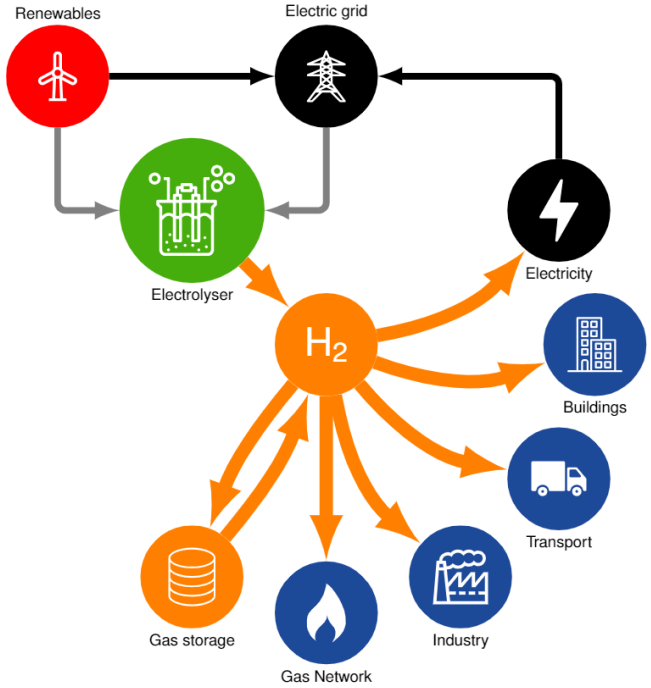
Implications for a hydrogen economy

A scaled-up hydrogen economy

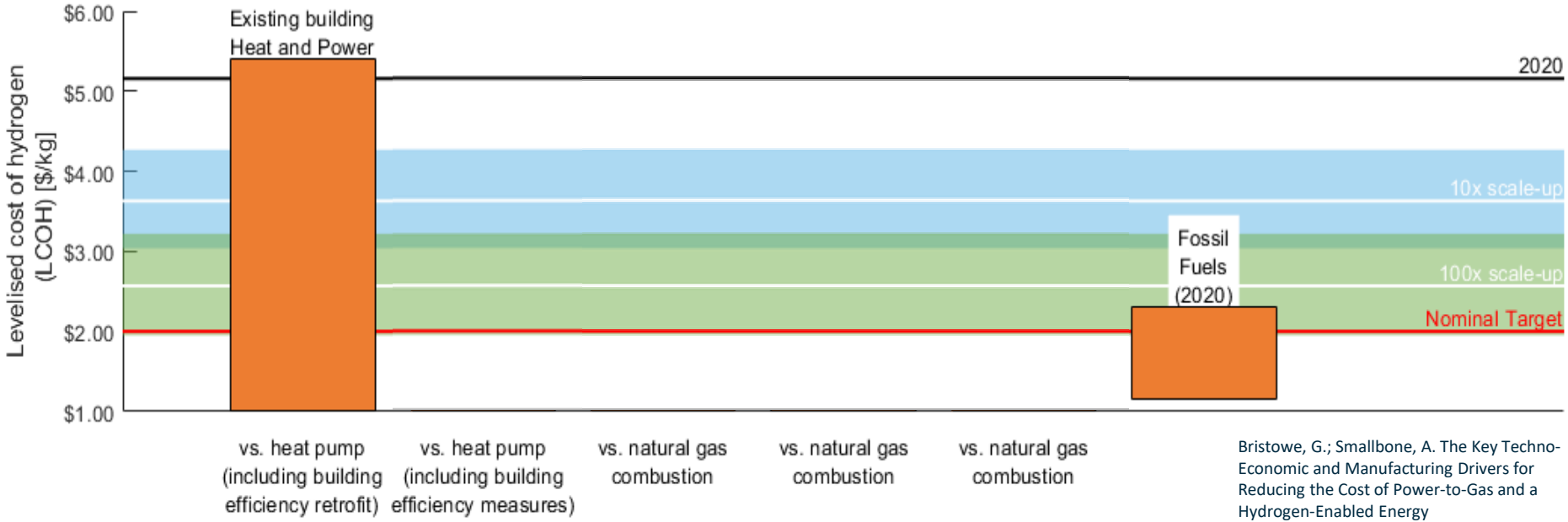
- Many pathways lead to hydrogen
- Opportunity across transport, heat, power and storage
- Other paths to a decarbonised economy
- Final cost is the sum of
  - Production
  - Distribution
  - End user demand
- Holistic answers to best option are complex!



