

UK Hydrogen Export Capability Guide

英國氫能出口指南

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Department for
International Trade

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GREAT
BRITAIN & NORTHERN IRELAND

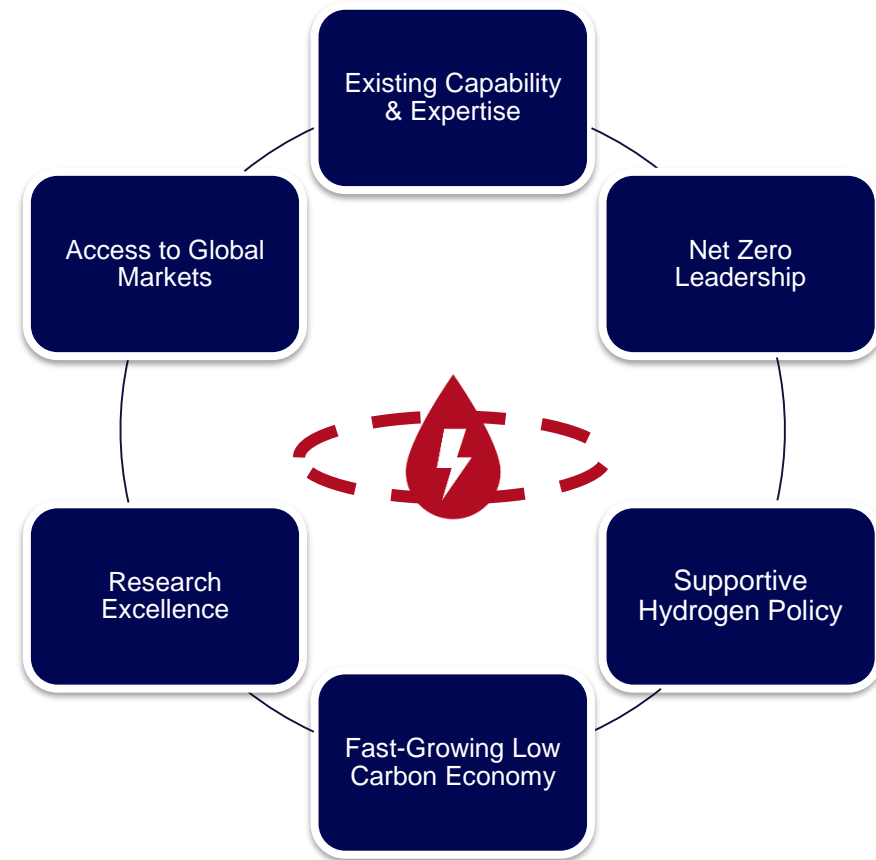
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The UK Set to Become a Global Hydrogen Leader

The realisation of the existential challenges associated with worsening climate change has spurred global action, triggering a transformative shift in how the world produces and consumes energy. Recent technological advancements in clean energy sources have coincided with this global push to decarbonise in order to mitigate the effects of potentially catastrophic climate change, making it possible to sustainably produce hydrogen on a mass scale. This capability guide sets out hydrogen's advantages and many opportunities and **why the UK is in an ideal position to export its capability and expertise across the globe.**

- Hydrogen is **light, storable, energy-dense, and produces no direct emissions** of pollutants or greenhouse gases. It is also the universe's most abundant chemical, known simply as H₂.
- **Hydrogen has traditionally been produced using fossil fuels** and has therefore been responsible for around 830 million tonnes of carbon dioxide per year.
- Through electrolysis and carbon capture technologies, hydrogen now presents **endless opportunities for sustainable energy production**, enabling the decarbonisation of a range of sectors, including transport, chemicals, and iron and steel.
- The UK has led in the green technologies sector and become the first country in the world to legislate the goal of reducing emissions to **Net Zero by 2050**.
- **The UK is ideally positioned** to lead the global switch from fossil fuels to hydrogen. In order to more quickly scale up the hydrogen sector, **the UK is supporting both Blue and Green Hydrogen production.**



英國即將成為全球氫能大國

由於意識到日益惡化之氣候變遷已對人類生存構成挑戰，人們因此發起全球行動，進而觸發全球在能源生產及消費方式上之轉型性變革。近年來，潔淨能源領域之技術進展，與全球推動減碳緩和氣候變遷之潛在災難效應的努力不謀而合，因而促成大規模永續生產氫能的可能性。本指南闡明氫能的優點和商機，並詳述英國為何立於理想地位，能夠向全球輸出氫能及專門知識。

- 氫氣是一種質輕、可儲存、能量密集的元素，且不會直接排放污染物或溫室氣體。氫氣也是宇宙間最豐富的化學元素，其元素符號為H₂。
- 傳統上，氫氣是利用化石燃料生產的，因此，每年產生約8億3,000萬噸的二氧化碳(CO₂)。
- 現在透過電解和碳捕集技術，氫氣為永續能源生產帶來無窮機會，可能幫助許多產業得以達成脫碳目標，包括運輸業、化學品製造業、和鋼鐵業。
- 英國一直是綠色技術產業的領頭羊，現在更成為全世界首個立法明定**2050淨零排放**目標的國家。
- 英國處於理想地位，可以帶領全球從化石燃料轉型為氫能。為了更快速擴大氫能產業的規模，英國目前同時支持藍氫和綠氫生產。



Strong Hydrogen Foundations

Home to a Fast-Growing Green Energy Sector

The UK has both an existing strength in and continuing ambitious goals for its renewable technologies economy that will be critical in developing the hydrogen sector. In 2019, the UK obtained **19.8% of its primary energy from low carbon sources**, up from 9.4% in 2000. Our offshore wind sector in particular is a stunning success story, built through **decisive government leadership and support alongside private investment**.

One of the ways in which the government has enabled this growth has been offering **Contracts for Difference**. CfDs are the main support mechanism for large scale low-carbon electricity generation projects. Successful projects are awarded a long-term contract which secures a price to which they will either be topped up if electricity prices are low, or pay back to if electricity prices are high. The Hydrogen Business Models will offer an analogous support mechanism to cover the cost differential of low- carbon hydrogen vs. fossil fuels.

460,000

employed in low-carbon industries in 2019.

£10.6bn

investment in electricity in 2019, double the amount in 2007.

98,000

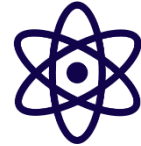
employed in the electricity industries in 2019.

According to the International Energy Agency, **wind and solar are expected to reach above 50% of the UK's power production by 2030**, more than in any other IEA member country.

Sources: UK Gov, 'UK Energy in Brief 2020,' 2020; IBISWorld, 'Non-hazardous waste treatment and disposal in the UK,' 2019; UK Gov, 'Ten Point Plan,' Nov 2020; IEA, 'United Kingdom: Wind Electricity Generation, UK 1990-2019,' 2021; UK Hydrogen Strategy, 2021.



Buttressed by government support, the UK's wind electricity generation has increased from 10.2TWh in 2010 to 64.1TWh in 2019, an increase of 524%. We now **generate more electricity from offshore wind than any other country** and aim to produce **40GWh** of offshore wind, including 1GW of innovative floating offshore wind, **by 2030** across key [clusters](#).



The UK's nuclear energy sector continues to provide a **reliable source of low-carbon electricity**, producing 37% of the UK's low carbon energy in 2019. While still pursuing large-scale nuclear, we are looking to the future through further investment in Small Modular Reactors and Advanced Modular Reactors, **committing £170m in R&D on AMR**. These reactors could operate at high-intensity heat, unlocking efficient production of hydrogen.



The UK's existing hydrogen research base is strong. As the **second most active country in hydrogen and fuel cell research in Europe**, we are well placed to capture part of the global innovation potential in the hydrogen value chain and position the UK as a leading hydrogen technology developer.

堅實的氫能基礎

快速成長之綠能產業的發源地

就再生能源技術經濟而言，英國不但已有現成實力，還擬定了遠大的目標。再生能源技術經濟對於發展氫能產業至關重要。2021年，英國產自低碳來源的初級能源佔比從2000年的9.4%上升為19.8%。尤其，我們的離岸風電產業，在政府果決領導和民間支持的雙重效應下，簡直是個令人驚嘆的成功故事。

英國政府促成此一成長的方式之一就是提供差價合約(CfD)。CfD是大規模低碳發電計畫的主要支援機制。成功的計畫被授以長期合約，以確保穩定的電價 – 當電價偏低時，可以獲得補足；當電價偏高時，再適度償還。氫能事業模型將提供一個類似的支援機制，以保障低碳氫能相對於化石燃料的成本差。

460,000

2019年低碳產業
僱用人數

£10.6bn

2019年發電業投資金額
(兩倍於2007年的
投資額)。

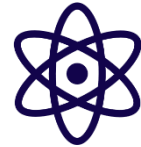
98,000

2019年發電業僱用人
數

根據國際能源署(IEA)的估計，2030年時，風力和太陽能發電預計將達到英國總發電量的50%以上，高於任何其他IEA會員國。



在政府的大力支持下，英國的風力發電量已從2010年的10.2TWh增加為2019年的64.1TWh，增幅達524%。目前我們的離岸風電發電量高於任何其他國家。我們並設定目標，2030年時，在各個重要群集中，離岸風電的發電量達到40GWh，包括1GW創新浮體式離岸風電。



英國的核能產業持續提供可靠的低碳電源。2019年，核能為英國提供37%低碳電力。我們在追求大規模核能發電的同時，也透過進一步投資於小型模組化反應爐(SMR)和先進模組化反應爐(AMR)，以掌握未來發展，迄今已斥資1億7,000萬英鎊投資AMR研發。這些反應爐可在高強度熱力下運作，因而促成氫能的有效生產。



英國現有的氫研究根基非常紮實。身為歐洲第二活躍的氫能及燃料電池研究國家，我們立於絕佳的地位，可以擷取部分全球氫價值鏈的創新潛力，並將英國定位為領先全球的氫技術開發國。

資料來源：英國政府 – 「2020年英國能源概況」(2020年)；IBISWorld – 「英國無害廢棄物之處置與處理」(2019年)；英國政府 – 「十點計畫」(2020年11月)；IEA – 「英國1990-2019風力發電發展概況」(2021年)；英國氫能戰略(2021年)。

Strong Hydrogen Foundations

Experience in Heavy Industry

The UK has earned a worldwide reputation as an **international centre of engineering excellence**. Engineering employs 5.6 million people in the UK with a 5.1% increase in employment over the last 5 years. Engineering generates 21.4% – **£1.2 trillion** – of the UK's total turnover.

71% of the hydrogen produced globally today is fed into the chemicals and oil refinery industries. The UK's existing capability in hydrogen across these industries provides the sector not just with a **large pool of engineering talent** with experience producing grey hydrogen but with **partners for collaborative innovation** and an **industrial market in which to scale up – domestically and internationally**.

Decarbonisation Roadmaps

Because the **industrial sector represents nearly a quarter of UK emissions**, the government set out [decarbonisation roadmaps](#) for the eight most heat-intensive industrial sectors (i.e. iron & steel, chemicals, oil refining, etc.); this effort is supported by the [£315m Industrial Energy Transformation Fund](#).



