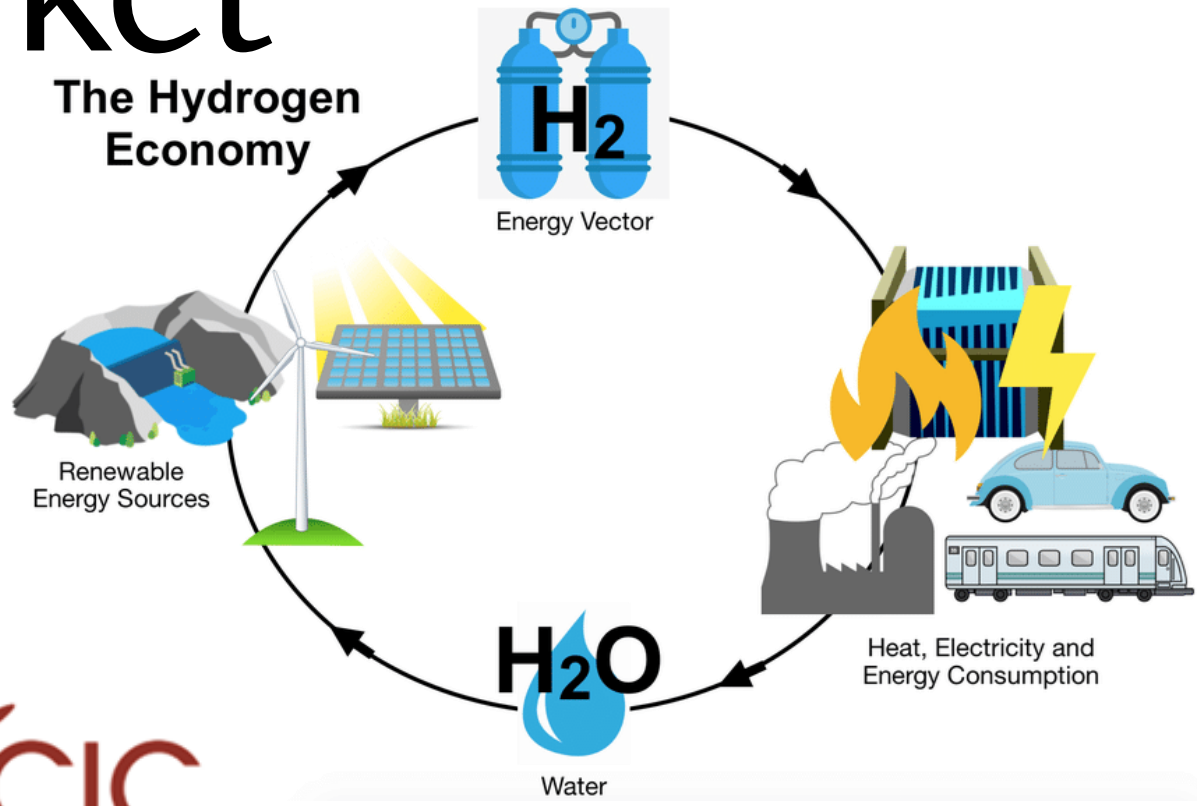
UK Hydrogen Market



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The role of hydrogen in net zero & the UK's energy transition

The case for hydrogen in the UK context

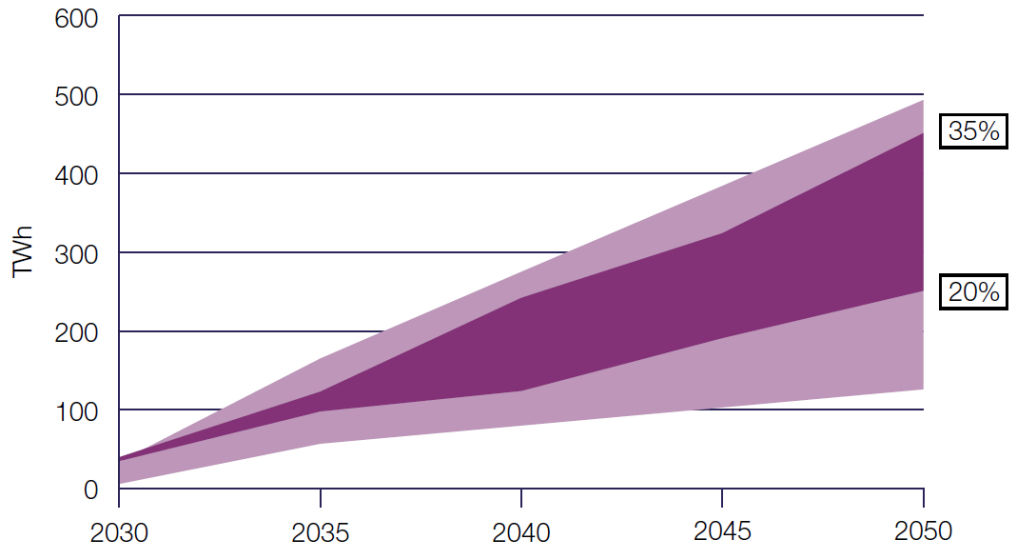
Low carbon hydrogen will be **critical for achieving net zero**, particularly in 'hard to electrify' **UK industrial sectors**, and can provide flexible energy deployment across **heat, power and transport**.

The UK's geography, geology, infrastructure, innovation and expertise make it **well suited to rapidly developing low carbon hydrogen economy** – with the secure **economic opportunities** across the UK.

The Government's ambition is for **5GW of low carbon hydrogen production capacity by 2030** (c. 42TWh). This could deliver **total emissions savings of around 41MtCO2e** between 2023 and 2032, equivalent to carbon captured by 700 million trees over the same period.

By 2050, low carbon hydrogen will be comparable in scale to existing electricity use in the UK – but there is **virtually no low carbon hydrogen production or use** today.