A scaled-up wind & hydrogen economy

Required hydrogen fuel price to become cheapest option (Total cost of ownership)

(Hydrogen gas distribution assumed via an existing natural gas network)



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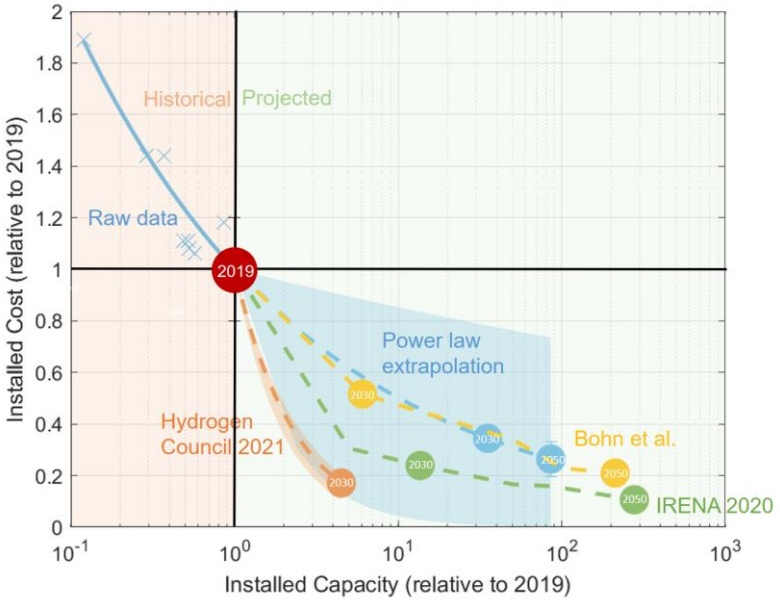
Hydrogen cost summary

- Hydrogen is an option for heat, transport, power and energy storage
- A scale up of green hydrogen *x*100-300 is expected to deliver on net-zero targets
- Green hydrogen expected to become cheaper than blue hydrogen within the next 15 years
- Mass-manufacture, lower electricity costs and improvements expected to reduce CAPEX and overall costs
- Even at x100 scale-up, net-zero heat is more expensive than fossil-derived



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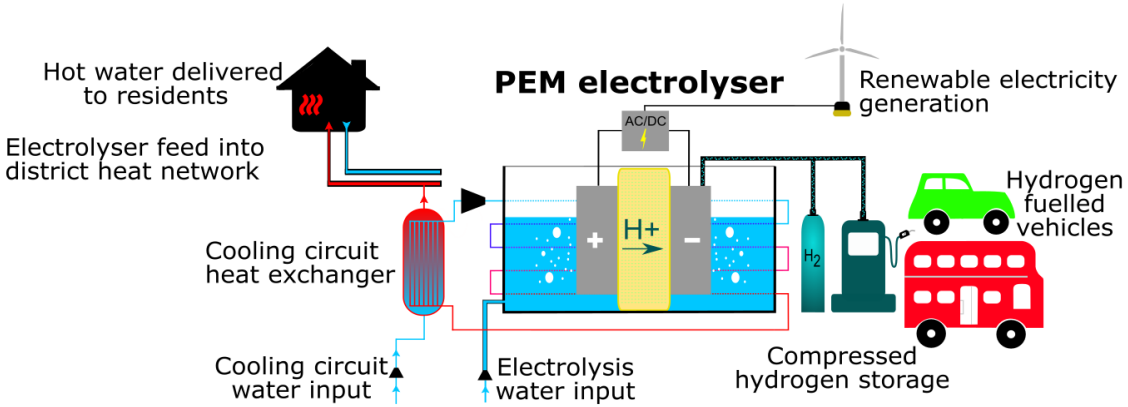
A local hydrogen-enabled energy system