Industry has joined the effort: OGUK, the UK's leading trade association for the offshore oil & gas industry, has released its own plan – '[Roadmap 2035: A Blueprint for Net Zero](#)' with hydrogen playing a significant role.

Hydrogen

27TWh

Current total UK hydrogen production

~95%

Hydrogen produced through SMR globally

Oil & Gas

280,000

employed in the oil & gas industries.

£7.8bn

investment in the oil & gas industries in 2019.

1.7m barrels

of oil equivalent are produced per day in the UK.

£27bn

of industry turnover, c.40% through exports.

Chemicals

153,000

employed in the chemical industry.

£19.2bn

Gross Value Added in 2018.

£57.6bn

of chemicals exports in 2019.

Sources: Engineering UK, 'Key Facts & Figures', 2019; UK Gov, 'UK Energy in Brief 2020,' 2020; H2FC SUPERGEN, 'Opportunities For Hydrogen And Fuel Cell Technologies To Contribute To Clean Growth In The UK,' May 2020; Statista, 'Chemical Industry in the UK,' 2020;

堅實的氫能基礎

重工業經驗

英國在全世界已贏得國際工程卓越中心的聲譽。英國工程界僱用560萬員工，過去五年裡，僱用人數增加5.1%。工程領域所產生的營業額達**1.2兆英鎊**，佔英國總營收21.4%。

當今全世界生產的氫氣，有71%被用於化學和煉油產業。英國在這些產業中的現有氫能力，不但僱用了大量具灰氫生產經驗的工程人才，也為業界引進許多協作創新夥伴，並促成一個具國內外擴張潛力的產業市場。

脫碳藍圖

由於工業產生的碳排放佔英國總排放量近四分之一，英國政府針對八個熱密集度最高的產業(如鋼鐵業、化學工業、煉油業...等)，擬定**脫碳藍圖**。這些努力已獲得**工業能源轉型基金(3億1,500萬英鎊)**的支持。



業界共襄盛舉：英國石油天然氣協會(OGUK)是領導英國離岸油氣產業的同業公會。該協會也公佈了自己的計畫 – **2035路線圖：淨零排放藍圖**。在此計畫中，氫能扮演著重要角色。

氫氣

27TWh

目前英國氫能總產量

~95%

全球透過SMR生產的氫氣

石油 & 天然氣

280,000

油氣產業僱用人數

£7.8bn

2019年對油氣產業的投資

1.7m桶

英國每日生產之桶油當量

£27bn

產業營收
約40%透過出口產生

化學品

153,000

化學產業僱用人數

£19.2bn

2018年附加價值毛額(GVA)

£57.6bn

2019年化學品出口額

資料來源：Engineering UK – 「主要事實&數據」(2019年)；英國政府 – 「2020年英國能源概況」(2020年)；H2FC SUPERGEN – 「氫氣和燃料電池貢獻於英國潔淨能源成長之機會」；Statista – 「英國化學工業概觀」(2020年)

A History of Climate Change Leadership



Net Zero

In 2019, the UK became the first major economy in the world to pass laws to end its contribution to global warming by 2050. The target will require the UK to **bring all greenhouse gas emissions to net zero by 2050**, compared with the previous target of at least 80% reduction from 1990 levels.

The **UK has already reduced emissions by 42%**, and estimates show the low carbon economy in the UK could grow 11 per cent per year between 2015 and 2030 – over four times faster than the rest of the economy. This could see the number of “green collar jobs” grow to 2 million and the **value of exports from the low carbon economy grow to £170 billion a year by 2030**. Analysis suggests that in 2030 the UK hydrogen economy alone could be worth £900m and support over 9,000 jobs.

Ten Point Plan

In November 2020, the Prime Minister outlined his ambitious **Ten Point Plan for a Green Industrial Revolution**. Spanning 10 areas including clean energy, buildings, transport, and innovative technologies, the plan will **mobilise £12bn of government investment** and unlock three times as much private sector investment by 2030. The plan's commitments on green buildings, carbon capture use and storage, offshore wind and internal combustion engine phase out, all create commercial opportunities for hydrogen in the UK.

Sources: UK Gov, 'UK becomes first major economy to pass net zero emissions law,' Jun 2019; UK Gov, 'UK primed for capital investment,' Oct 2019, 'Solving the Integration Challenge', OWIC & ORE Catapult, July 2020, UK Hydrogen Strategy, Aug 2021.

氣候變遷領袖地位沿革



淨零排放

2019年，英國成為全世界首個通過立法設定2050年終結其對全球暖化貢獻度目標的主要經濟體。這項目標要求英國必須在**2050年時**，使其國內所有溫室氣體排放達到淨零，之前的目標僅要求碳排放至少減至1990年水準的80%。

英國已減少碳排放量達42%。根據估計，2015至2030年之間，英國的低碳經濟可望每年成長11% – 比英國其他領域快四倍以上。依此一成長速度，2030年時，英國的“綠領工作”數量可望增加到200萬，**低碳經濟出口值亦將成長到1,700億英鎊**。分析認為，2030年時，單單英國氫經濟價值便可望達到9億英鎊，提供超過9,000個工作機會。

十點計畫

2020年10月，英國首相提出雄心勃勃的**綠色工業革命十點計畫**，範圍橫跨十個領域，包括潔淨能源、建築、運輸、和創新科技。到了2030年，這項計畫將**動員120億英鎊的政府投資**，並帶動二倍於此的民間投資。十點計畫在綠色建築、碳捕集/利用/封存、離岸風電、和內燃機逐步淘汰等領域的投入，都將為英國氫能發展創造商機。

資料來源：英國政府 – 「英國成長率先通過淨零排放立法的主要經濟體」(2019年6月)；英國政府 – 「英國資本投資蓄勢待發」(2019年10月)；OWIC & ORE Catapult – 「克服整合挑戰」(2020年7月)；英國氫能戰略(2021年8月)。

UK Hydrogen Strategy

Overview

The UK Hydrogen Strategy is an extension of the Prime Minister's *Ten Point Plan for a Green Industrial Revolution*, setting out a regulatory and market framework for how we will deliver our ambition of 5GW installed low carbon hydrogen production capacity by 2030.

The Government's roadmap to 2030 expects most projects to be small (up to 20MW) electrolytic projects with a closely-linked, local end use in the early 2020s, larger (up to 100MW) electrolytic projects supporting a broader range of hydrogen uses by the mid-2020s before scaling up to 500MW+ blue hydrogen production facilities by the end of the decade.



Sources: UK Hydrogen Strategy, Aug 2021.

Supporting the Hydrogen Strategy

Measures included in the UK's first-ever Hydrogen Strategy are:

- A consultation on the design of the £240 million Net Zero Hydrogen Fund, which aims to support the commercial deployment of new low carbon hydrogen production plants across the UK.
- Collaborating with industry to develop a UK standard for low carbon hydrogen giving certainty to producers and users that the hydrogen the UK produces is consistent with net zero while supporting the deployment of hydrogen across the country.
- A consultation on the preferred Hydrogen Business Model to provide longer term revenue support to hydrogen producers to overcome the cost gap between low carbon hydrogen and conventional fossil fuels.
- A 'twin track' approach to support multiple technologies including 'green' electrolytic and 'blue' carbon capture-enabled hydrogen production, and committing to providing further detail in 2022 on the government's production strategy.
- A review to support the development of the necessary network and storage infrastructure to underpin a thriving hydrogen sector.
- Working with industry to assess the safety, technical feasibility, and cost effectiveness of blending 20% hydrogen into the existing gas supply. Doing so could deliver a 7% emissions reduction on natural gas.
- A commitment to launch a hydrogen sector development action plan in early 2022 setting out how the government will support companies to secure supply chain opportunities, skills and jobs in hydrogen.

英國氫能戰略

概觀

英國氫能戰略是首相的“綠色工業革命十點計畫”的延伸。英國氫能戰略針對如何達成2030年建置5GW低碳氫能裝置容量之宏偉目標，規劃出監管及市場架構。

政府為2030年擬定的藍圖，要求在2020年代初，大多數計畫必須為以密切關聯及在地終端使用為特色之小型電解計畫(最多20MW)；2020年代中期則要求支援更廣泛氫能利用之較大型電解計畫(最多100MW)；到了2020年代後期，則要求建立產能達500MW的藍氫生產設施。



資料來源：英國氫能戰略(2021年8月)

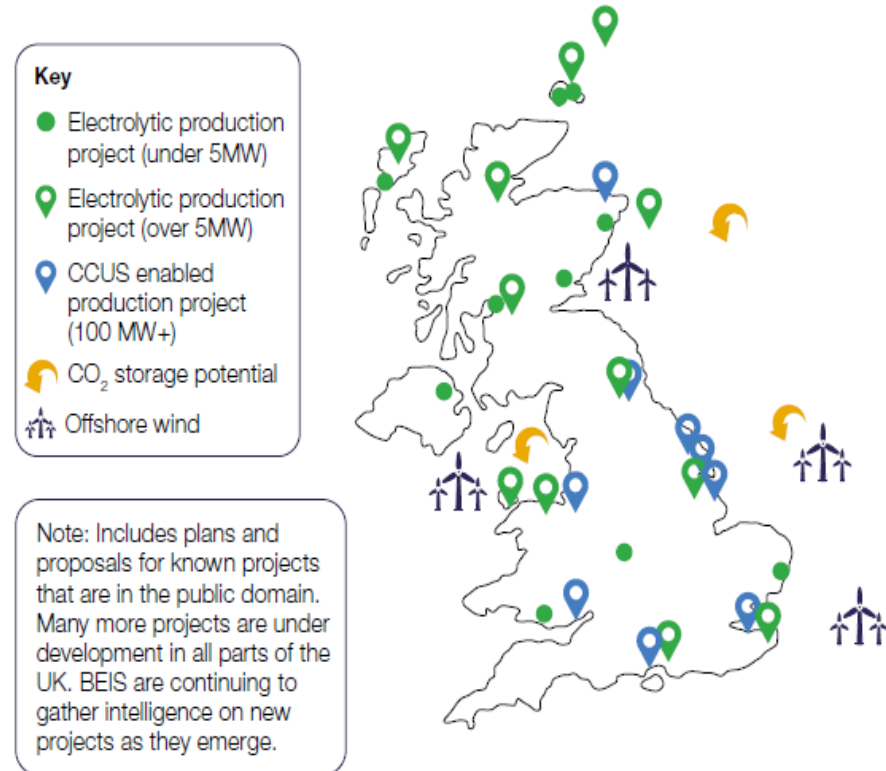
支持氫能戰略

英國率先提出之氫能戰略的相關措施包括如下：

- 為“淨零排放氫基金”(2億4000萬英鎊)之設計提供諮詢。該基金之成立目的為支援全英國低碳氫能生產廠之商業部署。
- 與業界合作發展英國低碳氫能標準，為氫氣生產業者及使用者提供確定性，讓他們放心，英國生產的氫氣絕對符合淨零排放要求，同時支持全國氫能部署。
- 為首選氫能事業模型提供諮詢，以支持氫氣生產業者之較長期收入，進而克服低碳氫能與傳統化石燃料之間的成本差。
- 提供‘雙軌’方法，支援多重技術開發，包括‘綠色’電解和‘藍色’碳捕集式氫氣生產，並致力於提供2022年政府氫生產戰略之細節。
- 審視必要網絡及儲存架構之發展，以支援蒸蒸日上之氫能產業。
- 與業界合作評估在天然氣供應中混入20%氫氣之安全性、技術可行性和成本效益。若此一混合方案可行，可望減少7%天然氣碳排放。
- 承諾於2022年初推出氫能產業發展行動方案，詳載政府將如何支援氫能業者確保供應鏈商機、技術、及工作機會。

