DNZ | DELIVERING NET ZERO

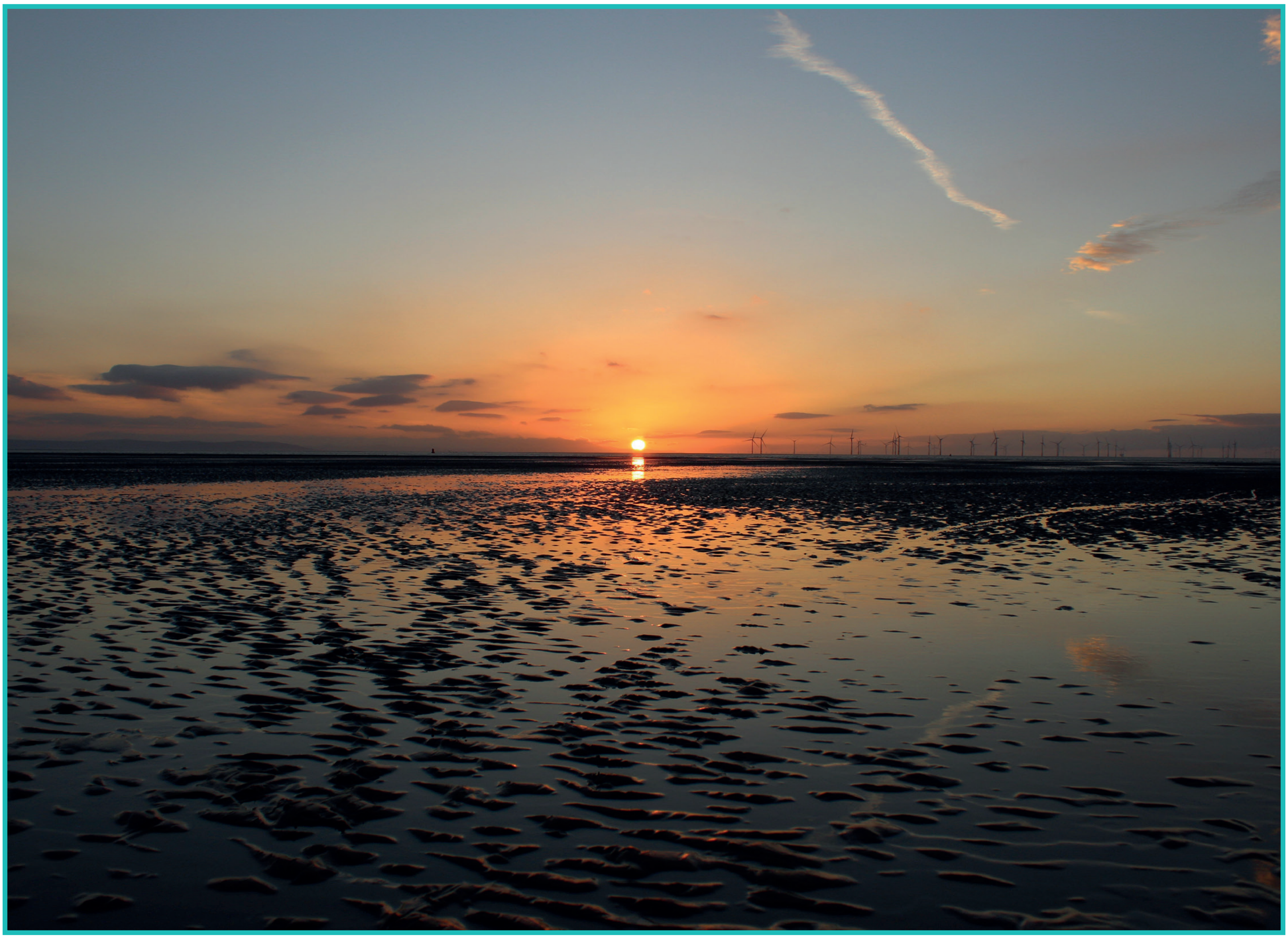
WORKSHOP BACKGROUND BRIEFING

ENERGY INNOVATION

INTRODUCTION

Meeting net zero targets requires an increase in both the pace and scale of energy innovation. As almost all areas of the economy need to be decarbonised, a change in the focus and impact of energy innovation to reach all sectors is essential, necessitating new and accelerated policy approaches[1 2 3] .

