Department for Energy Security & Net Zero

Net Zero Innovation Portfolio and the Advanced Nuclear Fund

Progress Report
2021-22

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Any enquiries regarding this publication should be sent to us at nzip@beis.gov.uk

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Foreword

We are witnessing a global transformation as the world pivots to a low carbon economy. Clean technologies will allow us to cut our carbon emissions and, if we lead and innovate, drive economic growth.

Innovation is a key part of the Government's Powering Up Britain – Net Zero Growth Plan. Innovation is a driver for reducing the cost of clean technologies and transforming the UK energy system. We launched the Net Zero Innovation Portfolio (NZIP) to focus on 10 priority themes. This includes, for example, our work on next generation nuclear reactors and the development of energy system flexibility and storage.

We are now halfway through delivering the NZIP and have already supported over 450 projects and nearly 4000 jobs. These projects reflect the energy challenges we face and the exciting technologies being developed to address them. Floating offshore wind turbines, for instance, can diversify UK energy generation, electrify and decarbonise oil and gas production, and may help incorporate green hydrogen into the whisky distillation sector. Through this portfolio we have funded projects across the length and breadth of the UK: from Northern Ireland and Wales to Cornwall, all the way to the Isle of Skye.

We have cut our CO2 emissions by more than any other major economy since 1990 but need to go further and faster.

As Minister for Energy Security and Net Zero it is inspiring to see how UK science is being harnessed to deliver low-carbon technologies, systems and business models in power, buildings and industry. It shows how government funding of research can be converted into sustainable commercial benefit for UK businesses.

Leading the world in moving to net zero is not only the right thing to do but, done right, can provide UK solution providers with export opportunities too. The NZIP is supporting our entrepreneurs, creating jobs, strengthening energy security and making a global difference. I am proud of what is being achieved. Enjoy the report.

Rt Hon Graham Stuart MP
Minister for Energy Security and Net Zero

Introduction

Innovation is a fundamental part of the transition to net zero. Development of key technologies needs to be accelerated with faster commercialisation, scale-up and consumer uptake to support delivery of the UK's net zero target. Providing a combined total of £1.3 billion, the Net Zero Innovation Portfolio (NZIP) and the Advanced Nuclear Fund (ANF) are UK government funds[1] delivered by the Department for Energy Security and Net Zero.[2] They are investing in ten priority themes, providing funding to develop green technologies and processes of the future. NZIP is key to supporting the UK's pathway to a low carbon future and contributing to the achievement of the UK's commitment to net zero emissions by 2050. Announced in the government's Ten Point Plan for a Green Industrial Revolution (HM Government, 2020) and the Net Zero Strategy (HM Government, 2021), NZIP aims to decrease the costs of decarbonisation, underpin innovation across the energy system and drive economic growth by anchoring new technology to the UK. NZIP was launched in April 2021 and will run to March 2025. It is part of a wider ecosystem of public funding as set out in the Net Zero Research and Innovation Framework (HM Government, 2021b) and the accompanying Delivery Plan (HM Government, 2023).

NZIP builds on the £505 million Energy Innovation Programme (EIP), which provided funding between 2015-2021 to accelerate the commercialisation of innovative clean energy technologies and processes. As successor to the EIP, NZIP has further increased funding for low carbon technologies and systems, progressing the technologies through the various stages of maturity, commonly referred to as technology readiness levels (TRLs), to become commercialised and market-ready. As these technologies and processes commercialise, they can benefit from further investment to help them access private finance. NZIP has the following strategic objectives.

1. Support the development and demonstration of new energy technologies, systems and processes.
2. Stimulate private sector investment in the most promising mid- to late-stage low-carbon innovations facilitating commercialisation.
3. Maximise international coordination and collaboration opportunities to achieve a timely and effective low carbon transition.
4. Maintain the UK's international leadership in areas that will benefit the UK clean energy sector.
5. Ensure UK net zero policies are based on the most up-to-date and robust technical evidence.
6. Drive international action on climate change by promoting research and innovation efforts to drive down costs globally and build new markets.