UK Hydrogen Strategy

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



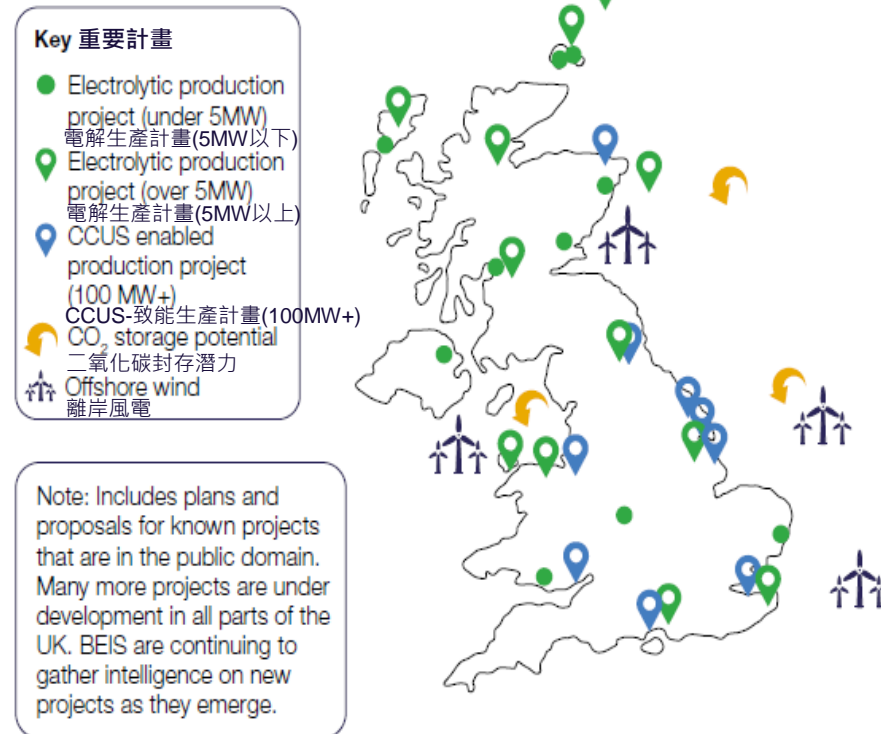
Key commitments

- BEIS grant **funding to support fuel switching technologies**, including low carbon hydrogen, through Phase 2 of the £315m Industrial Energy Transformation Fund.
- **Hydrogen for heat trials** – a hydrogen neighbourhood by 2023, hydrogen village by 2025 and potential pilot hydrogen town by 2030.
- Consultation on **‘hydrogen-ready’ boilers** by 2026.
- Multi-million pound support for transport decarbonisation, including for deployment, trials and demonstration of **hydrogen buses, HGVs, shipping, aviation and multi-modal transport hubs**.
- Assessment of the value for money case for **blending up to 20 per cent hydrogen** into the existing gas network by late 2022, and aim to make a final policy decision in late 2023.

英國氫能戰略

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

圖1.3：建議之英國電解及CCUS-致能氫氣生產計畫



註：包含公共領域既有專案之計畫和建議案。英國各個領域有更多計畫正在發展中。BEIS將持續蒐集新出現之有關新計畫的資訊。

重要承諾

- 英國商業、能源及產業策略部(BEIS)透過工業能源轉型基金(3億1,500萬英鎊)第2期計畫提供資金，支持燃料轉換技術開發，包括低碳氫能。
- 氫換熱試驗 – 氫社區(2023年)、氫村莊(2025年)和可能的前導氫市鎮(2030年)。
- 為2026年的‘氫就緒’鍋爐計畫提供諮詢。
- 提供數百萬英鎊支援運輸業脫碳，包括氫能巴士、重型貨車(HGV)、海運、空運、和多式聯運運輸中心之部署、試驗及示範。
- 評估2022年底在現有天然氣網絡中混入20%氫氣並於2023年底做出最終決策物有所值案例。

Export capability in a growing UK hydrogen sector



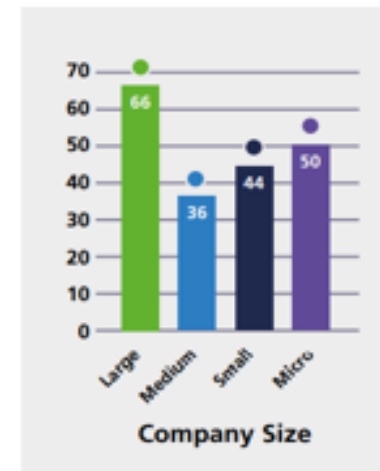
Over 66% of UK hydrogen companies surveyed **already export goods and services** to the growing hydrogen market. Low carbon hydrogen could support up to 100,000 UK jobs by 2050 with **£0.5 billion export opportunities**.



The UK has been consistently within the **top ten countries globally for hydrogen technology patent rates**. UK hydrogen companies have world leading fuel cell, hydrogen production and material technologies, and some have secured substantial foreign direct investment. Consulting, transport, and fuel cells are the most common market areas, but companies work **across the entire supply chain**.

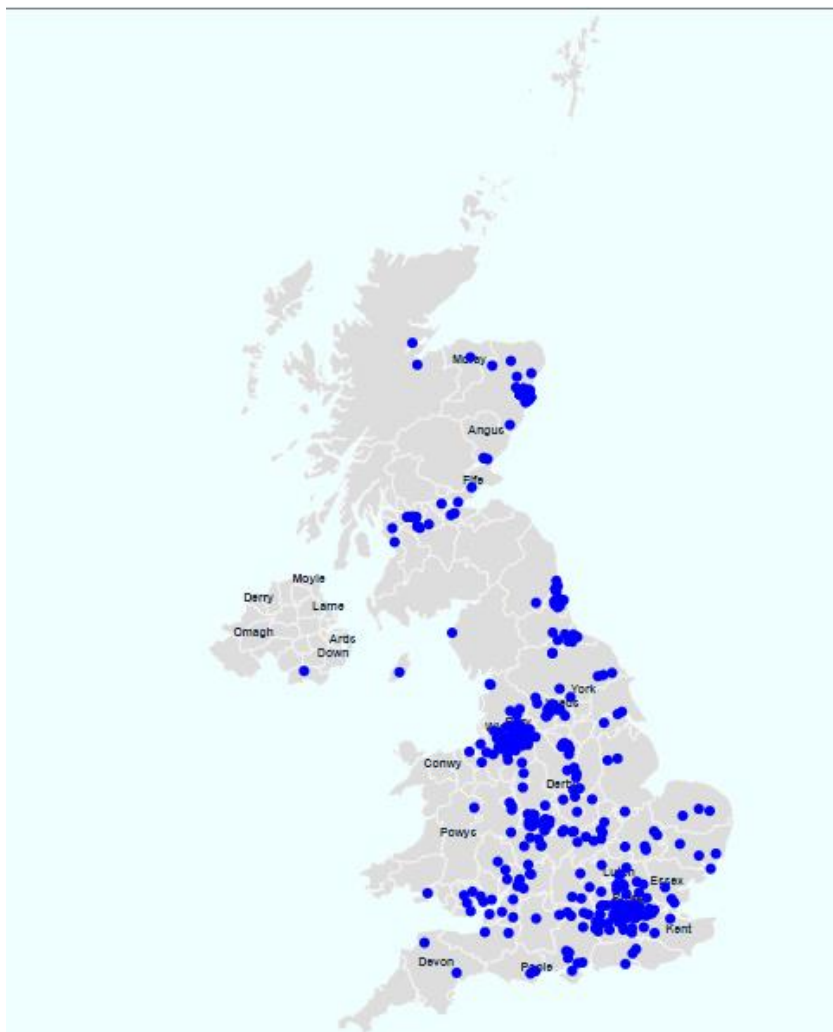


196 companies in the UK work on Hydrogen Fuel Cell (H2FC) technologies, ranging from micro spin-offs to multinational companies with H2FC divisions, as shown in the graph below.



Sources: H2FC SUPERGEN, 'Opportunities For Hydrogen And Fuel Cell Technologies To Contribute To Clean Growth In The UK,' May 2020; UK Gov, 'Ten Point Plan,' Nov 2020; EY, 'Renewable Energy Country Attractiveness Index (RECAI),' Nov 2020; [Hydrogen & fuel cells EINA](#), Nov 2019. *The image above depicts all EIC members that fall within the "hydrogen (derived)" category.*

英國成長中氫能產業之出口能力



資料來源：H2FC SUPERGEN – 「氫氣和燃料電池貢獻於英國潔淨能源成長之機會」(2020年5月)；英國政府 – 「十點計畫」(2020年11月)；EY – 「再生能源國際吸引力指數」(RECAI)(2020年11月)；「[氫能&燃料電池EINA](#)」(2019年11月)；上圖標出隸屬於「氫能(衍生)」類別之所有能源工業委員會(EIC)的會員。



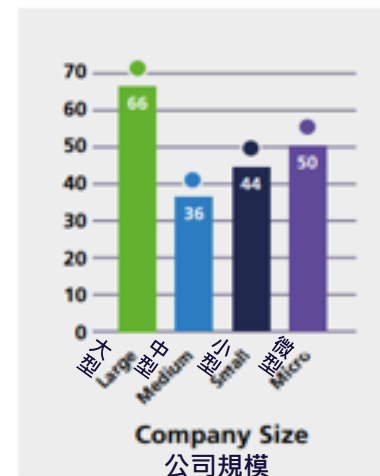
所調查的英國氫能公司中，**66%**以上已經向成長中的氫能市場輸出產品及服務。2050年時，**低碳氫能產業**可望為英國提供**10萬個**工作機會，**出口商機**價值可望達到**5億英鎊**。