Studies indicate that energy technologies take between 20 and 68 years to move from first prototype to 1% of a national market[4 5 6]. This is due to both the iterative, cyclical process of innovation and the requisite development of supporting policies, regulatory frameworks, firm engagement and societal support to create markets and consumer demand[7]. Different technologies necessitate different innovation journeys and timescales, for example building a large-scale, bespoke power station will require different support to the mass consumer roll out of heat pumps. Pursuing the multitude of innovation pathways needed will require adapting, upscaling and replicating existing aspects of the energy system, which will be shaped by and potentially disrupt existing technologies and institutions[8 9 10 11 12]. Policy makers therefore need to take a more prominent role in funding research, implementing conducive policy and shaping markets if energy innovation is to effectively support the delivery of net zero[1 13].



UK LOW CARBON ENERGY INNOVATION

PAST TRAJECTORY

Figure 1 details UK public energy innovation funding, 1980-2018. After energy system privatisation and liberalisation during the 1980s and 90s, innovation spending had drastically reduced by the early 2000s[14]. In response to increasing concerns over energy security and climate change, funding levels started to rise from the mid-2000s and continue to grow, supporting a more diverse range of technologies[a]. As investment has increased, the institutional landscape supporting energy innovation has also grown rapidly, with substantial innovation system remaking occurring since 2000[15]. These efforts have been successful in supporting the recent deployment of renewable electricity technologies, such as offshore wind.

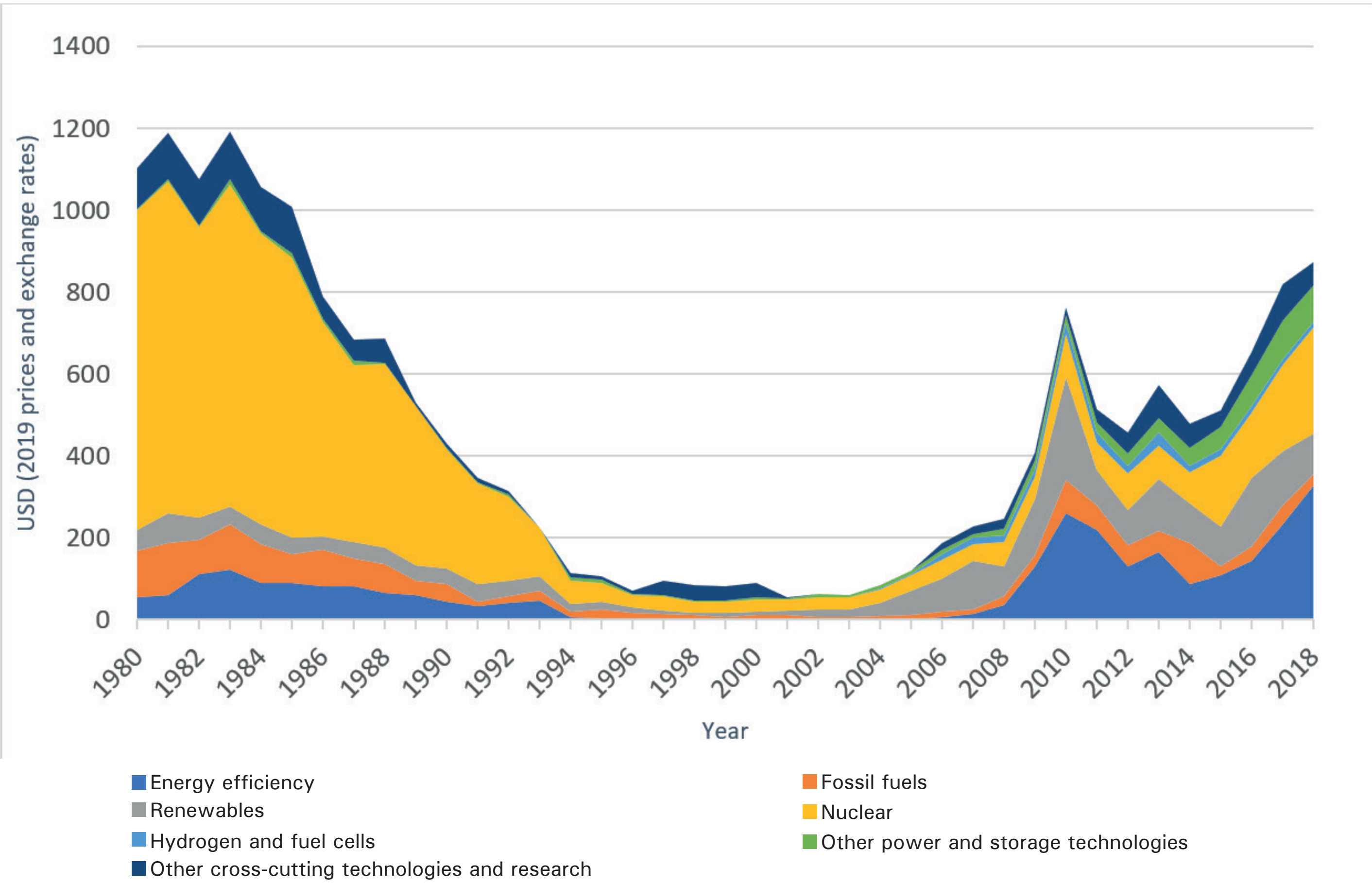


Figure 1- UK Energy RD&D spend (USD)

The innovation approach taken to achieve this progress is recognised to have had *"an emphasis on relatively short-term dynamics (years rather than decades), a focus on cost reduction and deployment support for large scale technologies, and a central role for the private sector and public-private partnerships"*[14] (p.8). The most prominent low carbon developments have occurred in the electricity sector, as opposed to heat or transport, with solutions like offshore wind being brought to market by incumbent firms utilising existing centralised infrastructure and markets. Whilst large, centralised technologies will continue to play a role, as pressure increases to deliver whole energy system innovation, underlying infrastructure and institutional arrangements in delivering net zero are being recognised as a potential bottleneck to a broader range of solutions[10 7 16].

CURRENT POLICY

The 2020 Energy White Paper announced funding for a £1 billion Net Zero Innovation Portfolio, which aims to reduce the cost of transition, nurture new products and influence consumer behaviour[17]. The portfolio has ten areas of focus, depicted in Figure 2, which will underpin innovation focus across the whole energy system to 2030. Key commitments include a £170 million research and development programme on Advanced Modular Nuclear Reactors and a £240 million Net Zero Hydrogen Fund[18], which will support a 5GW of green hydrogen production by 2030[17].

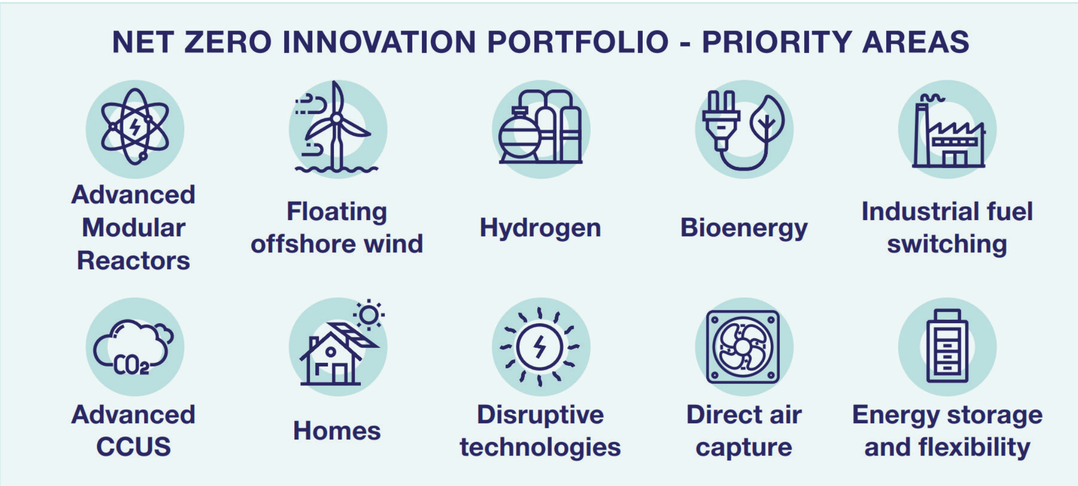


Figure 2- Net Zero Innovation Portfolio- Priority Areas

These commitments build on the 2018 Clean Growth Strategy, which dedicated £2.5 billion to low carbon innovation 2015-2021, across the sectors outlined in Figure 3[19]. In 2018, the UK spent £832.48 million on energy innovation funding, an increase of £365.45 million since 2015 to align with Mission Innovation commitments[20].

Ongoing funding includes the £505m BEIS Energy Innovation Programme[a], up to £1.2 billion of UKRI funding[b] and up to £246 million in the form of the Faraday electric battery challenge. In addition, Ofgem will make up to £720 million of regulated expenditure available to gas and electricity network companies to support flexible network investment to 2021[19].