Figure 1.2: Hydrogen demand and proportion of final energy consumption in 2050



% = hydrogen as proportion of total energy consumption in 2050

Source: Central range – illustrative net zero consistent scenarios in CB6 Impact Assessment. Full range – based on whole range from UK Hydrogen Strategy Analytical Annex. Final energy consumption from ECUK (2019).

UK Hydrogen Strategy: developing and scaling up over the 2020s

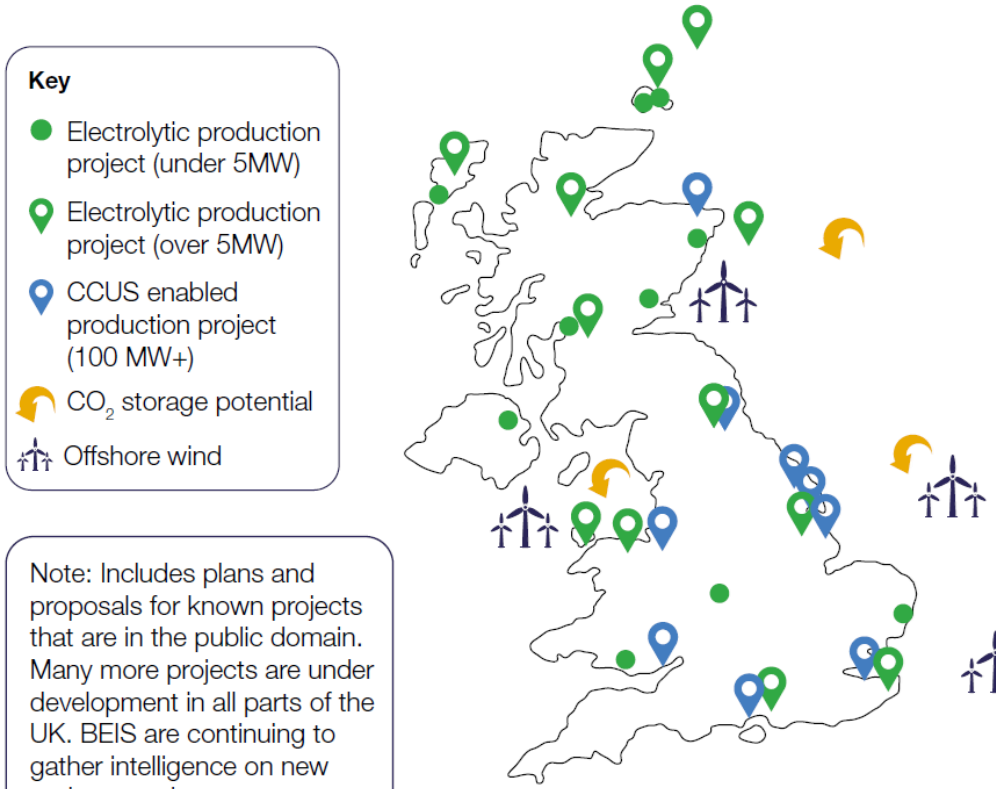
Key elements:

- Sets out up to **£1bn in UK Govt support** for hydrogen and low carbon technologies, including **over £400m for hydrogen** specifically.
- **Consultations** on support for **hydrogen production**:
  - **Hydrogen Business Model** to provide revenue support – finalise in 2022, enabling first contracts to be allocated from Q1 2023
  - **£240m Net Zero Hydrogen Fund** for capital co-investment – launch in early 2022
  - A **UK standard for low carbon hydrogen** – by early 2022.
- Sets out innovation and demonstration funding for hydrogen applications across **industry, power, heat** and **transport**.
- Seeks to secure **economic opportunities** from outset – **9,000 UK jobs** and **£900m GVA by 2030**, unlocking **£4bn investment**.

Twin track approach

further detail by early 2022

Figure 1.3: Proposed UK electrolytic and CCUS-enabled hydrogen production projects



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Early 2020s (2022-2024)	Mid-2020s (2025-2027)	Late 2020s (2028-30)	Mid-2030s onward

Hydrogen economy 'archetype'

Production

Early 2020s (2022-2024): Small-scale electrolytic production

Mid-2020s (2025-2027): Large-scale CCUS-enabled production in at least one location; electrolytic production increasing in scale

Late 2020s (2028-30): Several large-scale CCUS-enabled projects & several large-scale electrolytic projects

Mid-2030s onward: Increasing scale & range of production – e.g. nuclear, biomass

Networks

Early 2020s (2022-2024): Direct pipeline, co-location, trucked (non-pipeline) or onsite use

Mid-2020s (2025-2027): Dedicated small-scale cluster pipeline network; expanded trucking & small-scale storage

Late 2020s (2028-30): Large cluster networks; large-scale storage; integration with gas networks

Mid-2030s onward: Regional or national networks & large-scale storage integrated with CCUS, gas & electricity networks

Use

Early 2020s (2022-2024): Some transport (buses, early HGV, rail & aviation trials); industry demonstrations; neighbourhood heat trial

Mid-2020s (2025-2027): Industry applications; transport (HGV, rail & shipping trials) village heat trial; blending (tbc)

Late 2020s (2028-30): Wide use in industry; power generation & flexibility; transport (HGVs, shipping); heat pilot town (tbc)

Mid-2030s onward: Full range of end users incl. steel; power system; greater shipping & aviation; potential gas grid conversion

Key actions and milestones

- Launch NZHF early 2022
- Phase 1 CCUS cluster decision 2021
- Finalise low carbon hydrogen standard 2022
- Finalise business model 2022
- Heat neighbourhood trial 2023
- Value for money case for blending Q3 2022

- Aiming for 1GW production capacity 2025
- At least 2 CCUS clusters by 2025
- Heat village trial 2025
- Hydrogen heating decision by 2026
- Decision on HGVs mid-2020s

- Ambition for 5GW production capacity 2030
- 4 CCUS clusters by 2030
- Potential pilot hydrogen town by 2030
- Ambition for 40GW offshore wind by 2030

- Sixth Carbon Budget

Supporting policy and activity: what needs to be in place to deliver?