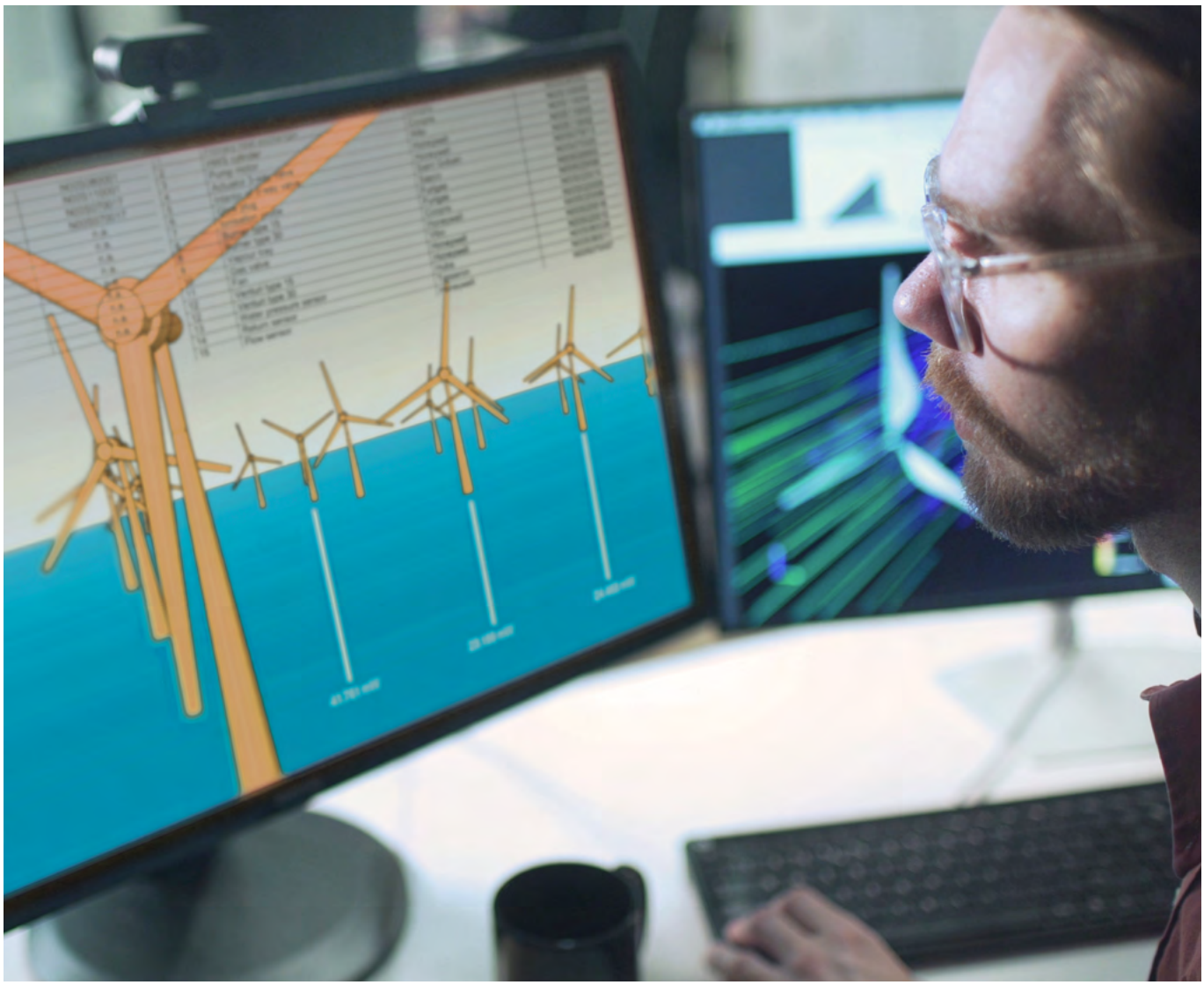
[1] Note that part of ANF is delivered through NZIP, and in this report is treated as part of advanced nuclear 'theme' within NZIP. References to NZIP in the report include the ANF.

[2] The department was formed in February 2023 from the Department for Business, Energy and Industrial Strategy, BEIS. Many references and some quotes will refer to BEIS.

This report provides an update on the progress of delivering NZIP by the end of 2022.

Progress in delivering NZIP programmes, projects and budget

	Completed / spent	Ongoing / committed	Forecast / yet to start	Total
Programmes	2	37	7	46
Projects	135	322	144	601
Budget	£332 million	£601 million	£352 million	£1,285 million



Progress by theme

NZIP is divided into ten technology-focused 'themes' which correspond to the innovation areas set out in the Net Zero Research & Innovation Framework.

- **Energy Storage and Flexibility**
- **Future Offshore Wind**
- **Advanced Nuclear**
- **Bioenergy**
- **Industry**
- **Hydrogen**
- **Advanced Carbon Capture Usage and Storage**
- **Greenhouse Gas Removal**
- **Homes and Buildings**
- **Disruptive Technologies**

NZIP has made good progress since it started in 2021. 39 programmes have been launched with a total of 457 projects across the ten themes. Across the portfolio, over £933 million has been committed or spent, with all themes having initiated their programmes (Table 1). Most programmes are currently live, with the first phases initiated, and two programmes completed in 2022. Whilst the primary focus has so far been on feasibility studies and plans, of projects that have either run for at least a year or completed, 35% report that they have moved their technology closer to commercialisation. NZIP is supporting nearly 4,000 full time equivalent jobs. Additionally, to date, NZIP funding has leveraged £345 million in private investment.

Despite the positive progress, there are some external risks that have impacted or are expected to impact the delivery. Projects have highlighted concerns relating to rising costs and inflation leading to staff and materials becoming more expensive at a project level and increasing supply chain and ultimately project risks. We are working closely with projects to identify and manage those risks. Nonetheless, NZIP is designed to support technologies which have not yet proven their commercial viability, and that means some innovations will fail to commercialise. Failure rate will inform further decisions related to risk appetite necessary to support a portfolio of innovations set out in the Net Zero Research and Innovation Framework.

Each of the themes' progress in 2021-2022 is further detailed in the next section.

Key performance statistics

Number of projects

457

projects completed or ongoing

TRL progression

35%

of projects increased their TRL so far (n=97)*

Finance leveraged

£345m

BEIS funding leveraged £345 million in matched funding (n=449)*

Jobs created

3,810

At least 3,810 full time equivalents have been supported by NZIP (n=354)*

Industry

Hydrogen

Bioenergy

Advanced Carbon Capture Usage and Storage

Advanced Nuclear

Greenhouse Gas Removal

Future Offshore Wind

Homes and Buildings

Energy Storage and Flexibility

Disruptive Technologies

* n=number of projects

NZIP and ANF funding by region (%)

Region	NZIP and ANF spend
East Midlands	41%
South East	10%
Scotland	10%
London	8%
North West	8%
South West	6%
Yorkshire and the Humber	4%
West Midlands	3%
Wales	2%
North East	2%
East of England	2%
Northern Ireland	1%

Location data based on 316 projects' lead and partner organisation location.
The large East Midlands spend includes £210m funding for the Rolls Royce SMR project.

How NZIP is managed

Each theme delivers its innovation objectives through one or more programmes, which focus on different research and innovation challenges within the theme. For example, the Homes and Buildings theme currently comprises two programmes, one focusing on heat pumps and another on green homes finance. Programmes typically distribute their budget through open competitions, where applicants with expertise and ideas compete for funding for their innovation project. Most programmes run multiple phases, often funding a smaller 'feasibility' phase in which projects produce a detailed plan, followed by a 'demonstration' phase where a smaller number of projects receive larger amounts of funding to implement their plans.
Most programmes are managed by staff at the department, but some programmes are managed with external resource.
NZIP also has contracted The Carbon Trust (and consortia) to deliver Acceleration Support Services to approximately 200 SMEs receiving NZIP funding to develop low carbon technologies.
The support focuses on identifying and addressing skills and knowledge gaps within companies which may prevent them from bringing their innovations to market. NZIP also contributes to the Clean Growth Fund, a privately run venture capital fund launched in 2020, to help support availability of follow on funding for innovators.

Energy Storage and Flexibility

Energy storage and flexibility technologies are fundamental to the UK's ambition to have decarbonised the electricity system by 2035 (HM Government 2023a). As significant volumes of variable electricity generation come online, and as electrification of sectors creates additional demand, it becomes ever more crucial to develop the systems and technologies to economically balance supply and demand. Such balancing can range from storing energy to be released when seasonal demand is high, to using market mechanisms to shift energy use to more convenient times of the day. The government has estimated that increased flexibility could save £6-10 billion per year by 2050 (Department for Business, Energy and Industrial Strategy and Ofgem 2021). This theme focuses on developing and demonstrating technologies, systems and processes necessary for the transition to a more flexible, resilient and sustainable energy system.

The theme consists of two programmes: the £68 million Longer Duration Energy Storage programme which supports energy storage solutions; and the £65 million Flexibility innovation programme which supports integrating systems for flexibility, data and digitalisation, and markets for flexibility.

The Longer Duration Energy Storage programme aims to accelerate the commercialisation of first-of-a-kind, longer-duration energy storage technologies that can utilise stored energy as heat, electricity, or as a low-carbon energy carrier such as hydrogen. The projects contribute to cost reductions of longer duration storage technologies, understanding and reducing the risks of non-conventional storage technologies, and securing buy-in from commercial investors. Additionally, the projects will provide data to inform policy formulation. In February 2022, NZIP awarded £6.7 million to 24 projects in the first phase of the programme to develop detailed feasibility studies. In November 2022, the first tranche of Phase 2 funding was announced, awarding £32.8 million to five projects to demonstrate their technologies.

The **Flexibility innovation programme** has launched six sub-programmes so far, in most cases funding feasibility studies ahead of selecting the best projects to develop further. The three largest sub-programmes are:

- Alternative Energy Markets programme to develop and later test innovative tariffs, products and services to increase domestic demand flexibility under alternative energy market scenarios of a future energy system; up to £18 million;
- Interoperable Demand Side Response programme, supporting the development and demonstration of "energy smart" appliances that enable consumers to change their consumption patterns in response to new tariffs and services (known as demand side response), up to £14 million and
- Vehicle-to-X programme, which is enabling energy flexibility from bi-directional electric vehicle charging, up to £11 million.

Three smaller programmes focus on innovation in energy system data and digitalisation to enable a smart and flexible energy system:

- Automatic Asset Registration, up to £2 million;
- Smart-Meter-based Internet of Things, up to £1.8 million and
- Smart Meter Energy Data Repository programme, up to £1 million.

Early in 2023, the Inclusive Smart Solutions programme launched as the seventh programme, aiming to achieve a step-change in access to, purchase of, and use of smart energy technologies, products and services among low income and vulnerable consumers.

2023 will see several feasibility study phases complete and move on to the next phase, developing and demonstrating the technologies and solutions funded. This includes the Longer Duration Energy Storage programme, the Interoperable Demand Side Response programme, the Vehicle-to-X programme, and the two smart-meter-focused programmes. Much of the early part of the year will be spent setting up those demonstration projects.

Case study:
Energy Storage and Flexibility

StorTera – SLIQ

StorTera is an Edinburgh based SME, developing a ground-breaking technology which could greatly increase energy system flexibility.

StorTera, an Edinburgh based SME, received £5 million through NZIP's Longer Duration Energy Storage Demonstration programme to develop their unique, highly energy dense Single Liquid Flow Battery (SLIQ).

The SLIQ will offer safe and low-cost energy system flexibility by storing excess renewable energy, generated when wind turbines and solar panels have periods of high electricity generation, and releasing it back to the grid when it is needed.

> "NZIP funding has enabled us to accelerate the development of manufacturing methods to build a large-scale long duration demonstrator of the SLIQ. Once proven, we plan to expand manufacturing while helping to make the UK a centre of excellence in energy storage innovation."

Dr Brenda Park, Chief Operating Officer for StorTera

The NZIP funding will see StorTera expand its laboratory and double its number of employees to 28.

Future Offshore Wind

The UK has considerable potential in offshore wind—high winds and a shallow seabed have enabled the UK to be a global leader in offshore wind capacity. Building on this, the UK Powering Up Britain plan set an ambition of up to 50GW electricity to be generated by offshore wind by 2030, including up to 5GW by floating offshore wind generation (Department Energy Security and Net Zero, 2023). Despite this success, there are significant technological barriers to further deployment, including challenges to locating wind turbines beyond shallow waters, wind turbines' efficiency limits and radar interference. This NZIP theme aims to address these challenges while incentivising private investment, supporting UK firms, creating green jobs and furthering export opportunities.

The theme is comprised of three programmes – Floating Offshore Wind, Windfarm Mitigation for UK Air Defence and Composites.

The up to £32 million **Floating Offshore Wind** programme began in April 2021, funding 11 innovation projects. Most of the supported technologies are moving from being validated in a relevant environment to being deployed and certified as a complete system. The programme is also supporting the Offshore Renewable Energy Catapult's Floating Offshore Wind Centre of Excellence which aims to share learning and expertise between industry stakeholders.

The up to £19 million **Windfarm Mitigation for UK Air Defence** programme aims to accelerate development of innovative technologies to mitigate the effects of offshore windfarms on UK Air Defence radar and enable their long-term co-existence. The first phase of the programme was funded through the 2016-21 Energy Innovation Portfolio. The NZIP-funded Phases 2 and 3 are aiming to support a demonstration. A key part of the programme's success has been working closely with the Ministry of Defence, through the Defence and Security Accelerator (DASA).

The up to £10 million **Composites** programme, known as the Joule Challenge, is aiming to demonstrate how lightweight composite materials can be incorporated into the next generation of offshore wind turbines and how they can be manufactured and delivered in the UK context. The department has partnered with two Catapult centres, the Offshore Renewable Energy Catapult and the National Composites Centre, to deliver this programme. Phase 1 was delivered as part of the Energy Innovation Portfolio and the ongoing Phase 2 is laying foundations for the demonstration of cutting-edge prototypes.

Case study:
Future Offshore Wind

SENSEWind

The "Self-Erecting Nacelle and Service" (SENSE) project aims to make the installation and service of wind turbines significantly easier, cheaper, and more accessible.

At present, most offshore wind turbines are fixed to the seabed. To continue expanding its wind generation capacity, the UK may need to deploy floating wind turbines in deeper water, where wind speeds are often higher.

Receiving £10 million in funding through the NZIP Floating Offshore Wind programme, SENSE's "self-installing" technology allows the turbine and rotor nacelle to be assembled on the tower at site during construction, reduces the time that turbines are offline during maintenance, the demand for specialist cranes and cost. This is combined with the Pelastar floating foundation and a robotic drilling system for setting anchors developed by Subsea Micropiles. All three elements are disruptive technologies which this project aims to demonstrate and integrate.

> "The floating offshore wind grant has been instrumental in enabling the demonstration of these three technologies in the UK, which allows us to bring together these disruptive technologies maturing the floating offshore wind industry."
>
> **Julian Brown, the Chair of SENSE Wind**

On-shore testing of the SENSE system in 2023 is due to be followed by off-shore testing of the anchoring system off the Orkney coast. If successful, this approach enables vast swathes of the ocean for offshore wind and, combined with the cost reductions SENSE promises, presents a significant export opportunity for the UK.

Advanced Nuclear

Nuclear power offers low-cost, low-carbon electricity and a predictable power output. The Nuclear NZIP theme, funded through the £385 million **Advanced Nuclear Fund**, aims to develop modern nuclear technologies to provide substantial and consistent power as part of a net zero electricity system. The theme intends to shorten timescales of building new nuclear power stations while increasing investor confidence.

The nuclear theme runs several programmes, to support the development of the two main nuclear technologies supported by the government: Small Modular Reactors (SMR), a traditional but small, standardised and modular nuclear reactor; and Advanced Modular Reactors (AMR), which combine new nuclear fuel and reactor designs with modular construction. In addition, the programmes seek to contribute to retaining and developing the UK's nuclear skills and capabilities.

The £210 million **Small Modular Reactor programme** (also known as Low-Cost Nuclear Challenge) is funding the development of the Rolls Royce UK SMR design and progressing it through the extensive regulatory assessment. Building on a first phase that developed a concept design, the second phase started in November 2021 and, supported with £258 million private sector funding, will further develop the concept reactor design to allow it to pass through the UK Regulators'[3] generic design assessment (GDA) process. That phase is expected to conclude by early 2025.

The £18 million **Advanced Fuel Cycle programme** supports work on AMRs by developing advanced and accident-tolerant nuclear fuels and fuel cycles. The programme has successfully constructed fully operational demonstrators for new types of nuclear fuel.

The up to £86 million **Advanced Modular Reactor programme** aims to demonstrate High Temperature Gas Reactor technology by the early 2030s, in time for any potential AMRs to support net zero by 2050. The programme is currently completing preliminary front-end engineering design (pre-FEED) work, taking key design decisions and estimating costs and risk. The next stage will start in mid-2023 and will appoint up to two organisations to develop a detailed front-end engineering design (FEED) of an actual AMR demonstrator. Following on from the Advanced Fuel Cycle programme, the AMR programme will also support scaling-up the development of coated particle fuel, which will be used in new reactors. Commercialisation of these technologies is the remit of the Nuclear Fuel Fund.[4] The programme also supports regulatory engagement with the successful projects in order to streamline and enhance future regulatory assessment.

In addition, we continue to work with and exchange knowledge with our international partners through a range of bilateral and multilateral forums. The **Engage** programme focuses on enhancing our knowledge capture from current and previous programmes and leveraging some of that to gain access to global research programmes.

[3] Office for Nuclear Regulation, Environment Agency, and Natural Resources Wales

[4] See https://www.gov.uk/government/publications/nuclear-fuel-fund

Case study:
Advanced Nuclear

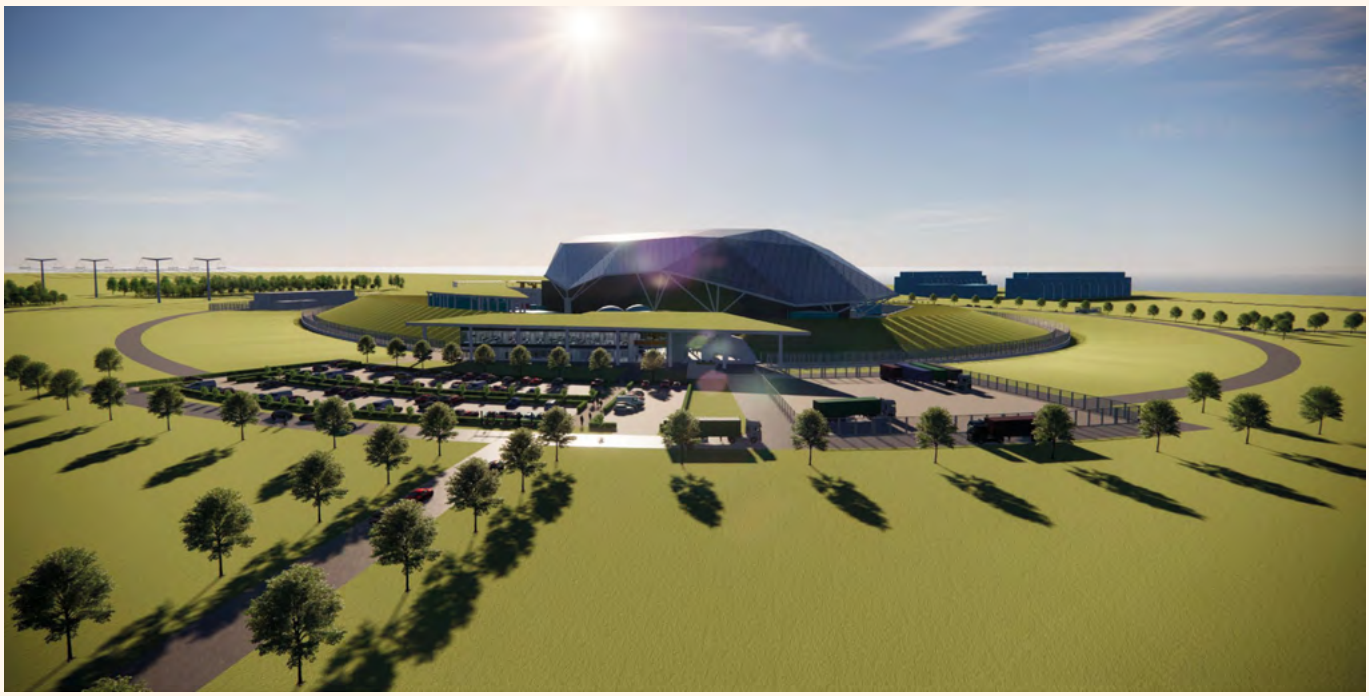
Developing Small Modular Reactors in the UK.

Small Modular Reactors offer the opportunity to reduce costs through deploying “factory built” methodologies and increasing delivery confidence.

Rolls Royce SMR Ltd are developing the design of a 470 MWe reactor, large enough to power a city the size of Leeds, using a range of innovations. These include breaking the design down into modules, which can be fabricated in factories before being brought to site and assembled under a temporary structure similar to the O2 Arena. They are planning for first deployments to be in the early 2030’s; another low carbon energy source which could help reach our net zero targets.

The design is the first SMR to be assessed by the UK’s safety and environment regulators through their Generic Design Assessment (GDA) process. BEIS is providing up to £210 million of funding through its delivery partner UKRI, with industry investing a further £285 million over the course of the project.

The project has created over 600 jobs, in a range of technical and specialist areas, in just two years, and is on course to complete the second of three stages of regulator assessment by the end of 2024.



Bioenergy

Bioenergy is energy produced using biomass such as wood, fast-growing grasses or biogenic waste. Bioenergy combined with carbon capture and storage (BECCS) is a potential negative emissions technology—as the carbon dioxide absorbed during plant growth is ultimately placed in long-term storage and is therefore removed from the atmosphere.[5] Biomass can also be used to produce hydrogen. Analysis suggests that biomass gasification with carbon capture and storage could provide up to 20% of total hydrogen production in 2050 (HM Government, 2021).

The NZIP Bioenergy theme aims to make it cheaper and easier to turn biomass into energy. Its **Biomass Feedstocks Innovation** programme aims to improve the production of UK biomass, by funding commercially viable technologies that help farmers grow bioenergy crops. The **Hydrogen from Bioenergy with Carbon Capture and Storage** programme supports technologies which can produce hydrogen from biogenic feedstocks[6] and be combined with carbon capture technologies.

In the £4 million first phase of the **Biomass Feedstocks Innovation** programme, projects developed proposals to deliver commercially viable innovations in biomass production. Completing in March 2022, the best proposals were selected for a second phase awarding a further £32 million for projects to develop demonstrators. The funding also stimulated private sector investment to design and develop these prototypes: 24 out of 25 projects reported having secured follow-on funding after completion of the initial phase. Furthermore, the funding supported 137 UK-based jobs.

Projects also collaborated with international partners to identify the biomass crop varieties most suitable for the UK climate. The projects' outputs will feed into the Climate Services for a Net Zero World research programme[7] focused on helping the UK adapt to the impacts of climate change.

The next year will see the demonstration projects develop and implement their technologies, assessing progress along the way. As most biomass research is bound to annual agricultural cycles, developing, testing and amending technologies can take several years.

The **Hydrogen from Bioenergy with Carbon Capture and Storage** programme started in June 2022. The programme's £5 million initial phase awarded funding to 22 projects to scope and develop feasible prototype demonstration projects that can produce hydrogen from biogenic feedstocks and be combined with carbon capture. These initial projects are completing in early 2023 and will be followed by an up to £25 million programme in which the best projects demonstrate their innovations at scale. The programme has so far supported 171 jobs across the 22 projects.

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[5] The production of biomass, e.g. the growing of trees, binds carbon from the atmosphere. Capturing and storing it during the energy production process prevents that carbon from being re-released into the atmosphere, thus creating negative emissions.

[6] Biogenic feedstocks are biological materials that can be converted into fuel. They include raw biomass, but also waste products such as straw or industrial waste

[7] See https://www.gov.uk/government/news/government-boosts-uk-resilience-against-climate-change

Case study:
Bioenergy

Rickerby Estates

Revolutionary technology will significantly scale up UK biomass production.

Burning biomass releases carbon embedded in the biomass as carbon dioxide. However, this carbon was extracted from the atmosphere during the growth of the biogenetic material. Therefore, for accounting purposes, when this carbon is captured and stored, the energy generation value chain captures more carbon than it releases. This makes bioenergy with carbon capture and storage a negative-emission technology.

Rickerby Estates Limited received £4 million from NZIP to develop their mechanical solutions for planting and harvesting willow by building on their experience in the industry and identifying shortcomings. They are producing a solution designed to increase efficiencies, decrease cost and improve the scaling-up of UK biomass production.

> "Being successful in our bid was a huge boost to not only our business but the short rotation coppice willow industry as a whole. It enables Willow Energy to develop and build cutting edge technology that will help scale up the industry quickly."

Jamie Rickerby, Director of Rickerby Estates Limited

The mechanical solutions will be lightweight, with a lower carbon footprint and increased efficiency. The most exciting benefits from this machinery are the lower costs and greater income potential for farmers. This will encourage more farmers to plant willow and help the UK reach its net zero goals.

Industry

This NZIP Industry theme aims to address technical barriers and challenges by investing in the development and practical demonstration of fuel switching technologies and processes. It covers five programmes: Industrial Fuel Switching, Red Diesel Replacement, Green Distilleries, Industrial Energy Efficiency Accelerator and the Industry of Future programme.

The £55 million **Industrial Fuel Switching** competition aims to support the development of fuel-switch and fuel-switch-enabling technologies for UK industry, for moving from high carbon fuels to hydrogen, electricity, biomass, and other low carbon fuels. Over the past year, we published outputs from 15 projects which have completed the planning and design stage, to inform the wider sector and drive progress towards the second stage. In October 2022, we opened the application window for the second stage of the programme, during which the most promising projects will be supported with up to a total of £49 million to demonstrate their fuel switching solution in real world conditions.

The £40 million **Red Diesel Replacement** competition provides funding for developing low-carbon alternatives to red diesel[8] for construction, mining, and quarrying. Last year, we awarded £7 million in grant funding across 17 feasibility studies, which expects to complete by mid-2023, and the most promising projects will move to demonstration stage.

The **Green Distilleries** competition seeks to support the development of technologies that enable a distillery to use low carbon fuels such as hydrogen, electricity or biomass and waste. In 2021, we provided a total of £1 million to 17 projects to complete a Phase 1 feasibility study on their proposed solution, with final reports published in March 2021. Since then, over £8.5 million has been provided to three Phase 2 demonstration projects, with the final project expected to conclude in March 2024.

The £8 million **Industrial Energy Efficiency Accelerator** programme aims to fund industrial scale demonstrations of novel technologies with the potential to reduce energy consumption, maximise resource efficiency and cut carbon emissions. It is designed to support partnerships between developers of efficient technologies and industrial companies willing to trial innovations on-site. The programme is delivered through the Carbon Trust, with support from Jacobs and the Knowledge Transfer Network. Phases 1 and 2 were delivered under the Energy Innovation Programme, Phases 3 and 4 are being funded under NZIP. In October 2021, Phase 3 allocated £3.6 million to eight demonstration projects selected on their energy, resource, and carbon saving potential, in addition to their technical feasibility and scalability. Phase 4 projects are currently being selected and are expected to commence in early 2023.

[8] Red diesel is the term used for diesel that is intended for use other than as fuel in road vehicles.

The **Industry of Future programme** aims to increase the range of decarbonisation options available to industry to enable them to decarbonise at a faster rate.
The programme focused on sites outside industrial clusters and on seven sectors: chemicals, paper, minerals, food, water, transport and pharmaceuticals. In October 2021, 15 industrial sites were selected to be part of the scoping study to develop industrial decarbonisation roadmaps specific to each site. Atkins, leading the study, conducted a series of workshops with each site and produced site decarbonisation roadmaps. A summary report with key findings is expected to be published in 2023.

Case study:
Industry

Locogen

Whisky distillery to cut energy demand on fossil fuels by 25%.

In 2019, UK whisky distilleries directly produced around 530,000 tonnes of CO2 equivalent, with the majority of these emissions coming from the generation of heat for the distillation process. The £3 million funding awarded through the NZIP Green Distilleries programme to Locogen, in partnership with Logan Energy and Arbikie Distillery, is financing the development and installation of a green hydrogen energy system. When completed, expected in mid-2023, this demonstration project will reduce the distillery's thermal demand on oil by 25% by generating the steam for the distillation processes from hydrogen.

This world-first project allows Arbikie to move away from traditional distilling processes that burn fossil fuels, instead using zero-carbon green hydrogen generated on site. The distillery began by growing the crops and botanicals needed to distil on site and is now tackling its energy usage and the environmental impact of packaging and shipping.

Arbikie's new Distillery Experience opened in 2022. The Green Hydrogen project will be showcased to private investors and developers. This project will offer a solution to other distilleries, providing a clean energy supply for distillation, reducing both emissions and energy costs.

> "These projects combine the best of traditional skills and methods with innovative technologies. It seems that "guid auld Scotch drink" has a great future in the new zero-carbon economy."
>
> **Andy Lyle, CEO of Locogen**

Hydrogen

Hydrogen will be critical to helping vital UK industries transition away from oil and gas, and can provide greener energy for power, transport and potentially space heating of buildings. By 2050, government analysis suggests that the UK may need 20-35% of its final energy consumption to come from hydrogen to meet its climate commitments (HM Government, 2021) and the government has an ambition of supporting up to 10GW of hydrogen production capacity by 2030, with at least half from electrolytic production (HM Government, 2022).

The NZIP Hydrogen theme aims to support scaling up hydrogen production and use across the value chain through three programmes, with projects advancing hydrogen technologies also being supported by other NZIP themes.

The £60 million **Low Carbon Hydrogen Supply 2** programme seeks to address specific technological gaps to make hydrogen production, storage and supply more efficient and cost-effective. Its Stream 1 seeks to identify, support and develop credible innovative hydrogen supply or enabling technologies to accelerate their development. In 2022, we awarded £6 million to assess the feasibility of 23 projects, including low and zero carbon hydrogen production as well as hydrogen storage, transport and supply solutions. Stream 2 directly funds the real-world testing of more mature innovative hydrogen supply solutions. Applications closed in 2022, and we awarded £38 million to five projects.

The £26 million **Industrial Hydrogen Accelerator** (IHA) programme aims to demonstrate the practical feasibility and viability of end-to-end hydrogen fuel switching in industrial applications, as well as reducing the costs and risks associated with this. Stream 1 aims to construct end-to-end industrial hydrogen systems from hydrogen production to end-use. It awarded over £3 million to one project in 2022, the Smart Hydrogen-Gas Network project, which uses the first-ever 100% hydrogen boiler for commercial applications for the energy intensive process of gas preheating. It will be powered by green electricity and supported by an AI-enabled optimisation software platform specifically designed for hydrogen systems. Stream 2A aims to assess the feasibility of less mature end-to-end hydrogen fuel switching solutions. In 2022, we awarded £3 million across nine projects, the best of which will be funded for real-world demonstration or front-end engineering design (FEED) studies in Stream 2B. We will soon be publishing the findings of the feasibility projects and announcing the projects that have received further funding.

The **Hydrogen Skills and Standards for Heat** programme builds on the success of the Hy4Heat programme, funded through the Energy Innovation Programme to support future hydrogen heating trial activities and the consideration of hydrogen for heat as a potential decarbonisation pathway. At its core, the programme aims to develop the technical standards for domestic and non-domestic hydrogen gas installations, for safely repurposing existing natural gas equipment for hydrogen, and for designing and installing new hydrogen-safe pipework and appliances. It will also support the training of a workforce of skilled hydrogen gas

installers. The outputs of the programme will be published in 2023/2024, supporting preparations for hydrogen heating village trials.

NZIP also funds the **Hydrogen Heating** programme, which aims to develop the evidence base necessary for strategic decisions on the role of hydrogen in heat decarbonisation. The programme is developing evidence on the costs, benefits and feasibility of hydrogen heating in relation to networks, end users, system transformation, safety, consumer trials and markets and regulation, in preparation for strategic decisions in 2026.

Case study:
Hydrogen

H2GO Power

Orkney energy storage project aims to demonstrate how green hydrogen can be stored at low pressure to support a low carbon future.

With £4.3 million funding through NZIP's Low Carbon Hydrogen Supply 2 competition, the SHyLO (Solid Hydrogen at Low Pressure) project will demonstrate the effectiveness of utility-scale solid-state green hydrogen storage.

Led by H2GO Power, the technology stores hydrogen at ambient temperatures and pressures, providing a safer, lower cost and more efficient alternative to current high-pressure and cryogenic hydrogen storage solutions. This could offer cost savings of up to 55 percent.

> "The funding has enabled us to translate the years of hard work and technology development into an opportunity to build a world's first commercial scale system."

Dr Enass Abo Hamed, CEO and co-founder of H2GO power

Orkney has the highest concentration of small and micro wind turbines in the UK and local wave and tidal generation. