Flexibility in Great Britain

Appendix 2: Delivering a smart, flexible energy system – Evidence base

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Who we are

Established in 2001, the Carbon Trust works with businesses, governments and institutions around the world, helping them contribute to, and benefit from, a more sustainable future through carbon reduction, resource efficiency strategies, and commercialising low carbon businesses, systems and technologies.

The Carbon Trust:

- works with corporates and governments, helping them to align their strategies with climate science and meet the goals of the Paris Agreement;
- provides expert advice and assurance, giving investors and financial institutions the confidence that green finance will have genuinely green outcomes; and
- supports the development of low carbon technologies and solutions, building the foundations for the energy system of the future.

Headquartered in London, the Carbon Trust has a global team of over 200 staff, representing over 30 nationalities, based across five continents.

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Abbreviations

Abbreviation	Meaning
ADE	Association for Decentralised Energy
BEAMA	British Electrotechnical and Allied Manufacturers Association
BEIS	Department for Business, Energy and Industrial Strategy
BSI	British Standards Institute
CCC	Climate Change Committee
CfD	Contracts for Difference
CHP	Combined Heat and Power
DH	District Heating
DHN	District Heating Network
DNO	Distribution Network Operator
DNUoS	Distribution Network Use of System Charges
DSO	Distribution System Operator
DSR	Demand Side Response
ESAP	Energy Smart Appliances Programme
ESO	Electricity System Operator
EV	Electric Vehicle
FES	Future Energy Scenario
GB	Great Britain
I&C	Industrial and Commercial
ICE	Internal Combustion Engine

Abbreviation	Meaning
ICT	Information and Communications Technology
LEM	Local Energy Market
MHHS	Market Wide Half Hourly Settlement
NSIP	Nationally Significant Infrastructure Project
P2H	Power-to-Heat
PAS	Publicly Available Specifications
PEM	Proton Exchange Membrane
R&D	Research and Development
RAG	Red Amber Green
SMIP	Smart Meter Implementation Programme
SMR	Small Modular Reactor
TCR	Targeted Charging Review
TES	Thermal Energy Storage
TRL	Technology Readiness Level
ULEV	Ultra Low Emissions Vehicle
V2G	Vehicle-to-Grid
VPP	Virtual Power Plant

Deployment readiness assessment - evidence base

The tables in this document provide details of the evidence used to support the deployment readiness assessment of six flexibility technologies described in Chapter 4 of the Flexibility in Great Britain report[1]:

- Demand side response (DSR) from domestic smart appliances
- Demand side response (DSR) from the non-domestic sector
- Electric vehicles (EVs) – smart charging and vehicle-to-grid (V2G)
- Thermal energy storage (TES)
- Electricity storage
- Hydrogen electrolysers and storage

The deployment readiness assessments were carried out for each technology based on Great Britain's perceived ability to achieve an 'interim' 2030 deployment goal required to deliver a net zero 2050 energy system. These 2030 goals are detailed in Chapter 4 of the Flexibility in Great Britain report and were based on the 2050 scenarios set out in Chapter 3 of the same report. The information was gathered before publication in May 2021, so does not take into account more recent publications such as BEIS's Smart Systems and Flexibility Plan 2021.

The deployment readiness assessments consider a holistic view of the market enablers, business models and other factors required to deliver the required level of deployment of each source of flexibility in 2030. A framework was developed for this study to support the identification of the key barriers to the deployment of sources of flexibility. This framework helps provide a snapshot of the deployment maturity of each source of flexibility at this moment in time, considering the indicative deployment need of the source of flexibility estimated for 2030. An overview of the framework is shown in Table 2. The framework assesses indicators across three themes: market enablers, the business model and capacity to deliver. Each theme has four indicators underpinning it. Evidence was collected across each indicator, through secondary research and

[1] Carbon Trust, Imperial College London, 2021. Flexibility in Great Britain. https://publications.carbontrust.com/flex-gb/report/

primary research conducted with the consortium partners, to understand the extent to which there are barriers to the deployment of the source of flexibility. A simple traffic light assessment was taken against each of these (Table 1), to help highlight areas that required particular attention in order to unlock the required levels of deployment. This appendix summarises the information gathered during that assessment.

This method has its limitations. The deployment readiness analysis is inherently subjective, based on an assessment of a sample of publicly available evidence and insights from consortium partners. There also could be other indicators that are helpful to assess the deployment status of a technology. However, the main objective of the analysis is to highlight the fact that there are a broad range of factors needed to support required deployment of the technology in 2050 and unlock the benefits highlighted in Chapter 3 of the Flexibility in Great Britain report.

Table 1: Description of red-amber-green (RAG) rating for deployment readiness assessment

Rating	Description of rating
Green	No significant barrier was identified to the deployment of a source of flexibility required to meet the indicated level in 2030.
Amber	Key barriers/needs have been identified, but there are processes in motion today that suggest the barrier could be overcome in time to enable the indicated level of deployment of flexibility in 2030.
Red	Key barriers have been identified that could hold back achieving the level of deployment of the source of flexibility. There is little or no evidence to suggest this barrier will be overcome to the extent to which the level of deployment indicated for 2030 can be achieved.

Table 2: Deployment readiness assessment framework

Theme	Indicator	Description of indicator
Enablers	**Enabling infrastructure**	The extent to which infrastructure, which itself is a prerequisite for the technology to be able to be deployed effectively, exists.
	Regulatory environment	The extent to which there exists a well-functioning regulatory environment that sends clear signals to the market regarding the regulations around a technology and doesn't contradict other regulations.
	Stakeholder acceptance	An assessment of the extent to which relevant stakeholders accept the deployment and use of the technology, and do not perceive there to be considerable risks to its adoption.
	Level of political support	An assessment of the level of support for a particular source of flexibility from government, indicated by clear signalling such as funding or policy targets.
Business model	**Availability of funding**	The availability of finance to invest in sources of flexibility at a low cost, for both consumers and businesses, commercial or for research and development (R&D).
	Willingness to pay	The extent to which the investor/business/consumer is willing to pay for the adoption of certain technologies to unlock flexibility, both in terms of time and resources.
	Financial performance	The strength of the financial proposition to investors/consumers, based on revenue generation through providing flexibility against the cost of developing the source of flexibility or accessing a source of flexibility that already exists.
	Market opportunities	The extent to which markets exist that internalise the value the model shows flexibility can deliver.
Capability to deliver	**Resource availability**	The extent to which there are adequate resources/raw materials available to deliver the required deployment of the technology.
	Technological maturity	The extent to which the technology/source of flexibility has been technologically proven and is readily available at the required scale.
	Supply chain and skills	The extent to which the necessary supply chain is in place to deliver the technology at the required scale and pace.
	Maturity of company landscape	An assessment of the maturity and competitiveness of the private sector landscape looking to deliver the source of flexibility.

DSR from domestic smart appliances

Table 3: Enablers - DSR from domestic smart appliances

Indicator	Evidence and RAG rating	
Enabling infrastructure	Completing the smart meter rollout needs, with Market Wide Half Hourly Settlement (MHHS) in place would make the implementation of residential DSR easier. As of Q3 2020, only 34% of households had a smart meter operating in smart mode[2]. The Smart Meter Implementation Programme (SMIP) has already been delayed by four years to 2024[3], and the rollout during 2020 and 2021 has been significantly impacted by the Covid-19 pandemic[2], potentially leading to further delays. Smart meters aren't essential for smart appliance flexibility. For example, it is possible to implement peak avoidance behavioural change without smart meters, although smart meters would make settlement easier. Smart meters are generally a prerequisite for the adoption of smart tariffs.	

[2] Smart Meter Statistics in Great Britain quarterly update September 2020, UK Government, 2020. https://www.gov.uk/government/collections/smart-meters-statistics

[3] Smart meter rollout deadline extended to 2024, Current News, 2019. https://www.current-news.co.uk/news/smart-meter-rollout-deadline-extended-to-2024

Indicator	Evidence and RAG rating
Regulatory environment	A BEIS consultation in 2018 identified regulation as being important to reduce risk around data privacy and cybersecurity[4]. The British Standards Institute (BSI) has been sponsored by BEIS to 'facilitate the uptake of safe, secure and interoperable' smart appliances, through the Energy Smart Appliances Programme (ESAP)[5]. The ESAP has developed two Publicly Available Specifications (PASs) that classify both energy smart appliances (PAS 1879) and create a framework for DSR (PAS 1878). British Electrotechnical and Allied Manufacturers Association (BEAMA) engagement in government consultations on both smart appliances and DSR, aiming to ensure international applicability of the work[6]. The market is regulated in to protect consumers and allow them to switch supplier regularly and end contracts early. This consumer protection may increase the risk to a supplier who might have to invest in a consumer (e.g. through hardware or through time) in order to unlock their domestic flexibility. Given consumers have the right to not be locked into long-term contracts,

[4] Smart Appliances Consultation, BEIS, 2018. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/748115/smart-appliances-consultation-government-response.pdf

[5] The Energy Smart Appliances Programme, BSI, 2018 (https://www.bsigroup.com/globalassets/localfiles/en-gb/smart-appliances-for-flexible-energy/the-energy-smart-appliances-programme.pdf)

[6] Energy Smart Appliances – The Policy Background, BEAMA, 2019 (https://www.beama.org.uk/resourceLibrary/energy-smart-appliances-the-policy-background-.html)

Indicator	Evidence and RAG rating	
	suppliers may consider the risk of a consumer leaving them too soon after the upfront investment to unlock DSR for there to be sufficient payback for their investment to be too high.	
Stakeholder acceptance	The SMIP has been impacted by a negative public perception of smart meters and their value to consumers. Perceived risks related to consumer security or privacy must be assuaged, as well as consumer attitudes towards autonomy and trust in smart devices[7]. Furthermore, unlike the adoption of smart meters, the use of domestic appliances is tightly linked to consumer behaviour and habits. While there may be segments who are willing to change their behaviour relating to certain wet appliances (e.g. dishwasher, washing machine) in response to price signals, achieving a high uptake is expected to be a significant challenge if even a minor change in consumer behaviour would be required. The lack of both smart appliances on the market and domestic DSR opportunities means there is little evidence currently of consumer acceptance of smart appliances. However, previous international research suggests that the willingness of consumers to adopt intelligent appliances depends on their perception of the maturity of the technology as well as financial gains[8]. Consumer	

[7] Trust in the smart home: Findings from a nationally representative survey in the UK, Cannizzaro S et al, 2020 (https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7259745/pdf/pone.0231615.pdf)

[8] Get smart! Consumer acceptance and restrictions of Smart Domestic Appliances in Sustainable Energy Systems, Mert W and Tritthart W, 2009 https://www.uni-muenster.de/imperia/md/content/transpose/publikationen/mert.pdf

Indicator	Evidence and RAG rating	
	knowledge of, and demand for, smart appliances is negligible today. Appliances themselves typically have lifetimes of 10-15 years. Therefore, in order to have a high level of potential flexibility in 2050, there may be a need to ensure all, or most, appliances sold from the 2030s onwards are 'smart enabled'. Some aggregators believe there is too much uncertainty around the level of acceptance in the residential market to consider entering it at all. There is a significant risk of negative stories emerging, such as exposure to very high market prices on time of use tariffs or cyber-security concerns around the control of domestic assets, which could severely impact the likelihood of high levels of smart controlled appliances. Smart appliances on the market today have been identified as being significantly more expensive than conventional alternatives, and they could become obsolete if a manufacturer decides not to update the software an appliance runs on, thereby shortening its lifetime[9]. However, these smart appliances are not designed purely for providing DSR.	
Level of political support	BEIS indicated its intent by sponsoring the BSI to develop the PAS standards for smart appliances in order to accelerate their deployment.	

[9] A fridge too far?, Which?, 2020, (https://press.which.co.uk/whichpressreleases/a-fridge-too-far-the-smart-appliances-that-cost-a-grand-more-but-may-only-last-two-years/)

Indicator	Evidence and RAG rating	
	BEIS consultation on Smart Appliances in 2018 reaffirmed its commitment to the development of smart appliances[10]. The Energy White Paper in 2020 confirmed government commitment to smart appliances, and stated that the government would take powers to regulate smart appliances[11]. Despite the commitments made by BEIS on the necessary regulatory frameworks, greater political leadership is likely to be required to help support engagement with the public.	

[10] Smart Appliances Consultation, BEIS, 2018 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/748115/smart-appliances-consultation-government-response.pdf

[11] Energy White Paper, BEIS, 2020 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/945899/201216_BEIS_EWP_Command_Paper_Accessible.pdf

Table 4: Business model - DSR from domestic smart appliances

Indicator	Evidence and RAG rating	
Availability of funding	Funding for appliances is available through consumer credit via commercial banks. BEIS are funding domestic DSR projects to explore its feasibility[12]. However, the focus of these trials is mainly on unlocking flexibility from heat-related technologies or battery storage, rather than smart appliances. Unlike smart chargers for EVs, there are no government incentives for smart appliances, although this is potentially due to the lack of smart appliances on the market.	

[12] Funding for innovative smart energy systems, BEIS, 2017. https://www.gov.uk/guidance/funding-for-innovative-smart-energy-systems

Indicator	Evidence and RAG rating	
Willingness to pay	Smart appliances, when combined with smart tariffs and DSR, could reduce the total cost of ownership of wet and cold appliances compared to their non-smart alternatives. From the consumer perspective, the willingness to pay for smart appliances, assuming they cost the same as non-smart appliances, will be linked to the stakeholder acceptance issues highlighted in the 'Enablers' section of this framework. It is unclear what the upfront cost might be for the supplier to engage with consumers and integrate with their smart appliances. It may require additional hardware or the installation of new firmware on a smart appliance that could necessitate a cost to the supplier. The potential value to engaging with consumers to make them more flexible may not necessarily outweigh or be sufficiently marginal to impact their willingness to pay to unlock flexibility.	
Financial performance	Smart appliances, when combined with smart tariffs and DSR, promise to reduce the cost of ownership of wet and cold appliances compared to their non-smart alternatives. However, the extent to which costs will be reduced is unclear, and the financial proposition will likely evolve as tariffs and price signals evolve, driven by an increasing penetration of renewables in the generation capacity portfolio. As above, it is unclear what the upfront cost might be for the supplier to engage with consumers and integrate with their smart appliances. It may require additional hardware or the installation of new firmware on a smart appliance that could necessitate a cost to the supplier. The potential value to engaging with consumers to make them more flexible may not necessarily outweigh or be sufficiently marginal to impact their willingness to pay to unlock flexibility. Energy-as-a-service models likely require long-term (multi-year) subscriptions, which may be less appropriate for most domestic consumer segments.	

Indicator	Evidence and RAG rating	
Market opportunities	Commercial smart time of use tariffs are starting to emerge, and more are likely to be released as the market transitions towards market-wide half-hourly settlement DSR events have also been trialled by a large energy supplier. There are challenges to ensuring the costs and benefits are shared appropriately across the range of relevant stakeholders, such as the Distribution Network Operators (DNOs)[13]. The emergence of Distribution System Operator (DSO) flex contracts has provided a market for overcoming local constraints. However, access to residential customers is limited. The analogous route to market for non-domestic sites is aggregators, but such a route hasn't yet been developed for domestic smart appliances. Furthermore, there is a lack of price signal related to local constraints within current energy tariffs (even time of use tariffs), meaning the local benefit of providing flexibility from smart appliances is not currently valued.	

[13] Delivering the Benefits of Smart Appliances, EA Technology, 2011

Table 5: Capability to deliver - DSR from domestic smart appliances

Indicator	Evidence and RAG rating	
Resource availability	There are no known resource availability challenges.	
Technical performance	Smart appliances are essentially normal wet and cold appliances whose operation can respond to a signal. The technology required to do this is well understood (e.g. smart charging of EVs). However, there is little to demonstrate smart appliances in UK residential homes responding to price signals from commercially available smart time of use tariffs and/or responding to price signals from providing flexibility. Cornwall Local Energy Market (LEM)[14] suggests technology exists for local optimisation of flexibility, including simultaneous contracting of flexibility from both ESO and DSO. However, this trial focuses on flexibility from storage and generation assets rather than smart appliances.	

[14] Cornwall Local Energy Market, Centrica, 2020. https://www.centrica.com/innovation/cornwall-local-energy-market

Indicator	Evidence and RAG rating	
Supply chain and skills	Supply chain and skills are in place for non-smart appliances, so not seen as a significant challenge to rollout of smart appliances.	
Maturity of company landscape	Appliance manufacturers are mature. Landscape of energy suppliers in UK is competitive, with innovation in smart tariffs resulting from efforts to differentiate. GB is also home to a strong aggregator market.	

DSR from the non-domestic sector

Table 6: Enablers - DSR from the non-domestic sector

Indicator	Evidence and RAG rating	
Enabling infrastructure	Industrial and Commercial (I&C) demand-side peak-shifting flexibility potential is estimated to be about 3GW[15,16] , with the Association for Decentralised Energy (ADE) estimating a potential for ~10GW by 2035[17]. The rollout of smart meters across the UK's 2.6m non-domestic sites will support the emergence of time of use tariffs, with or without combination with smart appliances and/or behind the meter flexibility, in addition to market wide half-hourly settlement. However, DSR programmes such as TRIAD[18] avoidance to reduce network charges (which is soon to come to an end), don't require smart meters to operate. Electrification of industry will increase opportunities for DSR (along with increased demand).	

[15] UK demand side flexibility mapped, Open Energi,. https://openenergi.com/uk-demand-side-flexibility-mapped/

[16] Industrial & Commercial demand-side response in GB: barriers and potential, Ofgem, 2016 https://www.ofgem.gov.uk/system/files/docs/2016/10/industrial_and_commercial_demand-side_response_in_gb_barriers_and_potential.pdf

[17] Demand Side Response Code of Conduct, The Association for Decentralised Energy, 2018 https://www.theade.co.uk/assets/docs/about/DSR_Code_of_Conduct.pdf

[18] Triads, National Grid ESO, 2020. https://www.nationalgrideso.com/industry-information/charging/transmission-network-use-system-tnuos-charges/triads-data

Indicator	Evidence and RAG rating	
	Building management systems where available also act as useful enabling infrastructure.	
Regulatory environment	The changing regulatory environment (e.g. Clean Energy Package, Targeted Charging Review, suspension and then reinstatement of Capacity Market) has led to uncertainty among market participants[19]. However, changes should also be viewed positively in the long term, as DSR is seen as a key provider of new and future products. Development of the ADE's Flex Assure Code[20] with aggregators is planned to extend to small customers. Elexon's code modification P375 enables businesses to supply assets behind the meter through a submetering arrangement and to access its flexibility, which should create more liquidity in I&C flexibility[21]. ISO50001 (Energy Management System) has become a good route to market for DSR providers[22].	

[19] Demand Side Response, The Energyst, 2019. http://theenergyst.com/wp-content/uploads/2019/09/DSR-Report-2019.pdf

[20] Flex Assure Code, ADE. https://www.flexassure.org/

[21] Ground-breaking modification to support net zero is approved, Elexon, 2021. https://www.elexon.co.uk/article/ground-breaking-modification-to-support-the-energy-transition-is-approved/

[22] ISO 50001 Energy Management Systems, ISO. https://www.iso.org/iso-50001-energy-management.html

Indicator	Evidence and RAG rating	
Stakeholder acceptance	There is an industry perception of risk to primary business, as well as difficulty understanding the monetary value of DSR options. Furthermore, the commercial and technical DSR requirements don't always fit the business. There are cybersecurity concerns regarding sharing data with outside parties and hardware that could potentially be hacked to compromise operations. Lack of technical knowledge among I&C is also a barrier to adoption of DSR. This knowledge gap is partially because of a lack of engagement due to not understanding the perceived value and potential risk to their business. National Grid Electricity System Operator's (ESO's) Power Responsive campaign[23] and ADE's Code of Conduct[24] aim to overcome this barrier.	
Level of political support	BEIS and Ofgem are looking to develop the market for DSR in I&C, as well as non-I&C[25].	

[23] Power Responsive. http://powerresponsive.com/

[24] Demand Side Response, Code of Conduct, ADE. https://www.theade.co.uk/resources/guidance/demand-side-response-code-of-conduct

[25] Smart Systems and Flexibility Plan: Progress Update, HMG and Ofgem, 2018, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/756051/ssfp-progress-update.pdf

Table 7: Business model - DSR from the non-domestic sector

Indicator	Evidence and RAG rating	
Availability of funding	There is early stage innovation funding for ICT, demonstration and trials[26] Availability for funding exists within businesses. However, accessing these funds alongside competing priorities is the challenge.	
Willingness to pay	Linked to the financial performance, and stakeholder acceptance, the financial value of providing flexibility can be seen as being marginal when it comes to perceived risk vs reward. The upfront cost and hassle of unlocking assets for DSR remains a barrier due to stakeholder acceptance issues and the lack of strong financial gains. From a building manager's perspective, the incentive for businesses to adopt DSR isn't always strong enough, especially when considering alternative methods of 'going green', such as investing in rooftop solar panels. Campaigns such as Power Responsive support industry engagement and uptake of DSR to provide flexibility services[27].	

[26] Funding for innovative smart energy systems, BEIS, 2017 https://www.gov.uk/guidance/funding-for-innovative-smart-energy-systems

[27] Power Responsive Annual Report 2020, National Grid ESO, 2020 http://powerresponsive.com/wp-content/uploads/2021/03/Power-Responsive-Annual-Report-2020.pdf

Indicator	Evidence and RAG rating	
Financial performance	Insufficient financial benefit is cited as reason for not flexing energy, with a lack of value in DSR products. However, increasing penetration of renewables is expected to sharpen price signals and increase flexibility products, alongside the further emergence of DSO markets. Difficulties around developing an investible business case are based on volatile and often short-term contracts across capacity market, balancing mechanism, ancillary services, wholesale market and local flexibility. The lack of clear long-term revenue opportunities makes investing in DSR challenging. Cost of deployment of DSR technologies at small business level is similar to that of unlocking large scale assets for flexibility, therefore creating a challenge to scaling up at these types of sites.	

Indicator	Evidence and RAG rating	
Market opportunities	National Grid ESO's ambition to run a net zero system in 2025[28] could reduce uncertainty around value streams. There is widening access to the balancing market and an expected increase in ESO products, which will boost market opportunities. However, services are still primarily geared towards large users. A current lack of smart tariffs for non-domestic sites is linked to delays in smart meter rollout, although some do exist on the market today. The emergence of DSO flexibility services provides further localised market opportunities. Markets mainly exist for the provision of flexibility, but engaging in them is complicated and normally requires a third party to manage on behalf of I&C flexibility participants. Financial signals may exist in markets, but there is a lack of carbon signals for flexibility provision.	

[28] Zero carbon operation of Great Britain's electricity system by 2025, National Grid ESO, 2019. https://www.nationalgrideso.com/news/zero-carbon-operation-great-britains-electricity-system-2025

Table 8: Capability to deliver - DSR from the non-domestic sector

Indicator	Evidence and RAG rating
Resource availability	No resource availability challenge exists.
Technical performance/TRL	DSR for large energy users has been partially unlocked (e.g. through turn-down DSR), but new technologies and ICT platforms need to be developed to unlock more distributed assets. Innovation is required across the entire industrial process before certain industrial processes and factories can provide more DSR beyond that through the use of back-up diesel generators. However, only two of the BEIS's eight industrial decarbonisation and energy efficiency action plans (from 2017) identified flexibility provision as a potential innovation area; these were chemical and pulp and paper[29]. Time of use tariffs exist in today's market and are expected to increase in number and popularity over time.
Supply chain and skills	Academic strength and leading innovation exist within networks and technology providers. The challenging commercial environment for UK industry could serve as a driver for innovation or as a barrier. Lack of confidence in the future means projects with long returns on investment may be deprioritised. The aggregation market is currently not held back by lack of skills.

[29] Industrial decarbonisation and energy efficiency action plans, UK Government, 2017. https://www.gov.uk/government/publications/industrial-decarbonisation-and-energy-efficiency-action-plans

Indicator	Evidence and RAG rating	
Maturity of company landscape	Great Britain (GB) has a world-leading aggregator market. Aggregators are reaching maturity and many have been acquired by larger suppliers. There is a fertile landscape for technology providers within ICT and the appliances sectors. Industrial players are primarily multinationals. There is an active and competitive non-domestic supplier market.	

Electric Vehicles

Table 9: Enablers - Electric vehicles

Indicator	Evidence and RAG rating	
Enabling infrastructure	The key piece of enabling infrastructure will be the EVs themselves. Deployment today is low (~320,000 ultra-low emissions vehicles (ULEV) in Q2 2020[30]), with target numbers for 2030 ranging significantly (3.6-15m across National Grid ESO's future energy scenarios (FES) 2020[31] and the Climate Change Committee's (CCC's) 6th Carbon Budget scenarios[32]), but significant. The adoption of EVs is expected to pick up during the 2020s as price parity with internal combustion engine (ICE) alternatives is reached; the UK has also moved to ban sales of new ICE vehicles from 2030 onwards[33].	

30 Electric vehicles and infrastructure, Hirst D (House of Commons Library), 2020. https://commonslibrary.parliament.uk/research-briefings/cbp-7480/

31 Future Energy Scenarios 2020, National Grid ESO, 2020. https://www.nationalgrideso.com/future-energy/future-energy-scenarios/fes-2020-documents

32 Sixth Carbon Budget, Climate Change Committee, 2020. https://www.theccc.org.uk/publication/sixth-carbon-budget/

33 Government takes historic step towards net-zero with end of sale of new petrol and diesel cars by 2030, UK Government, 2020. https://www.gov.uk/government/news/government-takes-historic-step-towards-net-zero-with-end-of-sale-of-new-petrol-and-diesel-cars-by-2030

Indicator	Evidence and RAG rating	
	The EV charging infrastructure is immature, although the government has prioritised £1.3bn funding to accelerate rollout of charge points across England[34]. However, there are barriers to address, including the fact that ~40-50% of homes do not have access to off-street parking[35].	
Regulatory environment	The Automated and Electric Vehicles Act (2018)[36] mandated that all connections are smart. An informed approach is recommended if V2G is enforced in a similar manner. There is a lack of certainty around the standards for V2G, which will be required for future market but this is expected to be addressed in the coming years. BSI standards on smart appliances (including EVs) and DSR are being published later in 2021. There are potential barriers related to DNO monitoring of LV networks, which could impact how DNOs are able to prepare and manage the deployment of EVs.	

[34] Energy White Paper, BEIS, 2020 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/945899/201216_BEIS_EWP_Command_Paper_Accessible.pdf

[35] Electric Vehicles: driving the transition, House of Commons, 2018. https://publications.parliament.uk/pa/cm201719/cmselect/cmbeis/383/38302.htm

[36] Automated and Electric Vehicles Act, UK Government, 2018. https://www.legislation.gov.uk/ukpga/2018/18/contents/enacted

Indicator	Evidence and RAG rating	
	The UK has banned the sale of new petrol and diesel car and vans from 2030, which aims to accelerate the deployment of EVs both before and after 2030[23].	
Stakeholder acceptance	Uptake of EV-specific tariffs for EV owners is not widespread, in part due to an inability to compare complex EV-specific smart tariffs and general lack of awareness of consumer benefits. Concerns around battery degradation and autonomy/control could lead to pushback by both domestic and non-domestic stakeholders on V2G specifically[37]. Range anxiety is identified as a potential barrier to the uptake of EVs, and therefore flexibility from EVs. Lack of consumer engagement has led to a failure to achieve uptake rates in some V2G trials[38]. There is uncertainty surrounding the future of business models, both for domestic and non-domestic fleets, and the extent to which each segment will be willing and able to provide flexibility.	

[37] Vehicle to Grid Britain, Requirements for market scale-up (WP4), Element Energy 2019. http://www.element-energy.co.uk/wordpress/wp-content/uploads/2019/06/V2GB_WP-4-report-Requirements-for-market-scale-up.pdf

[38] A fresh look at V2G value propositions, Cenex, 2020. https://www.cenex.co.uk/app/uploads/2020/06/Fresh-Look-at-V2G-Value-Propositions.pdf

Indicator	Evidence and RAG rating	
Level of political support	The government has an ambitious 2030 target to end ICE sales, and has demonstrated support through funding of V2G demonstrators, grants for low emission vehicles and charge points and support for local authorities to invest in public charge points[39]. There is a lack of independent leadership to lay out vision for DSO procurement of flexibility and uncertainty around the responsibility for decision-making around dispatching flexibility.	

[39] Innovation in Vehicle-to-grid systems, Innovate UK, 2017 (https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/681321/Innovation_in_Vehicle-To-Grid__V2G__Systems_-_Real-World_Demonstrators_-_Competition_Results.pdf)

Table 10: Business model - Electric vehicles

Indicator	Evidence and RAG rating	
Availability of funding	Availability of commercial funding and credit is expected to be available once the financial performance of the technology improves. Innovation is required for financial products to overcome the uncertainty associated with flexibility contracts. Grants are available for EVs and chargers, and funding is also allocated to support rollout of charging infrastructure across the UK. Innovation trials are shifting from being publicly funded to completely privately funded.	
Willingness to pay	Financial benefits of switching to EV time of use tariff should support the adoption of smart charging. However, financial benefits and market opportunities are not necessarily sufficient; consider the relatively low number of households who switch supplier every year despite the potential financial gains. Lack of evidence around battery degradation and high costs of charging equipment, combined with low consumer engagement, could impede V2G adoption. A move towards mobility-as-a-service could support growth of smart charging/V2G as ownership of EVs switches away from consumers to businesses.	

Indicator	Evidence and RAG rating	
Financial performance	Linking EV-specific time of use tariffs with smart chargers has been shown to reduce the cost of EVs to consumers, indicating a positive financial performance. Financial performance of V2G chargers is set to become cost competitive with standard smart chargers before 2030[40].	
Market opportunities	EV-specific time of use tariffs are already on the market, and further innovation is expected for smart tariffs and EV owners as suppliers look to compete. DSO markets provide clear and consistent market opportunities for both domestic and non-domestic EVs. Aggregation of domestic EVs has successfully engaged in DNO flexibility tenders. However, wider adoption of V2G is expected to take place in the latter half of the 2020s. Currently, the various benefits and value that can be provided from smart charging and V2G are split across multiple actors (consumer, ESO, DSO, EV manufacturers and suppliers), which makes the proposition complex[41], while business models and market opportunities are still evolving. Furthermore, traditional revenue streams from V2G are currently changing (e.g. triad	

[40] A Fresh Look at V2G Value Propositions, Cenex, 2020 (https://www.cenex.co.uk/app/uploads/2020/06/Fresh-Look-at-V2G-Value-Propositions.pdf)

[41] Long term estimates of size of V2G market, Energy Systems Catapult, 2018 (https://esc-non-prod.s3.eu-west-2.amazonaws.com/2019/07/ESC-_V2GB_D1.3-Long-term-estimates-of-size-of-V2G-market_Final.pdf)

Indicator	Evidence and RAG rating	
	avoidance, DNUoS charging, ESO services and DSO services), meaning clear and consistent market opportunities have yet to be developed for either domestic or non-domestic-owned EVs. Further uncertainty can arise over time due to saturation points being reached, although EVs are expected to be most competitive for local services. However, this picture is expected to evolve throughout the 2020s.	

Table 11: Capability to deliver - Electric vehicles

Indicator	Evidence and RAG rating	
Resource availability	Resource availability challenges exist related to components of lithium-ion batteries, which are currently the primary battery technology used in EVs. Research is on-going looking at other chemistries beyond lithium ion[42] but will involve long commercialisation timeframes.	

[42] Including at the Faraday Institute: https://www.faraday.ac.uk/research/beyond-lithium-ion/

Indicator	Evidence and RAG rating	
Technical performance	Smart charging and EVs are available and in operation today. V2G technology needs to mature: few vehicles support V2G, few bidirectional chargers exist and there are several competing protocols. Battery degradation (and minimising battery degradation) presents a key innovation opportunity. Virtual Power Plant (VPP) models to aggregate and coordinate domestic V2G have been demonstrated for DSO flexibility from multiple operators (charge-point operators, aggregators and suppliers). EV chargers and batteries will likely only improve to 2030 and beyond.	
Supply chain and skills	Supply chain and skills are growing along with relevant skills from automobile, ICT and power sectors, supported by strong centres of academia. There are difficulties around developing interdisciplinary skills on V2G, and challenges of scale related to installing charging infrastructure. There is also a potential resource shortage among DNOs to carry out the relevant and required reinforcement work as more EVs connect.	
Maturity of company landscape	Significant competition exists across the landscape of early-stage technology providers, automobile manufacturers and energy suppliers. However, a complex value chain means there is a danger of innovation being stifled.	

Thermal energy storage

Table 12: Enablers - Thermal energy storage

Indicator	Evidence and RAG rating	
Enabling infrastructure	Penetration of district heating (DH) schemes needs to rise from 2% to 20% by 2050 to enable potential benefits from collocated TES outlined by the model. Currently 90% gas powered, the value from TES arises when DH schemes are powered by heat pumps, as the TES decouples heat supply from electricity demand reducing peak electricity demand. However, there are significant barriers to DH deployment, including a lack of policy framework and regulatory barriers, grid access and capacity, and high upfront capital costs compared to gas heating[43]. The government is set to launch a new £122m Heat Network Transformation Programme to accelerate deployment of low-carbon DH schemes, in addition to £270m in the Green Heat Network Fund[44]. There is lack of clarity around long-term land use, given that land surrounding DH schemes tends to be prioritised for housing, and a thermal store could influence the value of the land itself.	

[43] Energy Innovation Needs Assessment: Heating & Cooling, Vivid Economics, 2019 (https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/845657/energy-innovation-needs-assessment-heating-cooling.pdf)

[44] Heat Network Fund Transition Scheme, UK Government, 2020. https://www.gov.uk/government/publications/green-heat-network-fund-ghnf-transition-scheme

Indicator	Evidence and RAG rating	
Regulatory environment	There is limited, if any, regulation specific to TES. The ADE's code of conduct is not mandatory but does set out guidance to sizing TES. There is a lack of clear guidelines and regulations for planning, building standards and environmental protection, which would assist in facilitating projects in which TES will be deployed alongside a DH/cooling asset. A lack of cross-vector regulation (and strategy) exists to cover the important role that TES could have across heat and power sectors.	
Stakeholder acceptance	Compared to other flexibility technologies, there is a general lack of understanding of the value and potential for TES among consumers, industry and policy makers. This has resulted in an aversion to adopt new technologies and business models related to TES for district heating networks (DHNs). There are public perception issues relating to the visual impact of DH TES. For building level TES, there are issues relating to the amount of space that TES takes up particularly in new builds driving energy density improvements. TES can help make heat pumps run more efficiently in DHNs, which works in favour of developing TES as part of heat pump-powered DHNs. However, handing over control of the heat pump and TES to a third party (i.e., an aggregator) in order to	

Indicator	Evidence and RAG rating	
	generate additional revenues is perceived to be potentially risky, especially given the often rigid contractual obligations around delivering heat to customers. The priority for local authority led heat networks is to ensure resilience of supply and overcome fuel poverty. Provision of flexibility is seen as a complexity that might act as a barrier to achieving internal buy-in, especially at the early stage.	
Level of political support	Lack of clear signals on the direction of heat decarbonisation impacts everything from role of thermal storage, as well as combined heat and power (CHP) and heat pumps, although a Heat and Buildings Strategy is expected from Government in 2021. There is a lack of certainty and political signalling as to how long CHP will continue to be able to supply heat networks. While TES may also support heat networks with CHP, the lack of clear decarbonisation pathway for heat networks means there will be hesitation before choosing to invest in heat pumps with TES, compared to CHP (with or without TES).	

Table 13: Business model - Thermal energy storage

Indicator	Evidence and RAG rating	
Availability of funding	There is a relative dearth of funding and attention on accelerating the development of TES technologies, despite the potential importance to the energy system. Research & Development (R&D) investment is required to support the commercialisation of sensible, latent and potential thermochemical TES technologies for both DH and building-scale TES, especially for long and inter-seasonal thermal storage. There is no specific support available for the installation of TES in DH networks, although there is general support through the Heat Networks Delivery Unit[45].	
Willingness to pay	While there may be an immediate incentive to install small amounts of TES in DHNs with heat pumps, the financial proposition isn't strong enough for this to be commonplace. There are also some stakeholder acceptance issues related to handing over of control of flexible assets (heat pumps) to third parties.	

[45] Heat Networks Delivery Unit, UK Government. https://www.gov.uk/guidance/heat-networks-delivery-unit

Indicator	Evidence and RAG rating	
Financial performance	High upfront investment costs for TES for DH are a significant barrier to investment, especially when combined with a lack of clear revenue streams from TES. TES, when combined with heat pumps, can help reduce the cost of energy through the adoption of dynamic time of use tariffs, as well as through providing grid services. However, the financial benefit of participating in such mechanisms is relatively minor, in part due to the size of TES and the associated heat pumps. This value may evolve as the price signals from grid services evolve. However, the lack of value today means that developers are not considering installing TES now or planning their sites so that installations can take place at a later date.	
Market opportunities	TES, when combined with heat pumps, can help reduce the cost of energy through the adoption of dynamic time of use tariffs, as well as through providing grid services. DHNs with TES and heat pumps participate in DSO flexibility tenders and the balancing mechanism and are linked to dynamic time of use tariffs today. The typical route to market for heat networks is through aggregators. In terms of building TES, some trials exploring smart tariffs combined with TES, and domestic hot water tanks are being aggregated to provide grid services.	

Table 14: Capability to deliver - Thermal energy storage

Indicator	Evidence and RAG rating	
Resource availability	There are a range of different TES technologies, based on different storage media. Generally, there is no perceived resource availability constraint. The key resource constraint is space for TES, especially in dense urban areas where DH schemes tend to focus on.	
Technical performance	Further innovation is required to better understand the benefits of integrating TES into DH schemes. A lack of standardisation keeps costs high. Size of TES acts as a barrier to deployment, especially for low density technologies, such as water tanks. There are other less technically mature latent and thermochemical TES technologies that are being demonstrated internationally, including phase change materials and salt hydrates. These technologies need to come to market to facilitate highly dense TES technologies suitable for urban areas. Further research is required to understand degradation effects on some TES technologies[46].	

[46] A UK Roadmap for Energy Storage Research and Innovation, Radcliffe J et al, 2020. https://ukesr.supergenstorage.org/

Indicator	Evidence and RAG rating	
Supply chain and skills	There is a potential skills gap in the management and operation of complex DH networks that have integrated TES. However, once these starts to be developed, it is expected there will be transferable skills from other flexibility sectors.	
Maturity of company landscape	There are a handful of small and large companies developing TES technologies, and suppliers are trialling these solutions, but the landscape in the UK is relatively immature.	

Electricity storage

Table 15: Enablers - Electricity storage

Indicator	Evidence and RAG rating
Enabling infrastructure	Sufficiently capable aggregation and optimisation platforms exist. Renewables plants are now being planned so they can have storage retrofitted to them in future if needed. No major infrastructure barriers exist now that the planning requirement has been lifted.
Regulatory environment	A dynamic regulatory environment, such as the targeted charging review (TCR), creates uncertainty the around business case for storage projects and deters risk-averse investors. However, the outlook is generally positive in terms of levelling the playing field and closing loopholes. Storage is still not formally recognised within the electricity licence framework as a technology in itself, rather than a subset of generation. However, the energy white paper stated it will define electricity storage in law when parliamentary time allows. The government has consulted and will legislate to remove storage from the national significant infrastructure project (NSIP) regime, which limited battery projects to less than 50MW.

Indicator	Evidence and RAG rating	
Stakeholder acceptance	Storage assets co-located with renewables have been successful in DSO flexibility tenders, and storage accepted as mainstream technology by industry, policy makers, aggregators and regulator. Concerns exist around metal use, supply chain sustainability and/or recycling.	
Level of political support	Storage is highlighted as a key source of flexibility, and therefore an enabler of a net zero energy system to enable renewable dominated system, in the energy white paper. The energy white paper also announced major competition to accelerate commercialisation of first-of-a-kind longer duration storage, which comes in addition to programmes such as the Faraday Institute. The BEIS/Ofgem Smart and Flexibility Plan indicates significant political support for industry growth. Lack of certainty on long-term policy for the deployment of storage and other parts of the energy system increases uncertainty for investors and industry.	

Table 16: Business model - Electricity storage

Indicator	Evidence and RAG rating	
Availability of funding	Banks are already financing energy storage projects, and specialist energy storage funds exist. Significant high-profile funding is available for early stage storage technology companies. There are barriers relating to the uncertainty of long-term revenue streams impacting the conversion of projects with green-lit applications. There is potential need for innovation within the financial sector to accelerate investment in storage despite lack of clarity on long-term revenues. There is a lack of refinancing options for second-life applications. Public funding has been allocated for innovation in long-term storage technologies.	
Willingness to pay	Storage is generally seen as an investible asset class, and although there are some issues related to perceived risks around long-term revenue streams, the storage market continues to develop.	
Financial performance	Storage in operation today is generally seeing strong returns thanks to the ancillary services market, Capacity Market and, in some cases, DSO services. Potential for arbitrage and balancing mechanism (as well as ESO and DSO services) will evolve as higher penetrations of renewables come on to the system, although services historically undergo periods of saturation, which increase the perceived risk of long-term revenue certainty.	

Indicator	Evidence and RAG rating	
	Battery costs have dropped significantly in recent years and are expected to continue doing so due to their importance in power and automobile sectors. Cost factors include economies of scale, the ability to achieve synergies in grid costs, land utilisation and existing energy infrastructure and rate of performance degradation. The cost of longer-scale storage using electrochemical batteries is still prohibitive. There is currently no market for second-life opportunities.	
Market opportunities	Generally speaking, the market is well set up for storage, with new services introduced by National Grid ESO, improvements to ancillary service markets with day ahead auctions, easier access to the balancing mechanism and opportunities in local DSO markets, as well as Capacity Market enabling storage to capture the value it provides to different stakeholders. There is still room for improvement for enabling stacking of services, but the outlook is positive.	

Table 17: Capability to deliver - Electricity storage

Indicator	Evidence and RAG rating	
Resource availability	Lithium-ion batteries contain lithium, cobalt, and nickel, which are finite resources. Given the market's current dependence on lithium-ion batteries in both the power and automobile sectors, resource availability issues could emerge as global demand increases.	
Technical performance	Further R&D is required on long duration storage technologies, although this has been prioritised by the government through the launch of a new innovation competition (the Longer Duration Energy Storage Demonstration innovation competition). However, given the scale of storage required (+200GWh) by 2050, there needs to be focused attention on bringing cost effective technologies to commercial scale.	
Supply chain and skills	Some of the raw materials required for electrochemical batteries are concentrated in regions with poor economic and political stability, in addition to human rights and environmental issues. There is a potential skills shortage for roles that require an understanding of how to install, maintain and optimise storage assets.	

Indicator	Evidence and RAG rating	
Maturity of company landscape	A healthy landscape exists of incumbent mining, electronics, chemicals and other technology companies, in addition to energy storage innovators. Aggregators have successfully commercialised and reached maturity.	

Hydrogen electrolysers

Table 18: Enablers - Hydrogen electrolysers

Indicator	Evidence and RAG rating	
Enabling infrastructure	Key questions remain around the capabilities of transmission and distribution networks to transport hydrogen safely. Distribution networks are aiming to be hydrogen-ready by 2032, but there is still an issue surrounding requirements to adapt transmission networks, given the embrittlement of steel pipes installed. Industry testing in 2023 is to allow 20% blending into the distribution grid; a ‘hydrogen town’ pilot study is planned for 2025. Hydrogen energy project HyDeploy has established a specification for a grid entry unit which forms a blueprint for future connections for 20% hydrogen. Large-scale deployment of hydrogen storage is required to make electrolysers viable Long lead times are required to convert storage facilities (i.e. caverns) into being hydrogen-ready. Significant designated additional scale-up of renewables (offshore wind) is required to provide input for green hydrogen. Cost of renewables needs to continue to decrease, given they are the feedstock for electrolysis. However, overcapacity of renewables on the system is also an enabler of electrolysers that benefit from times of excess generation.	

Indicator	Evidence and RAG rating	
Regulatory environment	Power-to-heat (P2H) includes power use, gas production and storage cutting across power and gas legislation and regulation. The UK is yet to state a clear position on its regulatory treatment within electricity and gas, which creates uncertainty for market development. A lack of clarity exists on co-located electrolysers with renewables and standalone plants, in terms of network and connection charges There is a lack of clarity on regulatory treatment of hydrogen storage. Gas injection is currently restricted to blending of 0.1%[47]; there is a requirement for it to be increased, aligned to proving the safety case.	
Stakeholder acceptance	There is a public preference for hydrogen boilers due to the ease of switch compared to heat pumps. There is also industry support for hydrogen, but safety concerns remain. Industry users' confidence remains low owing to perceived immaturity.	

[47] Hydeploy, 2020. https://www.itm-power.com/news/hydeploy-uk-gas-grid-injection-of-hydrogen-in-full-operation

Indicator	Evidence and RAG rating	
	Potential issues could arise related to the required footprint of renewables to support green hydrogen production.	
Level of political support	There is strong political support for low-carbon hydrogen production, but this is not yet translated into a strategy for deployment. The energy white paper announced a dedicated hydrogen strategy will be published in 2021. Targets for clean hydrogen production in 2025 and 2030 have been set out (but these do not necessarily involve green hydrogen), along with significant funding for low-carbon hydrogen innovation. The CCC's net zero report outlines non-optional role for hydrogen usage, including for electrolysers[48].	

[48] Net Zero – The UK@s contribution to stopping global warming, Climate Change Committee, 2019. https://www.theccc.org.uk/publication/net-zero-the-uks-contribution-to-stopping-global-warming/

Table 19: Business model - Hydrogen electrolysers

Indicator	Evidence and RAG rating	
Availability of funding	There is available funding for low-carbon hydrogen innovation projects, with a dedicated £240m net zero hydrogen fund announced in an energy white paper, albeit for both blue and green hydrogen. However, level of ambition is put into perspective when compared to the EUR7bn hydrogen strategy published by the German government. Lack of mechanisms have been seen for other technologies, such as Contracts for Difference (CfDs), to incentivise the scale-up of green (or other) hydrogen supply.	
Willingness to pay	Willingness to pay for green hydrogen over non-green hydrogen is unclear, given the immaturity of both markets. Green hydrogen is more expensive (currently £6-10/kg) than grey and blue hydrogen (£2-4/kg) and requires support mechanisms in the short to medium term.	
Financial performance	Uncertainty exists over the way in which electrolysers can access curtailed power, which can be used to produce and store green hydrogen. PEM production scale-up is contributing to system cost reduction.	

Indicator	Evidence and RAG rating	
	The UK government is working to produce business models for hydrogen for 2022[49].	
Market opportunities	The key challenge is developing demand in conjunction with supply. The UK government aims to draft hydrogen business models for 2022. There is currently a lack of overarching policies that incentivise the adoption of hydrogen across different demand uses (e.g. industry, transport and heat). No revenue support mechanism, such as. CfDs, is yet in place for green hydrogen. Green hydrogen is not currently planned to be supported under green heat schemes such as the green gas levy. No market frameworks are in place for P2H participation in balancing or ancillary services. There is a lack of wider incentive frameworks for P2H that takes into account wider system benefits. There is a lack of market frameworks for large-scale hydrogen storage.	

[49] Business models for low carbon hydrogen production, Frontier Economics for UK Government, 2020. https://www.gov.uk/government/publications/business-models-for-low-carbon-hydrogen-production

Table 20: Capability to deliver - Hydrogen electrolysers

Indicator	Evidence and RAG rating	
Resource availability	Concerns surround the availability of iridium for large-scale PEM production, but research is ongoing to reduce iridium content and potentially replace it with more widely available materials[50]. Potential resource issues may arise with scale in terms of electricity supply and water.	
Technical performance	Electrolysers are being manufactured and are operational today at the ~10MW scale, with the challenge over the coming years to scale up manufacturing to reduce capital costs. There is greater efficiency improvement on hydrogen compression required, particularly in higher pressures. Metering and viable billing regimes for hydrogen are still not available. Full-scale demonstrations are vital for P2H, with renewables important to determine key factors such as operating efficiency, response rates, capacity factor and associated economics of deployment.	

[50] Green Hydrogen Cost Reduction, IRENA, 2020. https://irena.org/-/media/Files/IRENA/Agency/Publication/2020/Dec/IRENA_Green_hydrogen_cost_2020.pdf

Indicator	Evidence and RAG rating	
	Alternate hydrogen storage research and demonstration is important.	
Supply chain and skills	There are more than 100 companies and 35 research groups active in fuel cell and hydrogen production technologies in the UK. Greater skilled personnel availability is expected to grow as market size increases. The UK benefits from strong oil and gas expertise to develop the hydrogen economy more broadly, as well as the gas networks themselves.	
Maturity of company landscape	ITM Power continues to dominate the UK electrolyser market and has developed strategic partnerships with the likes of Linde and Snam, while large utilities such as Scottish Power have established dedicated green hydrogen businesses. Initiatives such as the Green Hydrogen Catapult[51] and other industry alliances are helping to further drive supply chain maturity.	

[51] Green Hydrogen Catapult: https://racetozero.unfccc.int/green-hydrogen-catapult/

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