- Networks & storage infrastructure
- Regulatory frameworks
- Market frameworks
- Grant funding
- Research & innovation
- Sector development
- International activity & markets
- Public & consumer awareness
- Private investment
- Industry development & deployment

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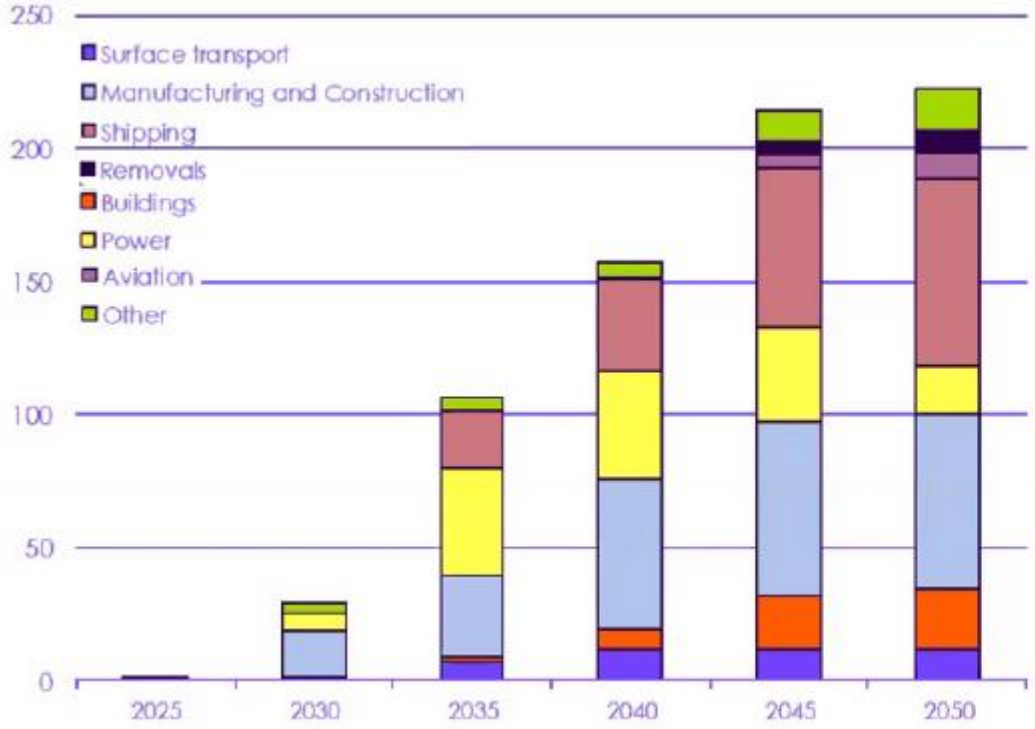
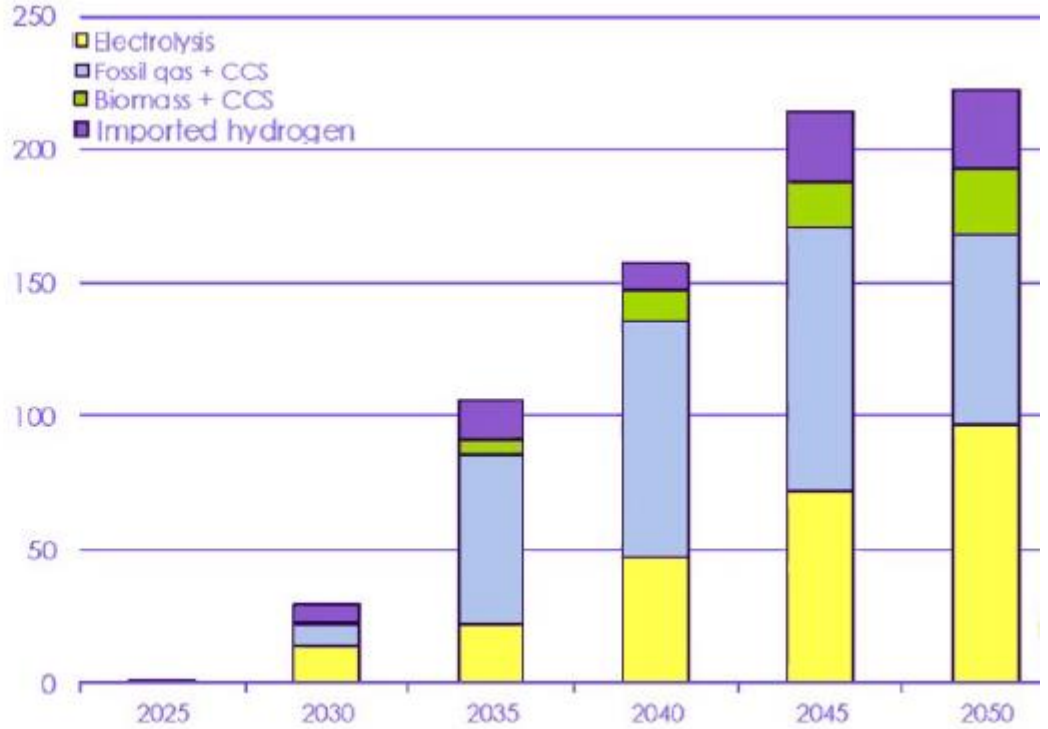
Use of hydrogen: decarbonisation & flexibility

Projection of Hydrogen Demand in the UK (TWH)



Projection of Hydrogen Supply in the UK (TWH)



The analysis suggest **potential hydrogen demand of up to 38TWh by 2030** split across sectors (not incl. gas blending). This could rise to **55-165TWh** by 2035 under CB6.