Integrated hydrogen energy systems

Zero-carbon emission integrated cooling, heating and power (ICHP) networks
Funder EPSRC (EP/T022949/1) ~£1.2m



- Techno-economics of hydrogen enabled energy systems
- Quantify impact via resilience, flexibility and demonstration
- Consumer attitudes

Imperial College London

Durham County Council

nationalgrid

WALES&WEST UTILITIES

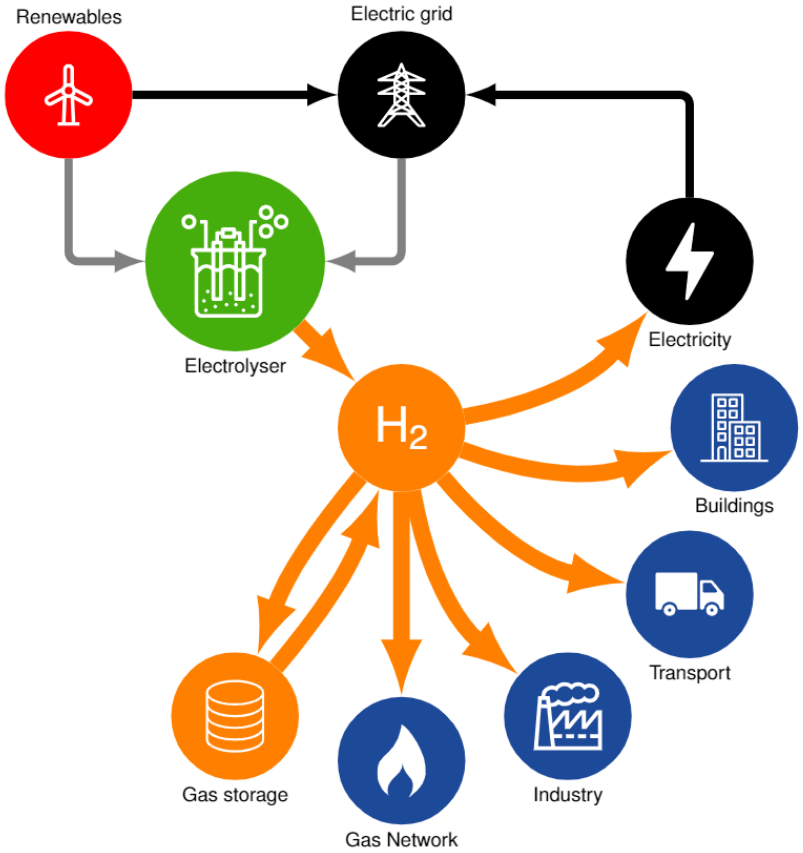
Committee on Climate Change

Durham University

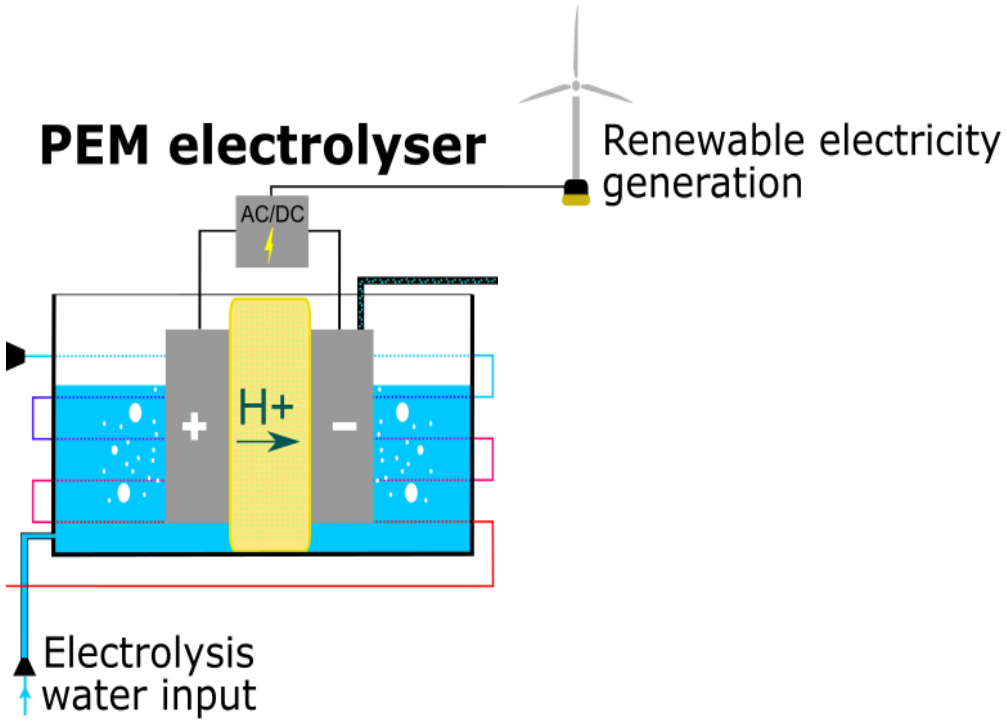
Combined heat, hydrogen and transport

Opportunity

- A large-scale PEM system is ~60-70% efficient
- 60-80^{o}C of losses are heat
- Fuelling stations are often closely co-located with residential and commercial buildings
- A combined heat and hydrogen (CHH) system



Combined heat, hydrogen and transport

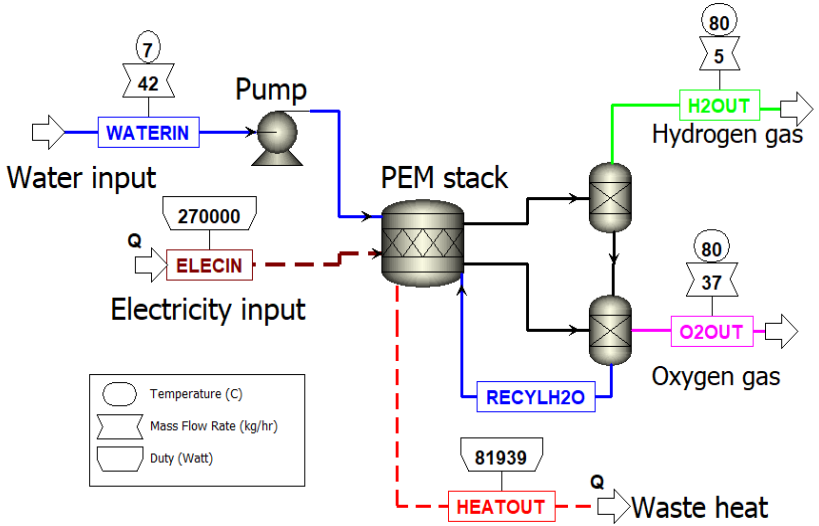


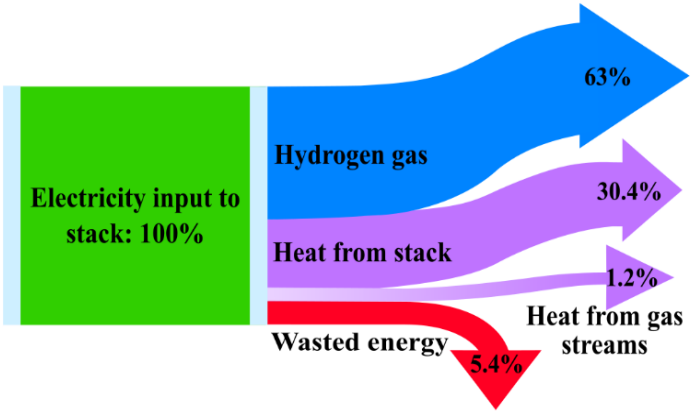
Source: *Dominic Burrin, Sumit Roy, Anthony Paul Roskilly, Andrew Smallbone, A combined heat and green hydrogen (CHH) generator integrated with a heat network, Energy Conversion and Management, Volume 246, 2021, 114686, ISSN 0196-8904, https://doi.org/10.1016/j.enconman.2021.114686.*

Methodology

Techno-economic model development

- ASPEN chemical process model of a 1 MW PEM electrolyser





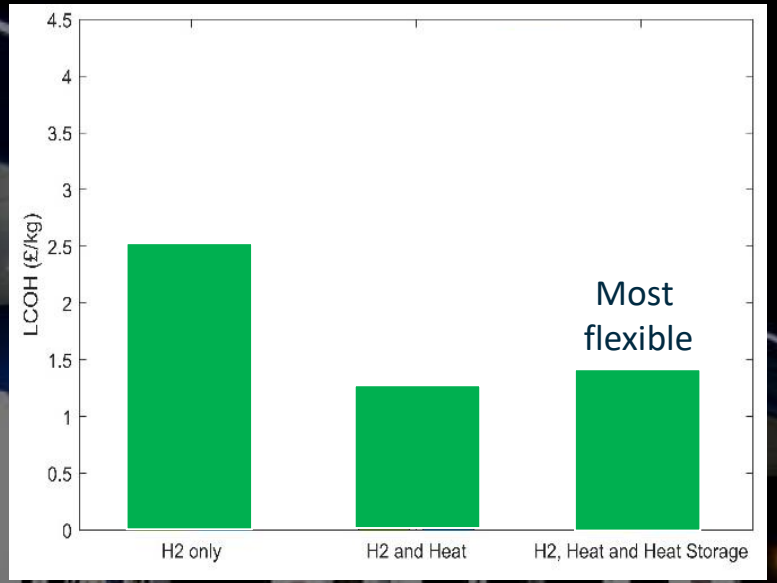
Scenario – A 2030 hydrogen fueling station

System details

- 12MWe peak power (off-peak)
- 1-6am off-peak cycle
- 1,200kg H_2 *i.e.* 15 trucks or 200 cars
- 19MWh heat/day (@ current DH cost)
- 190 homes directly
- 20% large heat network (75°C)

Observations

- Price of hydrogen/heat highly sensitive to price of electricity
- Option of hot water storage for load shifting



Levelised cost of hydrogen

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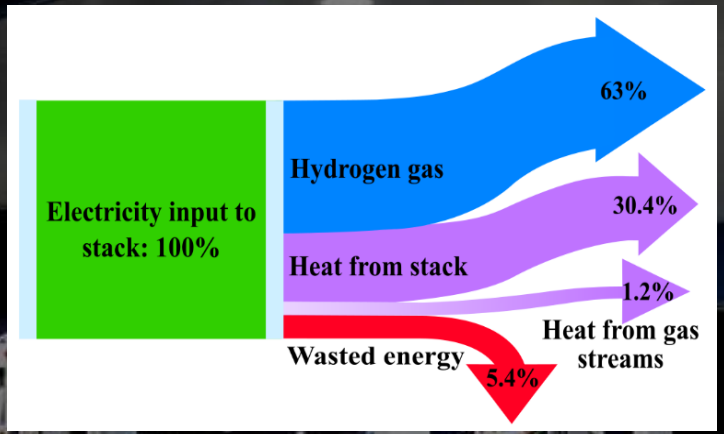
Summary of the outcomes



- A distributed model of hydrogen production for transport and integration into heat networks decarbonises both sectors.
- Co-production of heat and hydrogen for transport brings huge cost benefits
- Hydrogen for industry or direct heating also possible
- Electricity rather gas networks (or trucks) used for distribution
- Improvements to energy system efficiencies (>90%) and resilience

Summary

Discussed the decarbonisation of heat:

1. **Complex**– challenge which cuts across every sector, industrial process and person living in the UK.
2. **Changing dynamics of price**– Heat is likely to become more expensive. Major capital expenditure required. Difficult decisions need to be made. Still uncertainty as to best solutions for each region, sector and application.
3. **Examples of how heat can be decarbonized** – huge scope for innovation and opportunity for solving the challenge.

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Decarbonisation of heating & cooling Network+

We have been established by UK Research and Innovation (UKRI) to maximise the impact of UK-funded research and innovation.

A research partnership between

Durham University

Oxford University

Brunel University London

Heriot-Watt University

University of Leeds &

Northumbria University.

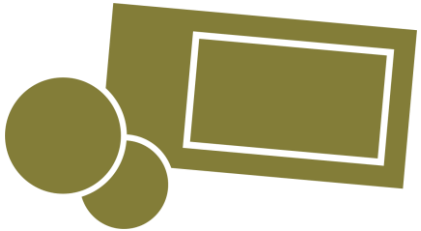
Durham University

Our planned activities over 4 years

net-zero research network

40 co-organised events

(national conferences, research sandpits, training & workshops)



Multi-disciplinary research feasibility funding

(16 small projects)

10 Researcher secondments & 40 travel bursaries

Technology roadmap & leadership

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More information

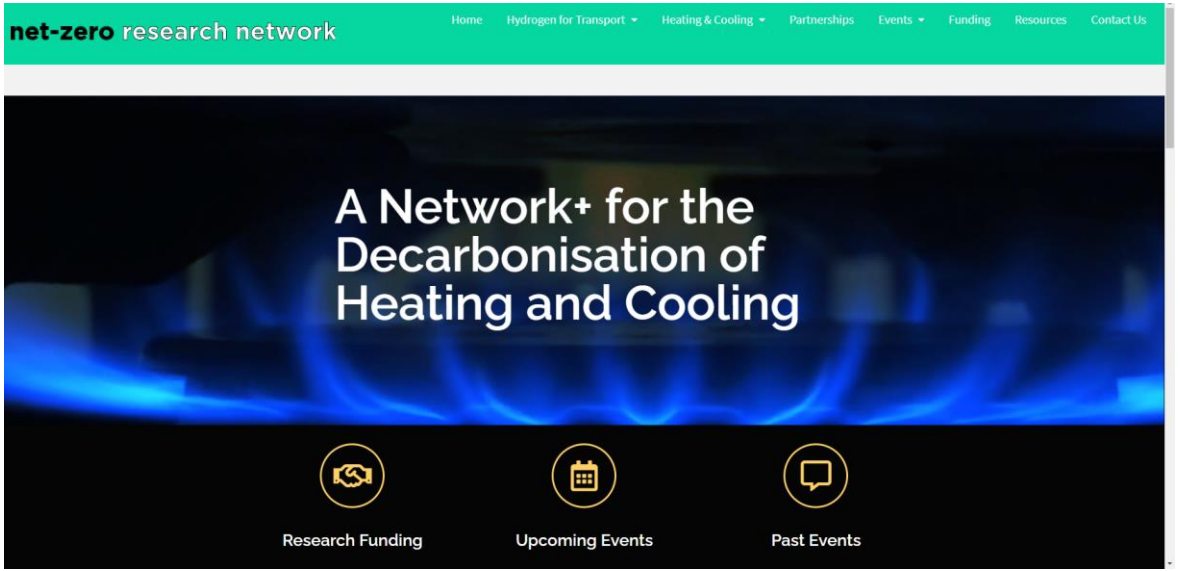
net-zero research network

Website

www.net-zero-research.co.uk

Sign-up for more information.

Watch this space!



Monthly on-line Webinars via Eventbrite – post-up videos

Next Event – BEIS “Heat & Buildings Strategy” – 28th January 2022

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Thank you!

Dr Andrew Smallbone
Associate Professor
Durham University

Email: andrew.smallbone@durham.ac.uk