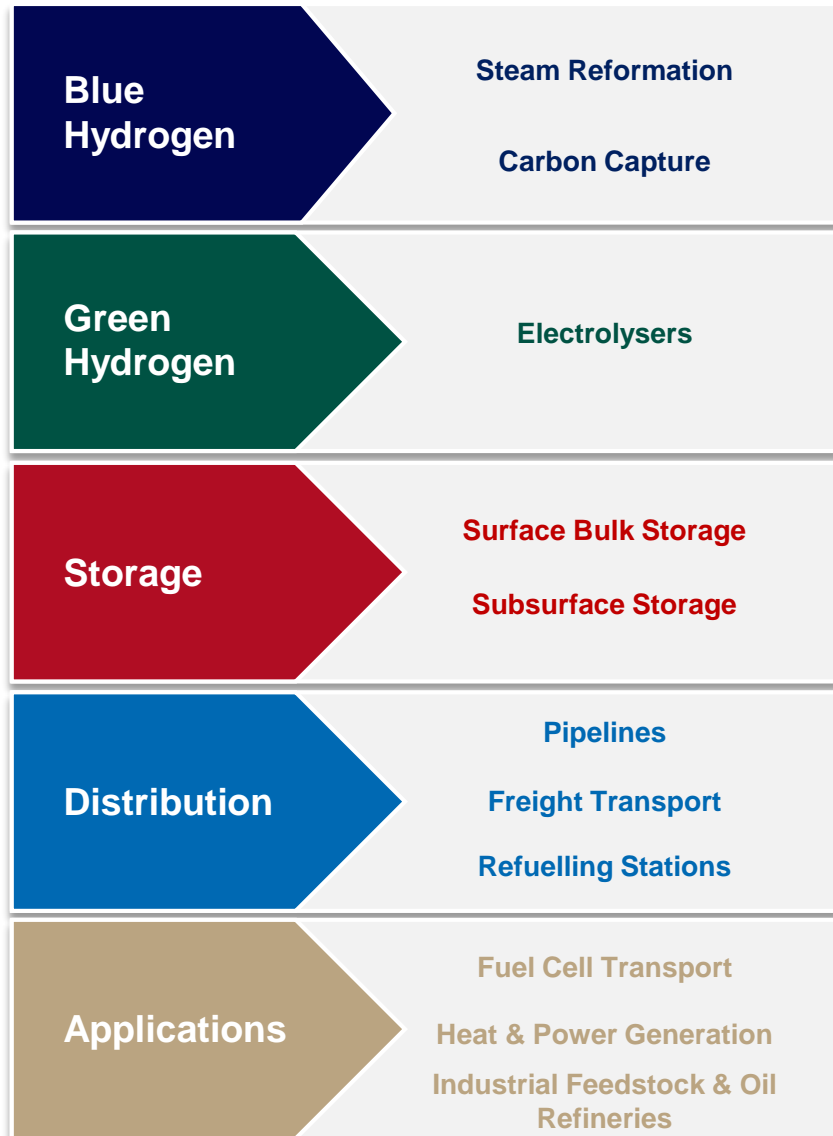
英國持續保持在全**球十大氫能技術專利擁有國**名單內。英國的氫能公司擁有領先全球的**燃料電池、氫氣生產及材料技術**，有些公司甚至已獲得**實質性的外國直接投資**。諮詢、運送和**燃料電池**是最常見的市場領域，但氫能公司的營運**涵蓋整個供應鏈**。



英國有**196家公司**致力於研發**氫燃料電池(H2FC)**技術，從**微型**衍生公司到設有**H2FC部門**之**跨國企業**不一而足。詳見下圖：



Capability Across The Hydrogen Value Chain

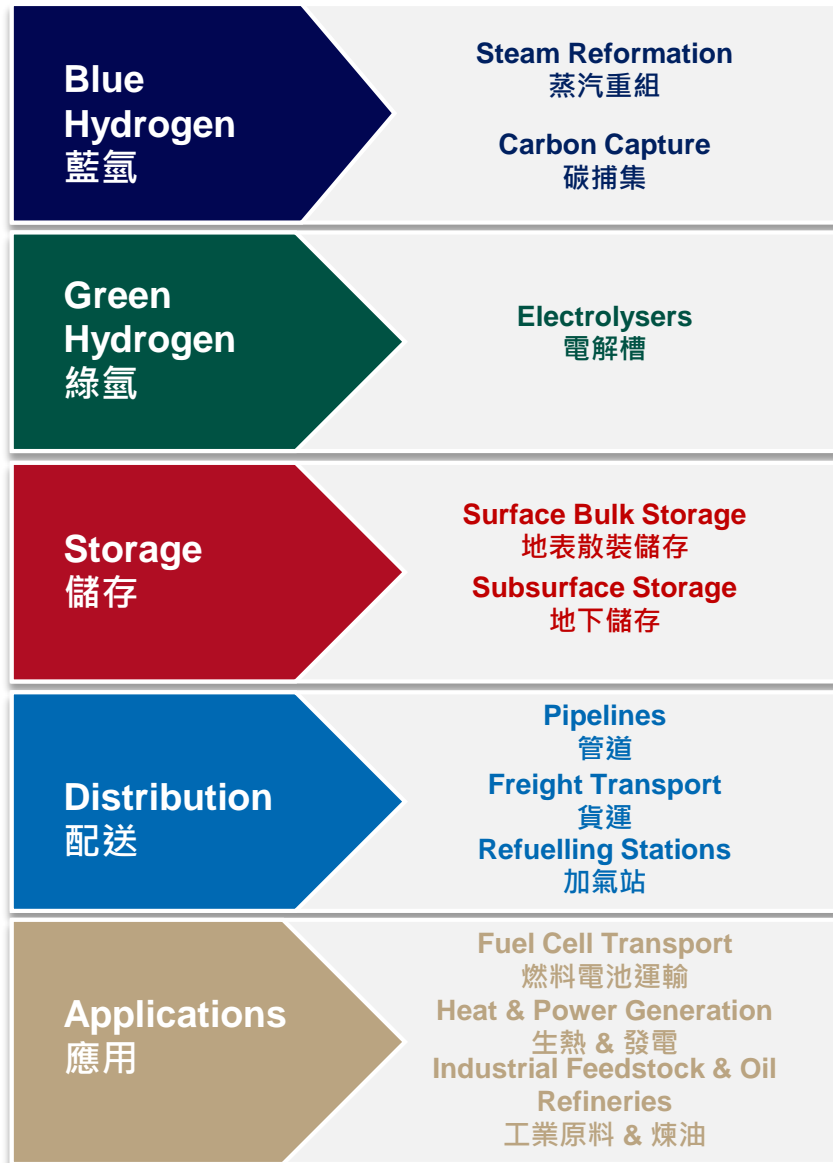


Hydrogen & Its Myriad Applications

UK companies with hydrogen ready technology are **already exporting overseas** particularly in fuel cell technology, methane reforming, green hydrogen production and project life cycle capability.

The UK has several **Engineering, Procurement & Construction Companies (EPCs)** who are **currently transitioning their skills, capability and supply chains** to clean growth projects including hydrogen projects. The UK is leading through trialling how hydrogen can be integrated into current energy systems and testing its many potential applications in numerous projects across the value chain.

在整個氫能價值鏈上的能力



氫能及各種應用

英國擁有氫就緒科技的公司已開始向海外輸出技術，尤其是燃料電池技術、甲烷重組、綠氫生產、和計畫生命周期能力。

英國有許多家工程總承包公司(EPC)。目前這些公司已將其技術、能力、和供應鏈轉用於潔淨成長計畫，包括氫能計畫。英國藉由試驗如何將氫能整合於現有能源系統，並在整個價值鏈的許多計畫中測試各種可能應用而領先群倫。

Supply chain analysis

The UK excels at:

- Water electrolysis materials, engineering, stacks and systems (power to gas and refuelling)
- Methane reforming catalysts and process engineering
- Consultancy including project development and safety
- Fuel cells including high power density PEM and Solid Oxide Fuel Cells (SOFC)
- Transport applications including bus design and combustion engine conversion
- Storage facilities such as salt caverns
- Prototypes for hydrogen ready boilers



Sources: UK Gov, 'Energy White Paper: Powering Our Net Zero Future,' Dec 2020; Hydrogen Europe, 'Electrolysers,' accessed Feb 2021; IEA, 'The Future of Hydrogen,' 2019; IRENA, 'Hydrogen: A Renewable Energy Perspective,' 2019.

供應鏈分析

英國擁有以下強項：

- 水電解材料、工程、堆疊、和系統(電轉氫和加氣)。
- 甲烷重組催化劑和製程工程。
- 諮詢，包括計畫發展和安全性。
- 燃料電池，包括高功率密度質子交換膜(PEM)和固態氧化物燃料電池(SOFC)。
- 運輸應用，包括巴士設計和燃機轉換。
- 儲存設施，譬如鹽穴。
- 氫就緒鍋爐原型。



資料來源：英國政府－「能源白皮書：推動零碳未來」(2020年12月)；歐洲氫能組織－「電解槽」(2021年2月發佈)；國際能源署(IEA)－「氫能之未來」(2019年)；國際再生能源總署(IRENA)－「氫能：一個再生能源觀點」(2019年)。

Capability – Blue Hydrogen

Blue Hydrogen

Steam Reformation

Carbon Capture

Manufacturers:

Generation technologies:

- [Hydrasun](#)
- [Johnson Matthey](#) (LCH™ technology)
- [Magma Catalysts](#)
- [Wood](#) (Terrace Wall™)

Carbon capture solutions:

- [Carbon Clean](#)
- [TP Group](#)

Developers, consultancies:

- [Arup](#)
- [BP](#)
- [Costain](#)
- [Environmental Resources Management \(ERM\)](#)
- [Equinor UK Ltd.](#)
- [Pale Blue Dot / Storegga Group](#)
- [Penspen](#)
- [Petrofac](#)
- [Progressive Energy](#)

Blue Hydrogen:

Blue hydrogen is produced by splitting natural gas into hydrogen and CO₂, either through Steam Methane Reforming (SMR) or Auto Thermal Reforming (ATR), with the CO₂ being captured and then stored. The 'capturing' is done through Carbon Capture Usage and Storage (CCUS) technology, and mitigates the environmental impact of the otherwise emissions-intensive SMR or ATR processes.

Blue hydrogen is considered fundamental in kick starting the establishment of a hydrogen economy in the UK and we have unique geological advantages for carbon storage. .

能力 – 藍氫

Blue Hydrogen 藍氫

Steam Reformation
蒸汽重組

Carbon Capture
碳捕集

Manufacturers: 製造商 :

Generation technologies: 發電技術

- [Hydrasun](#)
- [Johnson Matthey](#) (LCH™ 技術)
- [Magma Catalysts](#)
- [Wood](#) (Terrace Wall™ 擋土牆)

Carbon capture solutions: 碳捕集解決方案

- [Carbon Clean](#)
- [TP Group](#)

Developers, consultancies: 開發商及顧問公司

- [Arup](#)
- [BP](#)
- [Costain](#)
- [Environmental Resources Management \(ERM\)](#)
- [Equinor UK Ltd.](#)
- [Pale Blue Dot / Storegga Group](#)
- [Penspen](#)
- [Petrofac](#)
- [Progressive Energy](#)

藍氫 :

藍氫的生產是藉由蒸汽甲烷重組(SMR)或自發性熱重組(ATR)將天然氣分離為氫氣和二氧化碳(CO₂)，再將二氧化碳(CO₂)捕集和儲存起來。‘碳捕集’係利用碳捕集/利用/封存(CCUS)技術完成，因而緩減排放密集之SMR和ATR流程對環境的衝擊。

藍氫被視為英國建立氫經濟的根基。我們在碳封存方面擁有獨特的地理優勢。

Capability – Green Hydrogen

Green Hydrogen

Electrolysers

Manufacturers:

Electrolyser systems:

- [CPH2](#) - Membrane-Free Electrolyser™ with cryogenic separation
- [ITM Power](#) – PEM
- [TP Group](#)

Catalyst coated membranes:

- [Johnson Matthey](#)

Anionic exchange membranes:

- [AFC Energy](#)

Catalysts & coatings:

- [Ames Goldsmith Ceimig](#) (PEM catalysts)
- [TFP Hydrogen Products](#)

Compression solutions:

- [Howden](#)

Green Hydrogen:

Green hydrogen is produced by splitting water through renewable energy-powered electrolysers. This produces only hydrogen and oxygen, without CO₂ as a by-product. There are two main types of electrolyser technology: **Alkaline (ALK)** and **Proton Exchange Membrane (PEM)**. PEM electrolysers are considered the next generation of technology, as they are more able to cope with the intermittent nature of electricity from wind or solar. Green hydrogen is currently more costly than blue hydrogen, but electrolyser costs are expected to halve by 2040-2050.

While scale up of blue hydrogen will help build the hydrogen demand economy, a move towards green hydrogen is seen as inevitable in the long-run. **Only 2% of current global hydrogen production is produced through electrolysis**, presenting an enormous opportunity for UK capability.

Developers, consultancies:

- [Arup](#)
- [BP](#)
- [Environmental Resources Management \(ERM\)](#)
- [Global Tower Solutions \(GTS\)](#)
- [INOVYN](#)
- [Octopus Energy](#)
- [Penspen](#)
- [Petrofac](#)
- [Protium](#)
- [Wood Plc](#)

能力 – 綠氫

Green Hydrogen 綠氫

Electrolysers 電解槽

Manufacturers: 製造商 :

Electrolyser systems: 電解槽系統

- [CPH2](#) - Membrane-Free Electrolyser™ with cryogenic separation 低溫分隔無膜電解槽
- [ITM Power](#) – PEM 質子交換膜
- [TP Group](#)

Catalyst coated membranes: 催化劑塗層膜 :

- [Johnson Matthey](#)

Anionic exchange membranes: 陰離子交換膜 :

- [AFC Energy](#)

Catalysts & coatings: 催化劑 & 塗層

- [Ames Goldsmith Ceimig](#) (PEM 催化劑)
- [TFP Hydrogen Products](#)

Compression solutions: 壓縮解決方案 :

- [Howden](#)

綠氫 :

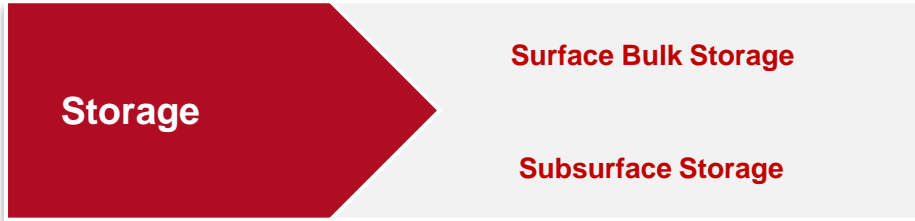
綠氫之生產是藉由再生能源供電的電解槽將水分離。此一過程只會產生氫氣和氧氣，沒有二氧化碳(CO₂)副產品。電解槽技術主要有兩種：**鹼性(ALK)**和**質子交換膜(PEM)**。PEM電解槽被認為是下一代技術，因為這種技術比較能適應風力及太陽能發電之間歇性本質。雖然目前綠氫的成本比藍氫高，但預期到了2040-2050年間，電解槽的成本可望減半。

儘管擴大發展藍氫有助於建立氫需求經濟，但一般認為，朝向綠氫發展是不可避免的長期趨勢。目前全球只有2%的氫產量是透過電解生產的，這點對英國能力而言，意味著龐大的商機。

Developers, consultancies: 開發商及顧問公司

- [Arup](#)
- [BP](#)
- [Environmental Resources Management \(ERM\)](#)
- [Global Tower Solutions \(GTS\)](#)
- [INOVYN](#)
- [Octopus Energy](#)
- [Penspen](#)
- [Petrofac](#)
- [Protium](#)
- [Wood Plc](#)

Capability – Storage



Storage solutions:

- [Acoustic Data](#)
- [Chesterfield Special Cylinders](#)
- [CPE](#)
- [H2GO](#)
- [Kubagen](#)
- [SSE](#)

For vehicles:

- [Arcola Energy](#)
- [Luxfer Gas Cylinders](#)

Solutions & integration:

- [BOC](#)
- [Howden](#)
- [Hydrasun](#)
- [INOVYN](#)
- [Logan Energy](#)
- [McDermott International](#)
- [Penspen](#)

Consultancies:

- [ERCE](#)
- [Hydrenor](#)

Hydrogen Storage:

Storage is an essential step in the hydrogen supply chain. Surface storage options include **compressed and liquid storage**: Hydrogen can be compressed into large tanks without liquefying, which is generally the preferred option. Hydrogen can also be stored as a liquid at very low temperatures (-253°C). Specially insulated tanks are required for this option. Due to the high energy density of liquid hydrogen, less space is required on site.

Subsurface options are dependent on geology, including **salt caverns and depleted oil & gas fields**. Hydrogen has been stored in caverns under Teesside since the 1970s and there is potential to repurpose caverns currently used for storing natural gas. The British Geological Survey suggests we have significant rock salt formations with **potential for 1000s of terawatt hours of future storage**. Underground storage is able to provide large volume storage at lowest cost per unit of energy stored. This is a significant strategic advantage for the UK compared to many other countries.

Hydrogen also has a key advantage over conventional electricity storage methods, mainly lithium batteries, namely its ability to be stored in large quantities for long periods of time, over days, weeks or even months, at low cost.

能力 – 儲存

Storage 儲存

Surface Bulk Storage
地表散裝儲存

Subsurface Storage
地下儲存

Storage solutions: 儲存解決方案：

- [Acoustic Data](#)
- [Chesterfield Special Cylinders](#)
- [CPE](#)
- [H2GO](#)
- [Kubagen](#)
- [SSE](#)

For vehicles: 運輸車：

- [Arcoia Energy](#)
- [Luxfer Gas Cylinders](#)

Solutions & integration: 解決方案 & 整合：

- [BOC](#)
- [Howden](#)
- [Hydrasun](#)
- [INOVYN](#)
- [Logan Energy](#)
- [McDermott International](#)
- [Penspen](#)

Consultancies: 顧問公司：

- [ERCE](#)
- [Hydrenor](#)

氫氣儲存：

儲存是氫氣供應鏈中不可或缺的步驟。地表儲存選項包括**壓縮和液態儲存**：氫氣可在未經液化的情況下直接壓縮儲存於大型儲槽中。一般而言，這是首選的儲存方式。氫氣也可液化後儲存於非常低溫環境中(-253°C)。此一選項特別要求絕緣儲槽。由於液態氫的高能密度，儲存場需要的空間較小。

地下儲存選項取決於地質條件，包括**鹽穴和枯竭的油氣田**。1970年代起，氫氣便一直被儲存於提斯賽(Teesside)地下的鹽穴中。目前儲存天然氣的鹽穴，也可能重新利用來儲存氫氣。英國地質調查局(BGS)表示，我們擁有大量岩鹽結構，**具有未來儲存1000 TWh氫氣的潛力**。地下儲存方式能夠以最低的儲能單位成本，提供大量儲存能力。相較於許多其他國家，這是英國的一項重要戰略優勢。

相較於傳統儲電方法(主要為鋰電池)，氫氣擁有重大優勢，因為氫氣能夠以低成本大量長期儲存(數日、數週、甚至數月)。

Capability - Distribution



Hydrogen Distribution:

The UK is currently establishing valuable expertise through several **hydrogen blending pilot projects** across its gas networks. The UK also has capability in the design, engineering, integration and operation of hydrogen **refuelling stations**, related components, as well as hydrogen **distribution as a service**.

Hydrogen refuelling station operators
/ Hydrogen as a service:

- [ITM Motive](#)
- [Octopus Hydrogen](#)

Components:

Hydrogen hoses & piping:

- [Hydrasun](#)
- [Parker Hannifin](#)

Compressors & valves:

- [Haskel](#)
- [Howden](#)
- [Oliver Valves](#)

Engineering consultancies & developers:

- [Costain](#)
- [Fichtner Consulting](#)
- [Otto Simon Ltd](#)
- [Penspen](#)
- [Progressive Energy](#)
- [Thyson Technology](#) (solutions for blending)

Hydrogen refuelling solutions

- [BOC](#)
- [CMB.TECH](#)
- [Fuel Cell Systems](#)
- [Haskel](#)
- [Nanosun](#)

能力 – 配送



氫氣配送：

英國目前正透過在整個天然氣網絡中實施多項氫氣混合先導計畫，以累積寶貴的專門知識。英國還擁有氫氣加氣站、相關元件、及氫氣配送服務等領域之設計、工程、整合、及運作能力。

Hydrogen refuelling station operators
/ Hydrogen as a service: 氫氣加氣站業者/供氫服務：

- [ITM Motive](#)
- [Octopus Hydrogen](#)

Components: 元件：

Hydrogen hoses & piping: 氫氣軟管 & 管道：

- [Hydrasun](#)
- [Parker Hannifin](#)

Compressors & valves: 壓縮機 & 閥門：

- [Haskel](#)
- [Howden](#)
- [Oliver Valves](#)

Engineering consultancies & developers: 工程顧問公司 & 開發商

- [Costain](#)
- [Fichtner Consulting](#)
- [Otto Simon Ltd](#)
- [Penspen](#)
- [Progressive Energy](#)
- [Thyson Technology](#) (混合解決方案)

Hydrogen refuelling solutions: 氫氣加氣站：

- [BOC](#)
- [CMB.TECH](#)
- [Fuel Cell Systems](#)
- [Haskel](#)
- [Nanosun](#)

Capability – Downstream applications

Applications

Fuel Cell Transport
Heat & Power Generation
Industrial Feedstock & Oil Refineries

Heat & Power Generation:

Hydrogen boilers:

- [Baxi](#)
- [Worcester Bosch](#)

Hydrogen turbines & compression

- [Baker Hughes](#)

Engineering consultancy:

- [Arup](#)
- [Costain](#)
- [Clarke Energy](#) (Engineering, Installation, Maintenance)

Road & rail transport:

- [Riversimple](#) (cars)
- [ULEMco](#) (dual fuel tech for commercial fleets)
- [Wrightbus](#)
- [Alstom](#) (trains)
- [Vivarail](#)

Excavators/ construction equipment:

- [JCB](#)

Consultancies:

- [Arup](#)
- [Element Energy](#)

Downstream applications:

The UK has capability across the downstream segment - from innovative fuel cell technologies, hydrogen turbines and boilers, to various modes of transportation.

Aviation

- [ZeroAvia](#)
- [HyPoint](#) (Turbo-Air Cooled HTPEM Hydrogen Fuel Cell Systems for aircrafts)

Fuel cells (FC):

- [Adelan](#) (microtubular solid oxide FC)
- [AFC Energy](#) (alkaline FC)
- [Auriga Energy](#)
- [Bramble Energy](#)
- [Ceres Power](#) (solid oxide FC- SteelCell®)
- [Enocell](#) (direct methanol FC)
- [Intelligent Energy](#) (PEM FC)

Integration & systems engineering:

- [Arcola Energy](#)
- [Fuel Cell Systems](#)
- [Logan Energy](#)

Catalysts, membranes & coatings:

- [Ames Goldsmith Ceimig](#) (PEM catalysts)
- [Johnson Matthey](#)
- [TFP Hydrogen Products](#)

能力 – 下游應用

Applications 應用

Fuel Cell Transport
燃料電池運輸
Heat & Power Generation
生熱 & 發電
Industrial Feedstock & Oil
Refineries
工業原料 & 煉油

Heat & Power Generation: 生熱 & 發電

Hydrogen boilers: 氫氣鍋爐 :

- [Baxi](#)
- [Worcester Bosch](#)

Hydrogen turbines & compression: 氫氣渦輪機 & 壓縮 :

- [Baker Hughes](#)

Engineering consultancy: 工程顧問公司 :

- [Arup](#)
- [Costain](#)
- [Clarke Energy](#) (工程、安裝、維護)

Road & rail transport: 公路 & 鐵路運輸 :

- [Riversimple](#) (汽車)
- [ULEMco](#) (用於商用車隊之雙燃料技術)
- [Wrightbus](#)
- [Alstom](#) (火車)
- [Vivarail](#)

Excavators/ construction equipment: 挖掘機
/ 營建設備 :

- [JCB](#)

Consultancies: 顧問公司 :

- [Arup](#)
- [Element Energy](#)

下游應用 :

英國擁有整個下游區段的能力，從創新燃料電池技術、氫渦輪機與鍋爐、到各種運輸模式不一而足。

Aviation: 航空 ;

- [ZeroAvia](#)
- [HyPoint](#) (飛機用渦輪-氣冷式HTPEM氫燃料電池系統)

Fuel cells (FC): 燃料電池 :

- [Adelan](#) (微管式固體氧化物FC)
- [AFC Energy](#) (鹼性FC)
- [Auriga Energy](#)
- [Bramble Energy](#)
- [Ceres Power](#) (固體氧化物FC- SteelCell®)
- [Enocell](#) (直接甲醇FC)
- [Intelligent Energy](#) (PEM FC)

Integration & systems engineering: 整合 & 系統工程 :

- [Arcola Energy](#)
- [Fuel Cell Systems](#)
- [Logan Energy](#)

Catalysts, membranes & coatings: 催化劑、薄膜 & 塗層 :

- [Ames Goldsmith Ceimiq](#) (PEM催化劑)
- [Johnson Matthey](#)
- [TFP Hydrogen Products](#)

Soaring Hydrogen Innovation from the UK to the World

UK Fuel Cells Deployed in...

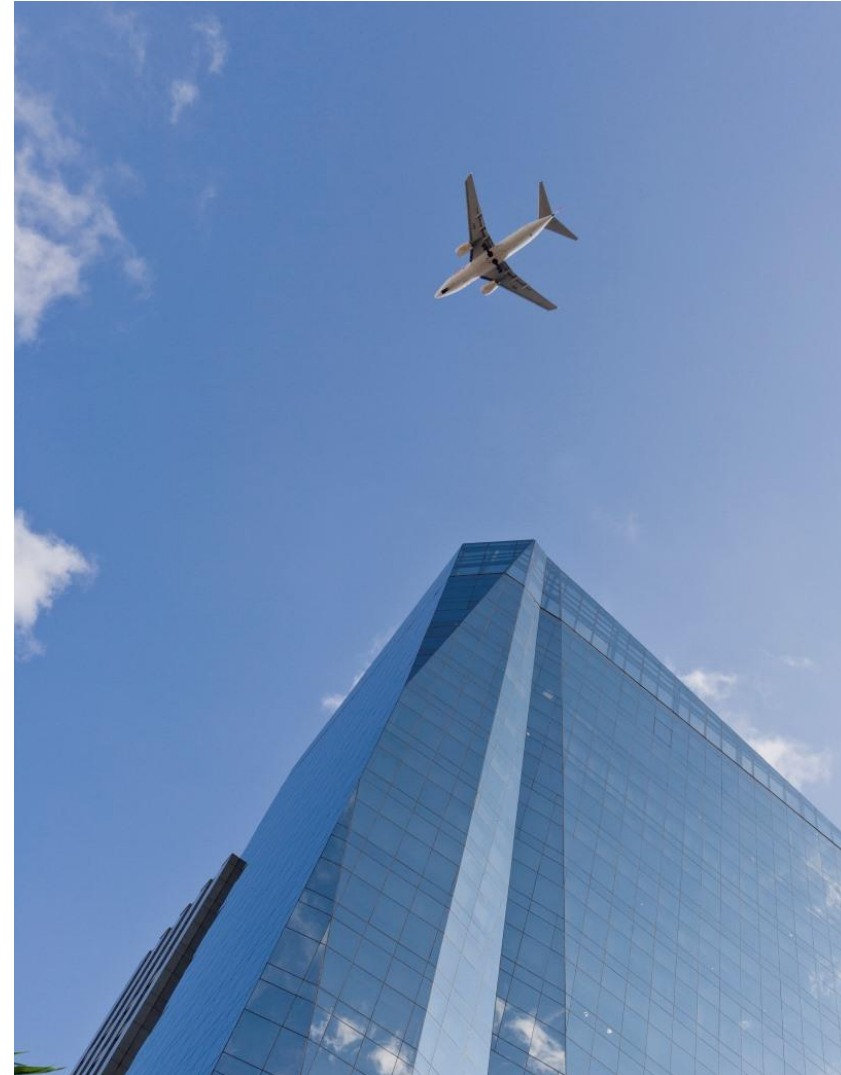


AVIATION – Hydrogen is emerging as a promising green fuel substitute for the aviation industry, whose use of jet fuel contributed over 1 billion tonnes of CO₂ in 2018. Hydrogen is faster to refuel and negates the need to onboard large, heavy batteries.

In 2020, UK aviation firm [ZeroAvia](#) completed the **world's first hydrogen fuel cell powered flight of a commercial-grade aircraft** in what has been hailed as a landmark moment for low carbon flight. As part of the [HyFlyer](#) project, ZeroAvia also helped develop a refuelling system at Cranfield Airport. Green aviation is further supported by the new [Jet Zero Council](#).



RAIL – Fuel cell trains are increasingly talked about in discussions over how to fully decarbonise the rail network. They are smoother, quieter, more efficient, and should be easier and cheaper to maintain than diesel trains. The UK's [first-ever hydrogen-powered train](#) started on the UK mainline in 2020 as part of **project HydroFLEX** conducted in the Midlands by Porterbrook and the University of Birmingham.



Sources: Our World in Data, 'Climate change and flying: what share of global CO2 emissions come from aviation?,' Oct 2020; The Engineer, 'World's first hydrogen powered commercial plane takes off from Cranfield,' Sept 2020; H2FC SUPERGEN, 'Opportunities For Hydrogen And Fuel Cell Technologies To Contribute To Clean Growth In The UK,' May 2020.

從英國到全球飆升的氫能創新

英國燃料電池之部署...

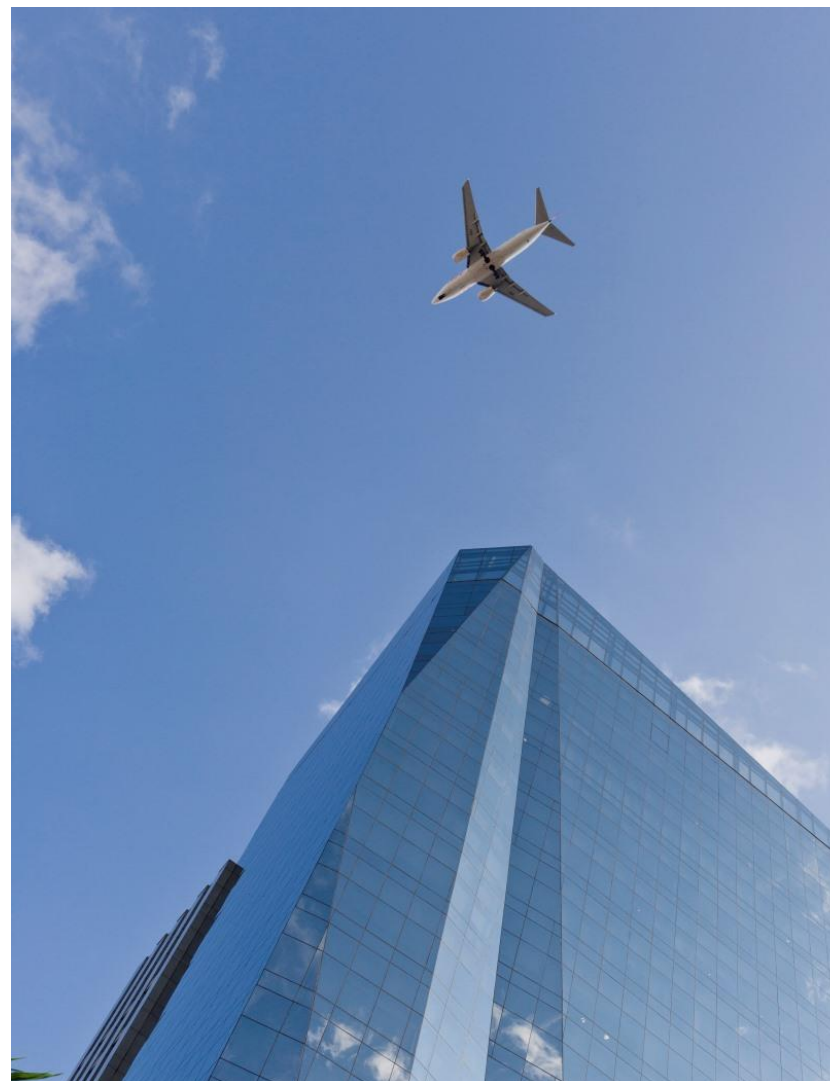


航空 – 氫氣是一種可取代目前航空業採用之噴射機燃料的新興且前途看好的綠能燃料。2018年，噴射機燃料所產生的二氧化碳(CO₂)便超過10億噸。氫氣補充燃料的速度很快，因而排除了在飛機上裝置大型笨重電池的必要性。

2020年，英國ZeroAvia航空公司完成全球首趟商業級飛機仰賴氫燃料電池供電的航班。那趟航班被譽為低碳航班的里程碑。ZeroAvia也協助在克蘭菲爾德機場(Cranfield Airport)設置一套加氣系統，成為HyFlyer計畫的一部分。綠色航空也已獲得新成立之飛航零碳排委員會(Jet Zero Council)的支持。



鐵路 – 有關燃料電池火車的討論越來越多，而討論最多的是如何促使鐵路網完全脫碳。燃料電池火車將比柴油火車更平順、更安靜和更有效率，且應更容易維護，維護成本也較低。在Porterbrook公司與伯明翰大學的合作下，英國首輛氫能動力火車於2020年開始行駛於英國主線鐵路米德蘭區(Midlands)，成為HydroFLEX計畫的一部分。



資料來源：Our World in Data – 「氣候變遷與航空：航空運輸在全球碳排放中佔比如何？」(2020年10月)；The Engineer – 「全球首架氫能商用飛機從蘭菲爾起飛」(2020年9月)；H2FC SUPERGEN – 「氫氣和燃料電池貢獻於英國潔淨能源成長之機會」(2020年5月)

Examples of Domestic Projects

Dolphyn

Environmental Resources Management has developed a concept design for the production of 'green' hydrogen at scale from offshore floating wind off the coast of Scotland. The concept integrates a wind turbine, desalination unit and electrolysis onto a single floating sub-structure to produce hydrogen that can be transported to shore via pipeline.

HyNet

HyNet North West aims to be the UK's first net-zero carbon industrial cluster and is based on the production of hydrogen from natural gas, using **Johnson Matthey's** proprietary technology. It includes the development of a new hydrogen pipeline; and the creation of the UK's first CCS infrastructure. This revolutionary project has the potential to reduce CO2 emissions by 10 million tonnes every year by 2030 – the equivalent of taking 4 million cars off the road. To be located at Stanlow Refinery, the ultimate project may include up to 3 plants, producing up to 18TWh per year of low carbon hydrogen.

Gigastack

This project demonstrated the delivery of bulk, low-cost renewable (green) hydrogen through Gigawatt-scale polymer electrolyte membrane (PEM) electrolysis, manufactured by **ITM Power**. This project developed next-generation innovative electrolyser stack technology, and evaluated cost drivers of renewable hydrogen such as the cost of renewable electricity, and possible cost reductions from economies of scale, standardisation and industrialisation.

HyDeploy

As the first ever live demonstration of hydrogen in homes, HyDeploy aims to prove that **blending up to 20% volume of hydrogen with natural gas** is a safe and greener alternative to the gas we use now. It is providing evidence on how customers don't have to change their cooking or heating appliances to take the blend, which means less disruption and cost for them. It is also confirming initial findings that customers don't notice any difference when using the hydrogen blend.

國內計畫實例

Dolphyn

環境資源管理公司(ERM)已根據蘇格蘭外海浮體式離岸風電的經驗，發展出一套大規模生產綠氫的概念設計。此一概念將風力渦輪機、海水脫鹽裝置、和電解設備整合於單一的浮體式次結構，以生產氫氣，並藉由管道將之運輸上岸。

Gigastack

本計畫透過由ITM Power製造的千兆瓦規模高分子電解質膜(PEM)電解設備，示範提供散裝低碳再生(綠色)氫能。
本計畫開發下一代創新電解槽堆疊技術，並評估再生氫能之成本動因，譬如再生電力之成本，以及規模經濟、標準化及產業化效益下可能減降之成本。

HyNet

HyNet North West計畫之目標為建立英國首個淨零碳排放產業群聚，其基礎為利用Johnson Matthey公司的專利技術，從天然氣中分解出氫氣。
本計畫的工作包括發展新的氫氣輸送管道和建立英國首創碳捕集與封存(CCS)基礎建設。
這項革命性計畫具有2030年後每年減少1,000萬噸二氧化碳(CO₂)排放量的潛力 – 相當於道路上減少400萬輛汽車。
本計畫之執行地點為斯坦羅煉油廠(Stanlow Refinery)，其最終成果包括三座氫能廠，每年可生產18TWh低碳氫能。

HyDeploy

HyDeploy是英國首創氫能現場示範計畫，其目的為證明在天然氣中混入20%氫氣是安全的，且為可取代當前所用天然氣之更環保選項。HyDeploy計畫希望提供證據，以證明採取此種混氫天然氣，顧客無需更換烹飪或供暖用具，意味著此種天然氣對顧客的干擾和成本衝擊較小。此計畫亦在證實採用氫混合天然氣時，顧客不會注意到任何差異之初步發現。

Examples of Domestic Projects

H100 Fife

SGN is developing a world-first hydrogen network in Buckhaven (east coast of Scotland) that will bring renewable hydrogen into homes in 2023, providing zero-carbon fuel for heating and cooking. In the project's first phase, the network will heat around 300 local homes using clean gas produced by a dedicated electrolysis plant, powered by a nearby offshore wind turbine. The project is the first of its kind to employ a direct supply of clean power to produce hydrogen for domestic heating – putting Fife at the forefront of the clean energy revolution. An on-site storage unit will hold enough hydrogen to ensure supply won't be disrupted during even the coldest weather conditions.

Architectural glass production powered by hydrogen in world first

Pilkington United Kingdom Limited, part of the NSG group, has successfully manufactured architectural glass at its St Helens facility using hydrogen power in a world-first trial. The trial is a key step in the manufacturer's plans to decarbonise and could see a transition to using hydrogen to power all production at the site, which currently uses natural gas. The aim of the trial was to demonstrate that the float glass furnace, in which the raw ingredients of the glass are heated to around 1,600 degrees centigrade, could run safely at full production without impacting product quality.

The Acorn Project

There are two key elements to the Acorn project – Acorn CCS Project and Acorn Hydrogen. Acorn Hydrogen can take North Sea natural gas and reform it into clean burning hydrogen with the CO2 emissions created from generating the hydrogen, safely removed and stored using the Acorn CCS infrastructure. The first Acorn Hydrogen plant can be online in 2025. Initially, Acorn Hydrogen will focus on blending hydrogen with the natural gas that is piped through the National Transmission System to transport the fuel into homes, offices and factories across the UK. Using this 'blending at source' method means that by replacing just 2% of natural gas with hydrogen we can easily cut around 400,000 tonnes a year of carbon emissions with no impact at all on the way gas is used. The project is led by **Pale Blue Dot Energy**, with funding and support from industry partners (Chrysaor, Shell and Total) the UK and Scottish Governments, and the European Union.

國內計畫實例

H100 Fife

SGN正在蘇格蘭東岸巴克黑文(Buckhaven)開發全球首創氫能網絡，計劃於2023年將再生氫能引入家庭，為用戶供暖和烹飪提供零碳燃料。在此計畫的第一階段，氫能網絡將利用一個專用電解廠所生產的潔淨天然氣，為約300個本地家庭供暖。該電解廠的用電則由附近的一個離岸風電渦輪機供應。

此計畫是直接利用潔淨電力生產氫氣為家戶供暖的首例 – 一舉將法夫(Fife)推上潔淨能源革命的前沿。廠內的儲存設備可儲備足夠的氫氣，確保即使在最嚴寒的天氣狀況下，家庭供暖仍不致中斷。

全球首創氫能供電生產建築玻璃

Pilkington United Kingdom公司是NSG集團成員之一。該公司已在其St Helens廠執行的全球首次試驗中，利用氫能供電成功製造出建築玻璃。此次試驗是該製造商脫碳計畫中的關鍵一步，並可能促成該廠目前使用天然氣的所有生產，全面轉型為氫能供電。此試驗之目的為證明浮式玻璃窯爐在滿負荷生產時可以安全運轉，且不致影響產品的品質。浮式玻璃窯爐運轉時，須將玻璃原料加熱到1,600 °C。

The Acorn計畫

Acorn計畫有兩個主要元素 – Acorn CCS專案和Acorn氫能專案。Acorn氫能專案可將北海的天然氣改良成為潔淨燃燒的氫能，並利用Acorn CCS基礎設施將生產氫氣所產生的二氧化碳(CO₂)安全地移除並封存起來。

首座Acorn氫能廠可望於2025年上線營運。在計畫初期，

Acorn氫能專案的目標為將氫氣混入天然氣，再透過全國輸送系統將之輸送到英國各地的家庭、辦公室、和工廠做為燃料。利用這種“源頭混合”方法意味著，只消以氫氣替換2%的天然氣，每年便可輕鬆減少約40萬噸的碳排放量，且不會對天然氣之利用方式造成任何影響。

本計畫由**Pale Blue Dot Energy**公司主導，資金分別由業界夥伴(Chrysaor、Shell和Total等公司)、英國及蘇格蘭政府、和歐盟贊助。

Examples of UK Export Projects

Blue Hydrogen & Ammonia facility in Ruwais, UAE

Adnoc has set out preliminary plans for a world-scale 1 million tonne per year blue ammonia facility in Ruwais.

Adnoc currently produces 300,000 tpy of hydrogen at Ruwais.

The company has appointed **Wood** to carry out the pre-front-end engineering and design (pre-FEED) work on the ammonia project. It also chose Wood for six additional projects at Ta'ziz. Adnoc said it would also work on a feasibility study to supply blue hydrogen to the project, from Ruwais.

A final investment decision (FID) is due in 2022, with start up in 2025.

The OYSTER Project

This project with funding from the EU Commission, will investigate the feasibility and potential of combining an offshore wind turbine directly with an electrolyser and transporting renewable hydrogen to shore.

UK companies **ITM Power and Element Energy** have formed a consortium with two European companies to provide compact electrolyser systems and technical/project expertise services respectively.

REFHYNE I project**

ITM Power supplied the 10MW PEM electrolyser for the REFHYNE project at the Shell Rhineland Refinery in Wesseling, Germany.

The electrolyser, which began operations in July 2021, is the largest of its kind to be deployed on an industrial scale.

The REFHYNE project will investigate feasibility for introduction in other industry plants, as well as potentially being a step towards the future of refining and determine the possible technical, economic & environmental benefits of the technology.

The REFHYNE project is funded by the European Commission's Fuel Cells and Hydrogen Joint Undertaking (FCH JU).

Arrowsmith Green Project

This project will be Australia's largest commercial-scale green hydrogen complex using electrolysis to produce hydrogen from solar and wind power. UK company **Petrofac** will review the conceptual work carried out on the project to date and produce the FEED (front end engineering design) study, as well as produce an Engineering, Procurement and Construction (EPC) design, cost and schedule estimation to support final investment decision.

Hydrogen production is expected to commence by the end of 2022 and will generate 25 tonnes of green hydrogen per day from the zero carbon energy sources.

英國出口計畫實例

藍氫 & 阿摩尼亞廠 (阿聯酋魯瓦斯)

阿布達比國家石油公司(Adnoc)已擬定世界規模初步計畫，將在魯瓦斯(Ruwais)的阿摩尼亞廠每年生產100萬噸的藍氫。目前Adnoc在魯瓦斯每年生產30萬噸氫氣。Adnoc已委託Wood集團執行這項氫計畫之預-前端工程設計(pre-FEED)工作。Adnoc並選擇Wood集團執行6項額外的Ta'ziz計畫。Adnoc表示，該公司亦將針對從魯瓦斯為此計畫供應藍氫進行可行性研究。此計畫之最終投資決定(FID)的期限為2022年，將於2025年開始執行。

OYSTER計畫

這項由歐盟贊助的計畫將調查直接結合離岸風機與電解槽，並將再生氫能輸送上岸之可行性與潛力。英國公司ITM Power和Element Energy已與兩家歐洲公司組成企業聯盟，將分別提供密實的電解槽系統和技術/計畫專門知識服務。

REFHYNE I計畫**

ITM Power公司為設於德國韋瑟靈(Wesseling)的Shell Rhineland Refinery煉油廠所執行之ITM Power計畫提供10MW PEM電解槽。該電解槽於2021年7月開始運作，是當今全世界最大的產業規模電解設施。REFHYNE計畫亦將調查將此電解設施引進其他工業廠房之可行性和進一步邁向精煉未來之潛力，並確定這項科技在技術、經濟、及環境方面之可能益處。REFHYNE計畫的資金由歐盟燃料電池及氫氣聯合事業(FCH JU)贊助。

Arrowsmith Green計畫

此計畫將是澳洲最大的商業規模運用電解技術從太陽能和風電生產氫氣的綠氫複合廠。英國Petrofac公司將負責檢討該計畫目前為止所執行之概念性工作、進行FEED(前端工程設計)研究、並估計工程總承包(EPC)之設計、成本、和期程，以支援最終投資決定。氫氣生產預計將從2022年底開始，屆時每日將可從零碳能源生產25噸綠氫。

Examples of UK Export Projects

Hydrogen Fuel Cells for Electric Charging Infrastructure

UK hydrogen fuel cell company **AFC Energy** has announced a strategic partnership project with Dutch company ABB to develop bespoke high power electric-vehicle charging products using AFC hydrogen gas-to-power technology.

Ceres Power – Doosan agreement

Ceres Power a developer of low cost, next generation fuel cell technology and Doosan Corporation, have signed a Collaboration and Licensing agreement to jointly develop SOFC distributed power systems initially targeted at the Korean commercial building market. The **£8 million agreement** is over two years and includes licencing, technology transfer and engineering services. Doosan will take a system-level licence of Ceres' proprietary **SteelCell® SOFC technology** to develop a low carbon 5-20kW power system.

英國出口計畫實例

氫燃料電池用於充電基礎設施

英國氫燃料電池公司**AFC Energy**已宣佈與荷蘭**ABB**集團合作執行一項策略夥伴計畫，將運用**AFC**的氫轉電技術，開發定制的高功率電動車充電產品。

Ceres Power – Doosan協議

下一代低成本燃料電池技術開發商**Ceres Power**已與**Doosan**集團簽署合作及授權合約，將共同開發**SOFC**分散式電力系統。此一計畫之初步目標鎖定韓國的商業建築市場。
這項價值**800萬英**的合約歷時兩年，其內容包括授權、技術轉移、和工程服務。**Doosan**集團將取得**Ceres**之專利**SteelCell® SOFC**技術的系統級授權，用以開發低功率**5-20kW**電力系統。



Department for International Trade
英國國際貿易部

Trade Offer 貿易提供

The Department for International Trade (DIT) can provide support and assistance for your business.
英國國際貿易部(DIT)可為您的事業提供支援和協助。

UK Policy Mechanisms to Export Globally

An International Powerhouse

Given its centrality to the world economy, the UK has **strong links to international markets to which hydrogen companies can export**. In fact, the value of UK merchandise exports reached almost \$470bn in 2019, with fuels making up 9% of the total exports.

The UK's **top five trading partners** are the United States, Germany, China, the Netherlands and France, accounting for 46% of UK total trade in goods in the first half of 2020.



Sources: UK Gov, 'Ten Point Plan,' Nov 2020; UNCTAD, 'World Investment Report,' 2020; UNCTAD Stat, 'General Profile: United Kingdom,' accessed Feb 2021; ONS, 'UK trading partners and trade relationships: 2020,' Jul 2020.

Supporting Exports

The hydrogen economy provides myriad export opportunities for companies in the UK, from electrolysers, fuel cells and steam reforming technology to stored hydrogen, alternative fuels and more. In order to take fully advantage of the international markets available, companies can make use of three key policy mechanisms that support UK exports.

- **DIT Support**

- **UK Export Finance (UKEF)**

The UK's export credit agency UKEF works alongside DIT as an integral part of its strategy and operations. It **helps UK companies win and fulfil export contracts and get paid by insuring against buyer default**. UKEF can support exports for any size of company and across all sectors, from capital goods to services and intangibles such as intellectual property.

- **Export Development Guarantee (EDG)**

EDGs help UK exporters access **high value loan facilities** for general working capital or capital expenditure purposes. Providing support for finance provided by a commercial lender, we can offer partial guarantees **covering up to 80% of the risk to lenders** for a maximum repayment period of up to 5 years.

英國全球出口政策機制

國際發動機

由於英國在世界經濟中的中心地位，我們擁有強大的國際市場聯繫，有利於氫能公司出口。事實上，英國2019年商品出口總值已達近4,700萬美元，其中燃料佔出口總值9%。

英國的前五大貿易夥伴分別為美國、德國、中國、荷蘭和法國。2020年上半年，五大貿易夥伴佔英國貨物貿易總額的46%。



資料來源：英國政府－「十點計畫」（2020年11月）；UNCTAD－「世投資報告」（2020年）；UNCTAD Stat－「一般概況：英國」（2021年2月發佈）；ONS－「英國之貿易夥伴與貿易關係：2020年」（2020年7月）

支援出口

氫經濟為英國公司提供許多出口商機，從電解槽、燃料電池、及蒸汽重組技術，到儲存氫氣和替代燃料不一而足。為了充分利用可供輸出的國際市場，英國公司可以利用支援英國出口的三个主要政策機制。

▪ DIT支援

▪ 英國出口信貸局(UKEF)

英國出口信貸局(UKEF)與國際貿易部(DIT)的合作，成為UKEF策略及運作不可分割的部分。**UKEF與DIT聯手協助英國公司贏得及履行出口合約，並確保當買方違約時仍能收到貨款。**UKEF可支援所有產業中任何規模公司的出口，從資本貨物到出口服務，甚至無形資產(如智慧財產)不一而足。

▪ 出口發展擔保局(EDG)

出口發展擔保局(EDG)幫助英國出口商接觸高價值貸款機構，以取得一般營運資金或資本支出融資。我們也支援商業放款業者提供融資。針對五年最長還款期的融資，我們可提供部分擔保，最多可吸收放款業者**80%**的風險。

Available DIT Support

Through our bank of knowledge, specialists expertise and extensive networks, DIT can help identify and leverage potential opportunities, both for trade and investment.

The services we provide to UK companies include:

- **Accessing market opportunities overseas:** helping UK companies break into new markets and offering insight and intelligence on large-scale international commercial projects.
- **Access and introductions to the right people:** working with overseas Posts to support access to a vast network of local stakeholders.
- **Bespoke market research:** compiling in-depth factual reports including market entry support, research and development collaborations and cost analysis.
- **Entrepreneurial assistance** through a network of mentors to help make a commercial success of early stage companies.
- **Export Support** through [UKEF](#), access to global events and trade missions, offering insight and intelligence on large-scale international commercial projects, and building export capability across supply chains through ongoing support.



可用的DIT支援

透過我們的知識庫、專家專門知識和廣大的網絡，國際貿易部(DIT)可以幫助英國公司發掘及利用潛在的貿易和投資商機。

我們為英國公司提供的服務包括：

- **接觸海外市場商機**：協助英國公司打入新市場，和提供有關大型國際商業計畫之洞察和情報。
- **接觸和引見適當人士**：與英國海外駐點合作，協助英國公司接觸廣大的當地利害關係人網絡。
- **定制的市場研究**：彙整深度事實報告，包括市場進入支援、研發合作、和成本分析。
- **創業協助**：透過一個導師網絡，協助新成立的公司商業上獲利。
- **出口支援**：透過出口信貸局(UKEF)，協助英國公司參加全球性活動和貿易參訪團，提供有關大型國際商業計畫的洞察和情報，和透過持續支援，協助業者建立整個供應鏈上的出口能力。



Appendix 附錄



Key Terms & Abbreviations Guide

Steam Methane Reformation – Around 95% of hydrogen today is produced through steam reformation, where steam reacts with natural gas to produce hydrogen and carbon dioxide.

Autothermal Reformation – Uses oxygen directly to create steam to react with natural gas and produce hydrogen.

Carbon Capture, Utilisation & Storage – The process of capturing carbon dioxide from industrial processes, power generation, blue hydrogen production and greenhouse gas removal technologies. The captured carbon dioxide is then either used, for example in chemical processes, or stored permanently in disused oil and gas fields or naturally occurring geological storage sites.

Electrolysis – Using renewable electricity to split water into hydrogen and oxygen.

Fuel Cells – Hydrogen acts directly as a fuel in fuel cells by reacting with oxygen to produce electricity and water. Individual fuel cells combine to create a fuel cell stack. In this way, hydrogen can be used as a fuel for transportation vehicles across the size spectrum, from passenger cars and buses to airplanes and cargo ships.

ATR	Autothermal Reformation
AE	Alkaline Electrolysis
AEM	Anion Exchange Membrane (electrolysis)
CCS	Carbon Capture & Storage
CCUS	Carbon Capture, Utilisation & Storage
CHP	Combined Heat and Power
CO₂	Carbon Dioxide
FCEV	Fuel Cell Electric Vehicle
GWh	Gigawatt hour, also gigawatt (GW)
H₂	Hydrogen
H2FC	Hydrogen and Fuel Cell
HGV	Heavy Goods Vehicle
HRS	Hydrogen Refuelling Station
LH₂	Liquid Hydrogen
LOHC	Liquid Organic Hydrogen Carriers
MtH₂	Million tonnes of hydrogen
MWh	Megawatt hour, also megawatt (MW)
PEM	Proton-electrolyte membrane (electrolysis)
SMR	Steam Methane Reformation
SOFC	Solid Oxide Fuel Cells
TWh	Terawatt hour, also terawatt (TW)
ZEV	Zero Emission Vehicle

關鍵詞 & 縮寫指南

蒸汽甲烷重組(SMR) – 當今約95%的氫氣是透過蒸汽重組生產的。在此過程中，蒸汽對天然氣作出化學反應，產生氫氣和二氧化碳(CO₂)。

自發性熱重組(ATR) – 直接利用氧氣製造蒸汽，再讓蒸汽對天然氣作出化學反應，以產生氫氣。

碳捕集、利用 & 封存(CCUS) – 從工業製程、發電、藍氫生產、和溫室氣體移除技術作業中捕集二氧化碳(CO₂)的過程。捕集到的CO₂可被再利用(如化學製程)，或永遠封存於廢棄的油氣田或天然的地質儲存場。

電解法 – 利用再生電力將水分解為氫氣和氧氣。

燃料電池(FC) – 藉由氫與氧的化學反應，將氫氣直接用作燃料電池中的燃料，以產生電力和水。結合個別燃料電池可形成燃料電池堆。透過這種方式，氫氣可被用作各種運輸載具的燃料，從客車和巴士到飛機和貨船不一而足。

資料來源：英國政府 – 「能源白皮書：推動零碳未來」(2020年)；H2FC SUPERGEN – 「氫氣和燃料電池貢獻於英國潔淨能源成長之機會」(2020年5月)；Forbes – 「氫氣生產之碳足跡估計」(2020年)

ATR	自發性熱重組
AE	鹼性電解法
AEM	陰離子交換膜 (電解法)
CCS	碳捕集 & 封存
CCUS	碳捕集、利用 & 封存
CHP	汽電共生
CO₂	二氧化碳
FCEV	燃料電池電動車
GWh	吉瓦時；亦稱吉瓦 (GW)
H₂	氫
H2FC	氫能和燃料電池
HGV	重型貨車
HRS	氫氣加氣站
LH₂	液態氫
LOHC	液態有機氫載體
MtH₂	百萬噸氫
MWh	兆瓦時；亦稱兆瓦 (MW)
PEM	質子交換膜 (電解法)
SMR	蒸汽甲烷重組
SOFC	固態氧化物燃料電池
TWh	太瓦時；亦稱太瓦 (TW)
ZEV	零排放車輛



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