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Current gaps and challenges to address

Significant policy gaps to address

- Revenue support missing for 10-50 MW applications
- Policy needed for short-term transport, industry development
- 18-month lead time for 20-MW electrolysers

Different support mechanism required for green hydrogen

- Proposal exposes renewable producers to gas price risk
- Calls for separate support mech for green hydrogen
- Calls on govt to set 5-GW renewable hydrogen target

Solving heating problem

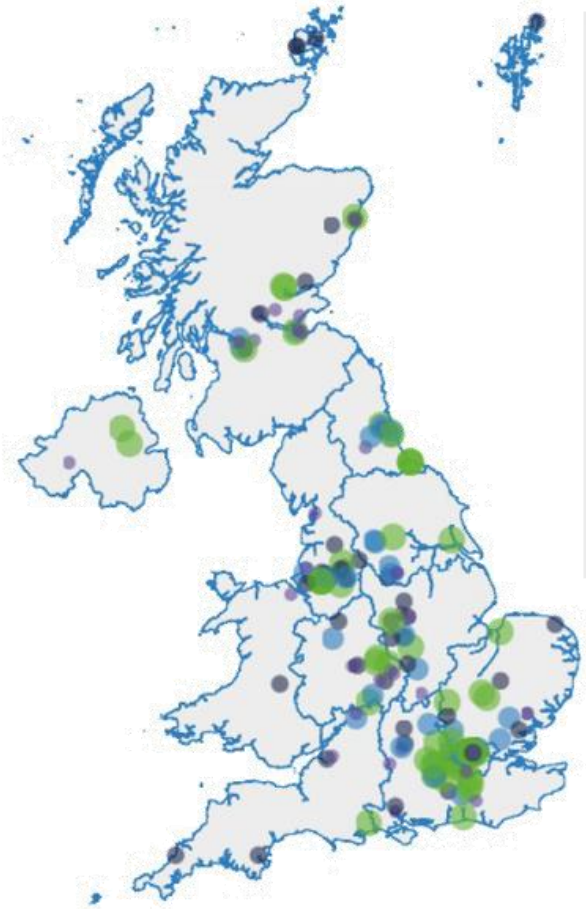
- Heating the homes and hot water in UK creates more than 10 times the amount of carbon dioxide created by the aviation industry.
- The most insurmountable challenge lies in the small in-house pipes, often concealed inside walls and under floors, that would need to be upgraded to handle smaller hydrogen molecules.
- Another option is heat pumps, and the government wants 600,000 of them to be installed in UK homes each year by 2028 (offering subsidies since recently).

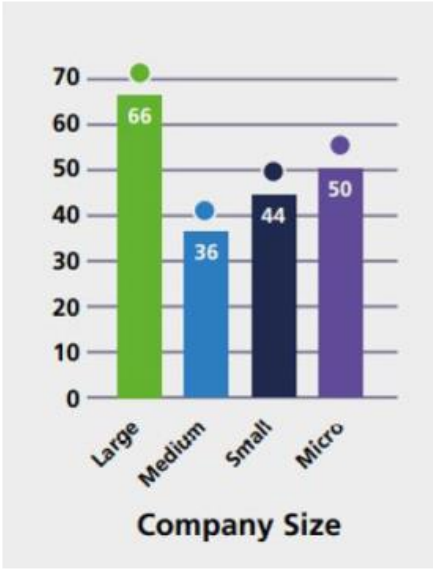
Dynamic ecosystem of Hydrogen businesses

Some firms along the supply chain

Blue Hydrogen	Johnson Matthey, Hydrasun, Parker Hannifin, TSP Engineering, Equinor, TP Group
Green Hydrogen	Intelligent Energy, ITM Power, Enocell, Bramble Energy, AFC Energy, TP Group, Equinor, Johnson Matthey, Ames Goldsmith Ceimig, PV3 Technologies, Ceres Power
Storage	Nanosun, LuxferGas Cylinders, H2GO, Kubagen, Logan Energy, INEOS
Distribution	Fuel Cell Systems, ITM Power, Arcola Energy, EDF Energy, Progressive Energy, Northern Gas Networks, National Grid
Applications	Porterbrook, Alstom, Wrightbus, JCB, Cadent Gas, Johnson Matthey, Ryse, Ulemco, U-Battery

UK businesses with commercial H2FC activities by company size





An overview of hydrogen projects and their locations in the UK

Mobility

	Name	Location	Output	Funding value	Leader
1	Towards commercial deployment of FCEV buses and hydrogen refuelling	Aberdeen Liverpool	1 station 30 buses	£6.4m	BOC
2	Hydrogen Mobility Expansion Project II	Crawley	1 station 51 cars	£3.1m	Element Energy
3	Northern Ireland Hydrogen Transport	Belfast	3 buses	£2.0m	Viridian Energy Supply Wrightbus
4	Tees Valley Hydrogen Transport Initiative	Middlesbrough and Stockton on Tees	2 stations 5 cars	£1.3m	Tees Valley Combined Authority
5	Riversimple Clean Mobility Fleet	Monmouthshire	17 cars	£1.3m	Riversimple
6	HydroFlex – fitting a hydrogen pack to an existing Class 319 train set	Birmingham	1 train	Confidential	Porterbrook BCRRE
7	HySeas III	Orkney	1 ferry	Confidential	Ferguson Marine Engineering
8	HyFlyer	Orkney	1 medium range small passenger aircraft	£5.3m	Zeroavia EMEC
8	Alstom H2 Breeze - conversion of existing Class321 trains for the UK market. Available in 2022[58].	n/a	Series of trains	Confidential	Alstom Eversholt Rail

An overview of hydrogen projects and their locations in the UK

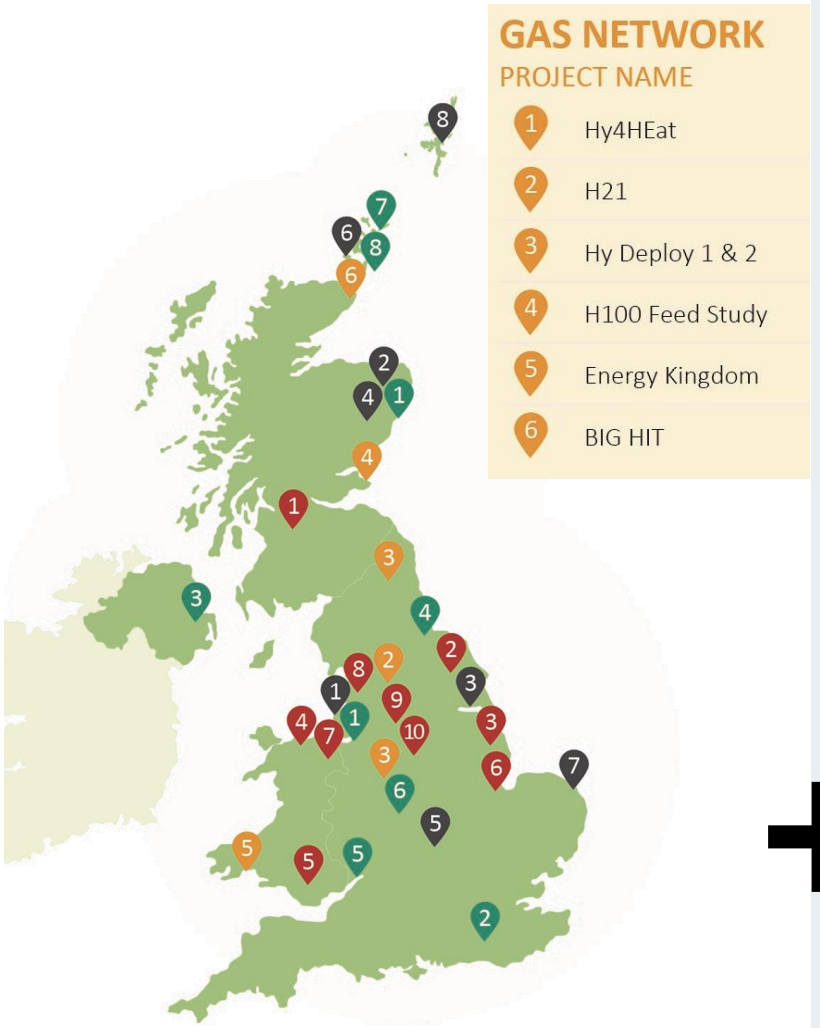
Production

	Name	Description	Location	Funding value	Partners
1	HyNet 1 & 2	Development and deployment of low carbon hydrogen plant which enables CCS	Liverpool Bay area	£7.5m	Cadent Progressive Energy
2	Dolphyn	Detailed design of a 2MW prototype system to enable the production of hydrogen at scale from offshore floating wind	Aberdeen	£3.1m	ERM
3	Gigastack	Feed study of PEM electrolyser using electricity from OSW farm to generate hydrogen for refinery	Grimsby	£7.5m	ITM Power, Orsted, Humber Refinery
4	Acorn Hydrogen Project	FEED study to develop an advanced reformation process for hydrogen production from North Sea Gas using CCS	Aberdeen	£2.7m	Production CCS
5	HyPER	Build a 1.5MW pilot scale demonstration of the sorption enhanced steam reforming process to supply hydrogen	Cranfield	£7.4m	Cranfield University GTI
6	Surf 'N' Turf	Tidal power devices and community-owned onshore wind turbine route their surplus electricity to a 500kW electrolyser.	Orkney	£1.46m	Community Energy Scotland, EMEC, ITM Power

An overview of hydrogen projects and their locations in the UK

Gas Network

	Name	Description	Location	Funding value	Partners
1	Hy4HEat	Study to establish technical and safety feasibility of 100% hydrogen residential gas supply	TBC	£25m	ARUP Kiwa
2	H21	Projects designed to support conversion of the UK gas networks to carry 100% hydrogen	Leeds (Yorkshire)	£10m	Cadent Northern Gas Networks SGN
3	HyDeploy 1 & 2	Energy trial to demonstrate the injection of (up to 20%) hydrogen into the public gas network	Keele & North of England	£22.1m	Cadent ITM Power
4	H100 feed study	Project to trial a 100% hydrogen residential gas supply	Levenmouth	£2m	SGN ORE Catapult
5	Energy Kingdom	Whole energy systems feasibility study to trade flexibility across electricity, NG and hydrogen, heat (hybrid heat pumps) and transport	Milford Haven	£2m	Pembrokeshire City Council ORE Catapult Riversimple
6	BIG HIT	Demonstrating Orkney Islands as a replicable Hydrogen Territory, using curtailed renewable energy generated locally to produce hydrogen.	Orkney	£5m	EMEC ITM Power

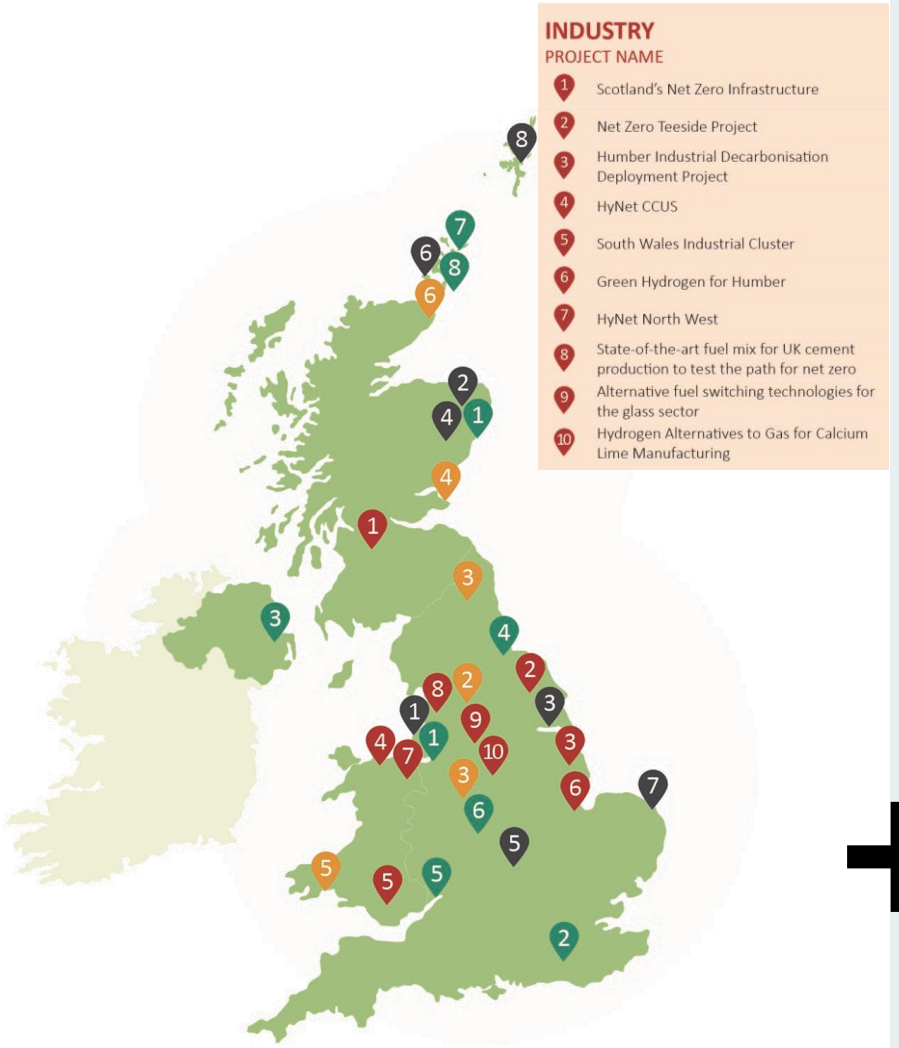


An overview of hydrogen projects and their locations in the UK

Industry

	Name	Description	Location
1	Scotland's Net Zero Infrastructure	CCS project that will link industrial emitters around Grangemouth, with a pipeline to St Fergus.	Scotland
2	Net Zero Teesside Project	CCUS project that aims to decarbonise a cluster by 2030.	Teesside
3	Humber Industrial Decarbonisation Deployment Project	It will identify and develop potential anchor projects to maximise emission reductions and develop industrial CO2 transport and storage system.	Humber
4	HyNet CCUS	Part of HyNet projects that will provide the infrastructure to transport and store the CO2 produced as a by-product of the hydrogen production process.	North West
5	South Wales Industrial Cluster	SWIC will identify process options to reduce carbon emissions and options for CCUS.	South Wales
6	Green Hydrogen for Humber	It will lead to the production of renewable hydrogen, at the GW scale, from PEM electrolysis. This will be distributed to a mix of industrial energy users in Humberside.	Humberside

7	HyNet North West	Testing a range of hydrogen industrial use opportunities across the North West and developing a hydrogen CHP	Glass Beauty Refinery	£5.2m	Progressive Energy Pilkington Unilever
8	State-of-the-art fuel mix for UK cement production to test the path for net zero	Testing switching UK cement production to operate on low carbon fuels including hydrogen, biomass and electrification	Cement production	£3.2m	Mineral Productions Association
9	Alternative fuel switching technologies for the glass sector	Trialling the potential for the glass sector to use alternative fuels (electric, hydrogen, biofuel and hybrid-fuel melting technologies)	Glass	£7.1m	Glass Futures Ltd
10	Hydrogen Alternatives to Gas for Calcium Lime Manufacturing	Testing the use of hydrogen in the high calcium lime manufacturing, servicing markets like iron or steel manufacturing.	Iron Steel	£2.8m	British Lime Association



Latest announcements & developments re green hydrogen

JCB signs deal to import 'green' hydrogen from Australia to UK

The construction equipment maker signed a deal with Australia's Fortescue Future Industries that will allow it to start selling "green" gas through a specialist division, Ryze Hydrogen, from early 2022.

H2 Green is to develop hydrogen and ammonia hub in Shoreham, UK, to decarbonize port

- Potential to fuel 800 trucks per day
- 20-MW of hydrogen capacity once at scale
- Eyes ammonia import facility

BP confirms 60 MW first phase of Teesside renewable hydrogen project

- First phase FID due in 2023 for 2025 start
- 2030 potential for 500 MW electrolysis
- Total 1.5 GW Teesside hydrogen ambition

Gigastack renewable hydrogen project is making good progress in bringing the ambitious scheme to reality

This will lead potentially to commercial operation of a 100MW scale electrolyser system powered by offshore wind in 2025

ITM Power to build second UK electrolyser factory

- 1.5 GW/year facility adds to existing 1 GW capacity
- Eyes 5 GW/year electrolyzer production by 2024

First phase of 20-MW Scottish renewable hydrogen project

- GBP9.4 million support for Whitelee project
- 10-MW phase to produce 2.5-4 tonnes/day
- ITM, BOC, ScottishPower partnership

Wood and Hygen Energy to accelerate green hydrogen production in the UK

They'll begin with the conceptual design for the facility at Herne Bay, Kent, which will generate green hydrogen from existing offshore wind farms to be used in zero emission mobility transport solutions in the Southeast of England.

Downstream application development

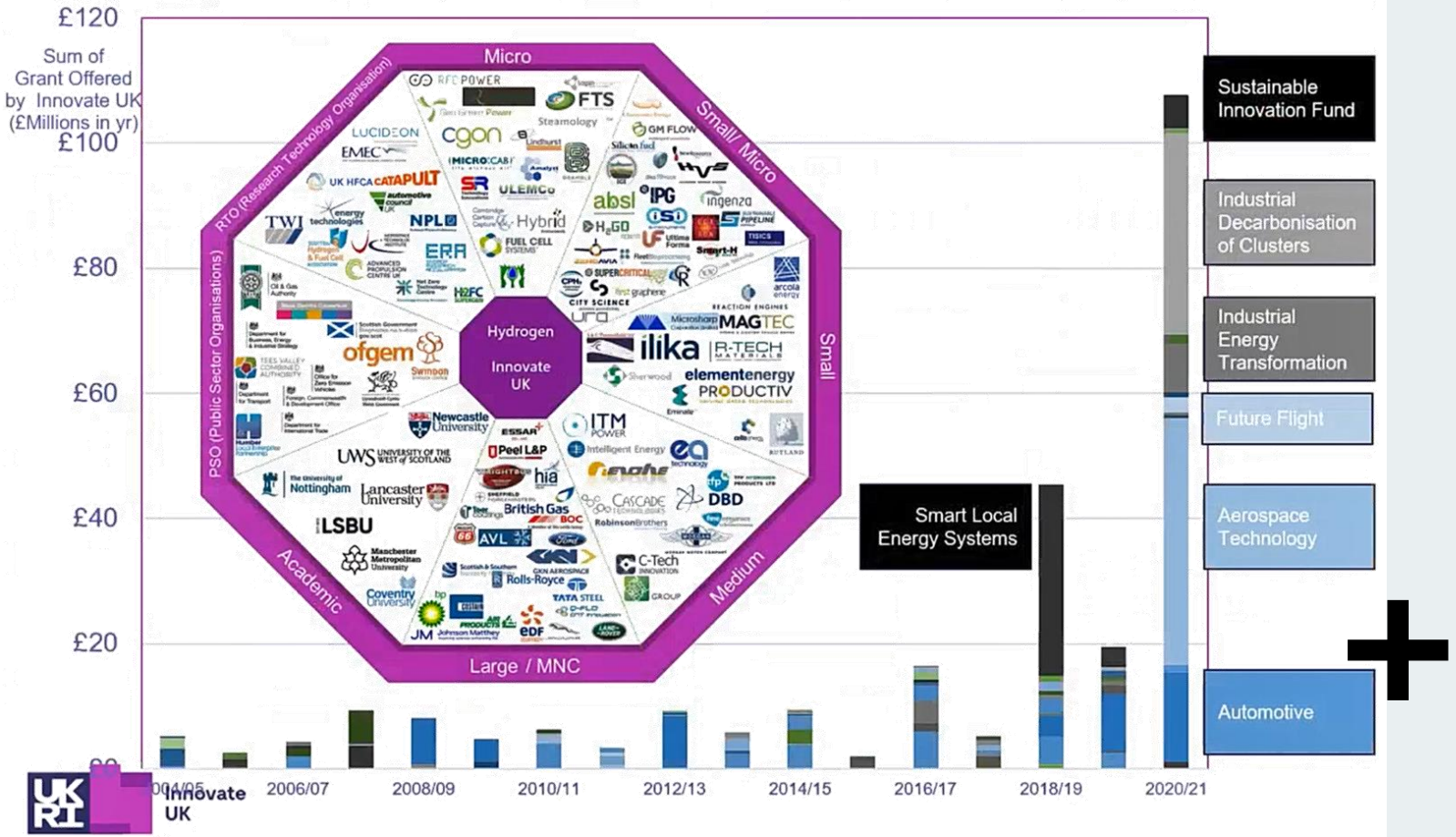
- **Air** - HyFlyer Sept 2020: First commercial hydrogen-fuelled aircraft, Cranfield UK. BEIS, ZeroAvia, Intelligent Energy.
- **Rail** – HydroFLEX Sept 2020: Porterbrook. Alstom, Uni of Birmingham developing hydrogen trains
- **Road** - Riversimple raising £150 million to go into hydrogen car production
- **Road** - ULEMCO retrofitting diesel vehicles to dual fuel
- **Road** – Wrightbus/Ryse Hydrogen – hydrogen fuelled buses
- **Construction** – JCB: Hydrogen excavators
- **Heating** - Hydrogen ready boilers – Worcester Bosch, Baxi
- **Marine** - H2 fuel cell ferry Auriga Energy

Support aimed at projects of research nature

Key national institutions providing support to the sector:

- HM Government's Department for Business, Energy and Industrial Strategy (BEIS)
- UK Research and Innovation
- Innovate UK
- Catapult Network
- KTN (Knowledge Transfer Network)
- Office of Gas and Electricity Markets (Ofgem)
- Health and Safety Executive
- NPL (National Physical Laboratory)
- British Standards Institution
- Advanced Propulsion Centre
- Aerospace Technology Institute

Innovate UK has invested £255m in 325 projects including hydrogen



Upcoming competitions

NERC large grant to tackle big environmental science questions

Funders:	**Natural Environment Research Council**
Funding type:	**Grant**
Total fund:	**£12,000,000**
Award range:	**£1,200,000 - £3,700,000**
Closing date:	**8 March 2022 16:00 UK time**

- Funding aims to support innovative, large-scale and complex projects that tackle big science questions and have the potential to produce world-leading research.
- This opportunity can fund research that crosses over into other research council areas. NERC will fund 80% of the full economic cost. Projects can last up to five years.
- International and non-academic collaborators can be involved as project partners, as long as the principal investigator is resident in the UK.

Hydrogen BECCS Innovation Programme

Funders:	**BEIS Net Zero Innovation Portfolio**
Total fund:	**£5,000,000 (Phase 1 - Feasibility)**
	£25,000,000 (Phase 2 - Demonstration)
Closing date:	**early March 2022**

- It is an innovation competition supporting the development of novel technologies with the potential to produce hydrogen from biogenic feedstocks while capturing CO2. Will fund 100% of eligible project costs, to develop, build and trial innovations.
- Consists of 3 categories, where the 3rd refers to Novel biohydrogen technologies: the development of novel biohydrogen technologies which can be combined with CCS. E.g., dark fermentation, anaerobic digestion, wastewater treatment.
- Projects are expected to be delivered by a project team or consortium. Lead company must be registered in the UK and more than 50% of the work carried out in the UK.

Possible EU grants

Recent

Integration of CCUS in hubs and clusters, including knowledge sharing activities

Deadline date	**05 January 2022**
Budget (EUR)	**2 000 000**

Recent

Energy Sector Integration: Integrating and combining energy systems to a cost-optimised and flexible energy system of systems

Deadline date	**05 January 2022**
Budget (EUR)	**30 000 000**

ongoing

Carbon-negative sustainable biofuel production

Deadline date	**23 February 2022**
Budget (EUR)	**15 000 000**

ongoing

Innovative biomethane production as an energy carrier and a fuel

Deadline date	**23 February 2022**
Budget (EUR)	**20 000 000**

ongoing

Innovation Fund Large Scale Projects

Deadline date	**03 March 2022**
Budget (EUR)	**1 500 000 000**

ongoing

Integration of hydrogen for replacing fossil fuels in industrial applications (Processes4Planet Partnership) (IA)

Deadline date	**30 March 2022**
Budget (EUR)	**42 500 000**

forthcoming

Demonstration of complete value chains for advanced biofuel and non-biological renewable fuel production

Opening date	26 May 2022
Deadline date	27 October 2022
Budget (EUR)	20 000 000

Stella Matthews, Hydrogen Development Manager at Northern Gas

UK experts' interviews key insights

"2035 to be completely net zero? It's very ambitious and probably unachievable. But hydrogen has a place for transport and industry.

"Need business models implemented for hydrogen production."

"From 2026 start to convert parts of the gas network to carry blended gas a 10-15 year conversion rollout"

"Different parts of Government, different viewpoint, so, some in the Department of Transport don't see hydrogen as having much of a place. Whereas others, like marine, it has to be that, HGVs it has to be hydrogen"

"The biggest concern is the storage then of hydrogen. Because above 5 tonnes of storage you're into COMAH [Control of Major Accident Hazards] regulations"

"For fuel sales you need 99.999%, five nines, so you are going to need some sort of scrubbing, cleaning up process. Currently hydrogen in the gas network is 98%"

Skill Gaps:"training is a huge one and not just on the gas distribution network, but your GasSafe registered staff and on the appliance side"

Graham Cooley CEO ITM Power & Member of the UK Hydrogen Advisory Council

UK experts' interviews key insights

"The UK government now revising its strategy and are more emphasizing green hydrogen over blue. the next round of funding, I believe will emphasize green hydrogen. There is £240 million available for green hydrogen projects, which is coming forwards"

"Large industrial clusters will go first. In clusters like Humberside and Teesside and South Wales."

"we're looking at new designs and industrial fuel switching, great for decarbonizing emissions heavy processes. "

"The UK Government has a five gigawatt target 2030. I think we can probably, in the next nine years, probably manufacture close to double that."

"The Govt have already put in an incentive in place in the CFDs for the adoption of long duration energy storage"

"Low carbon steel is a product that I do believe has got a very important future for the whole supply chain for big construction, car making or shipbuilding"

Skill Gaps: "If somebody was going to collaborate with the Finns in hydrogen In the UK, it would probably have something to do with ITM Power. And would we be interested in doing so? I think we would."

Keith Lawton, Strategy Director, Wood PLC

UK experts' interviews key insights

"I still think that green hydrogen is probably going to be a fair few years before it is actively taking what will be new hydrogen gas market share"

"Green hydrogen is being used to fuel transport, with vehicles effectively not able to run because there isn't enough gas, therefore building delivery capacity is key."

"we're looking at new designs and industrial fuel switching, great for decarbonizing emissions heavy processes. "

"Many green hydrogen projects are at an incredibly early stage, pre FID, they're still in the fact finding, feasibility concept stage. They're not at the stage where some of the blue hydrogen projects are starting to get "

"the train industry are under significant pressure to take away and off out of service, a lot of old diesel engines providing an opportunity to use alternative fuel like hydrogen "

"There are incredible opportunities for collaboration, as an example, digitalization is an interesting piece"

Skill Gaps: "using waste plastics to turn back into energy and a resourcerequires a different level of both chemical and mechanical engineering capabilities to just keep those innovations coming "

UK experts' interviews key insights

"We are worried about the integration challenge of large amounts of renewables onto the UK electricity grid. And see hydrogen as one of the key solutions to that challenge (we need a way of buffering the electricity generation profiles)"

"by the time we get to 2050, looking at about 100 gigawatts of offshore wind, we're going to need the equivalent of 200 terawatt hours of hydrogen. Broadly 18 to 20 gigawatts storage capacity

"We're going to see costs decrease significantly. And that's partly because about 50% of the economics of green hydrogen is down to the input costs. And we're seeing costs tumble hugely of offshore wind. There's an issue already with fuel poverty in the UK. Anything that could compound that, I think would be highly unpopular "

"For five gig, you've got to have a functioning market where you've got people who want to buy hydrogen at a commercial rate, and people who want to generate hydrogen at a commercial rate. So I'd say the big uncertainty is how do we set up that hydrogen market?"

"Definitely, heavy transport is one of the much more compelling applications economically. We think that's going to be one of the first (after industrial) and then space heating"

Skill Gaps: "I think we've got a challenge there in the UK around the sort of the systems integration piece of hydrogen"

BUSINESS FINLAND

UK Hydrogen Market

There are opportunities in the UK related to

- Digitisation
- Network Distribution
- Storage
- System Integration

Government policy is still evolving, a greater emphasis on Green Hydrogen is expected

UK based global corporations such as BP are taking an increasingly leading role in the sector

The UK is open to, in fact is looking to, collaborate with non-UK partners

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EU Grants are still up for grabs

- Integration of CCUS in hubs
- Energy sector integration
- Carbon negative biofuel production
- Innovative biomethane production as an energy carrier & fuel
- The integration of hydrogen to replace fossil fuels in industrial applications

Additionally, literally hundreds of research projects which are open to UK government funding are open to collaboration

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Is it a duck or a rabbit?

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Expert Interview viewpoints

- The electrolyser manufacturer CEO
- The wind power expert
- The gas distribution network
- The academics

Thank you for joining us!

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