The delivery of the Clean Growth Strategy forms part of the broader Industrial Strategy, which identifies clean energy as a key area of capabilities that will contribute to developing new markets and creating cross-over opportunities with other emerging sectors, like artificial intelligence[21].

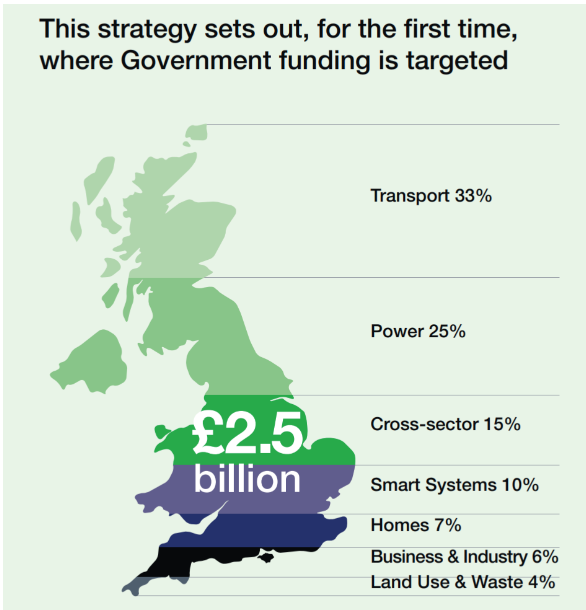


Figure 3 - UK low carbon innovation investment by sector, 2015-2021

a This aims to invest around £70 million in smart systems, around £90 million in the built environment (energy efficiency and heating), £100 million in industrial decarbonisation and carbon capture, usage and storage (CCUS), around £180 million in nuclear innovation, around £15 million in renewables innovation, and around £50 million in support for energy entrepreneurs and green financing (HMG, 2018).
b Including funding for the Energy Systems Catapult and Offshore Renewable Energy Catapult (HMG,2018).

Key support mechanisms within this consist of the Prospering from the Energy Revolution Challenge, focused on smart local energy system demonstrators; the Smart Systems and Flexibility Plan, which supports smart meter roll out; the nuclear and offshore wind sector deals to help build world class supply chains; and ongoing exploration of low carbon hydrogen[21]. The Energy Innovation Board, now the Net Zero Innovation Board (NZIB), was established in 2016 and will be key in providing strong coordination across the innovation system to maximise the impact of this funding.

At a global scale, the International Energy Agency (IEA) have identified the UK as key in the delivery of 35 of 433 technologies key to the delivery of net zero, summarised in Annex A. These technologies span the heating and cooling of buildings, chemicals and cement industries and the production and delivery of electricity, hydrogen and biofuels[1].

ACCELERATING ENERGY INNOVATION

Advancing the range of technologies identified above will require a stable, coherent innovation policy mix that encourages the mainstream deployment of existing technologies, ongoing research into earlier-stage technologies, and the reform of institutions and infrastructure to enable new solutions to emerge[22 13 7 16]. There are several approaches to innovation policy making explored in the literature that could support these efforts.

GREATER POLICY SUPPORT FOR DEMONSTRATION AND DEPLOYMENT

If the deployment of complex, high-cost technologies like carbon capture usage and storage (CCUS) are to be accelerated, they will require greater public policy support and co-funding to reduce investment risk and reach a tipping point for broader diffusion[5 6 13]. This could be achieved by committing larger-scale public resources or tilting policy and regulatory frameworks to begin to favour certain approaches, creating market demand[7].

CONVENE CROSS-SECTOR COALITIONS

Mobilisation of cross-sector technology coalitions that exert pressure on policy makers are important agents in accelerating change[23 24 25], assisting with the development of pervasive narratives that provide legitimacy for new approaches[26 27]. Key UK industry associations engaged in low carbon technology diffusion, such as Renewable Energy Association and Renewables UK, could play a key role in creating strong cross-sector collaboration[6].

SHIFT FROM A FOCUS ON INDIVIDUAL INNOVATIONS TOWARDS MANAGING BROADER SYSTEM CHANGE

Supporting the rapid diffusion of existing technologies alongside the development of complementary innovations could help to prevent innovation bottlenecks[28]. For example, accelerated energy storage technology development would facilitate greater renewables penetration, whilst the concurrent development of digital technologies could improve system efficiency and create new market opportunities for storage technologies[6].

ONGOING GREEN INDUSTRIAL POLICY

Economic policy is an important tool for aligning innovation policy with strengthening industrial advantages, market demand and knowledge spill-overs between sectors[6]. Public procurement is an option that is receiving increasing attention as a means to catalyse early market development, stimulate stable market demand and shape systems transformation[29 30]. The development of equitable public-private partnerships could be an effective way of engaging industry partners whilst minimising public sector risk[31].

FOCUS ON BUILDING FAVOURABLE PUBLIC NARRATIVES

Results of the recent Citizen's Assembly on Climate Change highlighted the need for social acceptability and equitable development of clean energy technologies in meeting net zero. Participants collectively backed measures that improve individual choice, with competition flagged as a means to reduce prices and speed up innovation of these solutions[32]. Business model innovation by incumbent and emerging firms will assist in achieving this, creating new ways to engage consumers[33]. Additionally, trusted voices could be harnessed to build consumer acceptability, which requires increased information sharing and responses to concerns[6]. This could support the development of successful public narratives and assist in delegitimising existing narratives that do not align with the aims of net zero[34].

CHALLENGE EXISTING INSTITUTIONS

The options discussed above could be complemented by policies that challenge existing institutions, facilitating opportunities for innovation to emerge[35 36]. This relates to addressing the influence of existing policy paradigms and political conditions on policy makers[7]; the role of policy maker interests in particular outcomes and shielding themselves from failure[37 38]; and the structure of regulatory environments that favour existing infrastructure and approaches[2].

Incumbent firms play a complex role in these structures, with research demonstrating their role in both defending existing systems[39 40 11]and their ability to drive, positively shape and adapt to changing institutional environments[12 41]. In this regard, incumbent firms should not be viewed as a monolithic aspect of the system to be overthrown, but rather worked with to accelerate change or confronted if their interests do not align with net zero[10].

To challenge existing institutions and industry relationships, policy makers could seek to change the dynamics of stakeholder access to institutional arrangements, reducing the ability for certain firms to lobby and overly influence Ministerial decisions[7]. The opening out of UK energy policy making to a greater number of evidence sources has been highlighted as important in developing the expertise needed to navigate the complexity of net zero beyond existing voices[42]. Additionally, policy strategies could seek to assist those actors that 'lose' in the process of energy system change, to assist in avoiding resistance or economic decline[16].

KEY ISSUES

The policy approaches discussed in the previous section face several challenges, outlined below.

LACK OF STABLE, LONG-TERM POLICY MAKING

Governments and the priorities of individual policy makers frequently change, contributing to the development of short-lived institutions and a contradictory policy environment. Due to the long-term timeframes associated with energy technology development, this lack of coherency may hinder the speed of technology and market development. This difficulty is further compounded by the need for policy makers to challenge existing institutions, which makes policy stability all the more challenging. Net zero policy approaches will therefore need to carefully navigate the tension between stability and change.

URGENCY OF DECISIONS ON LARGE SCALE INFRASTRUCTURE

Key decisions in relation to the direction of energy system decarbonisation, such as choosing to develop hydrogen or electric vehicle infrastructure, need to be made if technologies are to be deployed at the pace required. These decisions however future system lock-in if the development of certain approaches exclude others. By international market developments in relation to identifying a dominant approach, which remains out of the control of UK policy makers. The urgency with which these decisions are made therefore needs to be carefully considered, with commercialisation pathways for long term innovation not completely closed where possible.

INTERACTION BETWEEN MULTIPLE SYSTEMS

As more decisions about energy system decarbonisation are made, tensions will likely arise between different technologies and sectors[43 36]. For example, transport and heat providers may compete for the same electricity system resources as they electrify, such as energy storage or decentralised grid capacity. Additionally, as technology decisions are made that inevitably exclude certain pathways this may affect the evolution of another system. High levels of cross system coordination are therefore required to enable effective decision making.

INCUMBENT RESISTANCE

Incumbent system actors continue to be able to influence government decisions and access critical resources, enabling them to deploy strategies that may resist or delegitimise emerging innovations. This is especially relevant in the UK, where the influence of centralised decision making remains strong[10]. Political struggles and conflicts may therefore arise, especially if phase-out technologies or policies are introduced[16].

UNDERLYING VALUES

UK approaches to energy innovation continue to be influenced by underlying values in relation to privatisation, market liberalisation and the role of the state in innovation funding[10]. In the past, funding has been focused on supporting earlier stage research, with markets relied on to bring technologies through to commercial deployment. This is important to consider in relation to the provision of longer-term, later stage support for the demonstration of large-scale technologies like CCUS or hydrogen infrastructure. Projects may prove particularly costly, high risk and not in the traditional domain of government support, making it difficult to galvanise political backing[44].

CHANGING CONSUMER AND SOCIAL PRACTICES

Results of the Citizen's Climate Assembly indicated that whilst changes to existing lifestyles are viewed as important on the path to net zero, especially post COVID-19, there were concerns in relation to restrictions on freedoms, especially regarding travel. This indicates that new technologies may meet public resistance if the benefits to society are not clear or they require large changes to current habits. It may also prove challenging for policy makers to encourage reduced levels of consumption, which may evoke further resistance[16]. It is therefore essential to consider the societal dimensions of innovating for net zero.

ANNEX A

TRL	STEP IN VALUE CHAIN	SECTOR	TECHNOLOGY	IMPORTANCE FOR NET-ZERO
11	End-use	Buildings > Lighting	Lamps and luminaries > LED > Conventional LED	High
10	Infrastructure	Buildings > Systems Integration	Demand response > Interval/Time of use meter > Electromechanical, radio-controlled switch	High
10	Transport	Buildings > Heating and Cooling	Advanced heat exchanger	High
9	Storage	Energy Transformation > Hydrogen	Salt cavern storage	High
9	Generation	Buildings > Heating and Cooling	Boilers > Hydrogen boiler	High
9	Generation	Buildings > Heating and Cooling	Heat pumps > Hybrid heat pump > Electric resistance back-up system or gas boiler back-up system	High
9	Infrastructure	Industry > Cross-cutting	Control systems > Demand response > Hybrid flexible demand and battery network	High
9	Production	Industry > Cement and concrete	Curing > CO_2 sequestration in inert carbonate materials (mineralisation)	Moderate
9	Production	Energy Transformation > Biofuels	Biomethane > Anaerobic digestion and CO_2 separation	Moderate
9	Storage	Energy Transformations > Power	Mechanical storage > Liquid air energy storage	Moderate
9	Generation	Energy Transformations > Power	Tidal > Tidal range	High
9	Generation	Energy Transformations > Power	Nuclear > Light water reactor-based small modular reactor	Moderate
8	Production	Energy Transformation > Hydrogen	Electrolysis > Polymer electrolyte membrane	Very High
8	Production	Energy Transformation > Biofuels	Bioethanol > Sugar and starch from agricultural crops > Enzymatic fermentation > CCUS	Moderate
8	Generation	Energy Transformation > Power	Biomass > CCUS > Post-combustion/chemical absorption	High
8	Generation	Energy Transformation > Power	Wind > Offshore > Floating offshore wind turbine	High
8	Generation	Energy Transformation > Power	Solar > Photovoltaic > Floating solar PV	Moderate
7	Generation	Buildings > Heating and Cooling	Booster > Water heating heat pump	High
7	End-of-life	Industry > Chemicals and Plastics	New recycling techniques with reduced downcycling > Solvent dissolution for PET	Moderate
7	Transport	Energy Transformation > Hydrogen	Hydrogen blending in natural gas network	Moderate
7	Production	Energy Transformation > Hydrogen	Natural gas auto-thermal reforming with gas heated reformed > CCUS	High
7	Production	Energy Transformation > Biofuels	Biomethane ?Biomass gasification and catalytic methanation	Moderate
6	Production	Energy Transformation > Biofuels	Biodiesel > Gasification and Fischer-Tropsch	Very High
5	Production	Energy Transformation > Hydrogen	Biomass / waste gasification > CCUS	Moderate
5	Generation	Energy Transformation > Power	Tidal > Tidal stream / Ocean current	High
5	Generation	Energy Transformation > Power	Geothermal > Enhanced geothermal systems	Moderate
5	Generation	Energy Transformation > Power	Wind > Offshore > Floating hybrid energy platform	Moderate
4	Generation	Buildings > Heating and Cooling	Solid-state equipment cooling > Barocaloric	High
4	Production	Industry > Cross-cutting	Manufacturing > Reducing metal forming losses > Ring rolling with variable wall thickness	Moderate
4	Production	Industry Cement and concrete	Cement kiln > Electrification (direct)	Moderate
4	Generation	Energy Transformation > Power	Ocean > Ocean wave	High
3	Production	Industry > Cross-cutting	Manufacturing > Reducing metal forming losses > Folding-shearing	Moderate
3	Production	Industry Cement and Concrete	Raw materials > Alternative binding material > Magnesium oxides derived from magnesium silicates	Moderate
3	Production	Industry Cement and Concrete	Cement kiln > Partial use of hydrogen	Moderate
3	Generation	Energy Transformation > Power	Nuclear > Fusion	Moderate

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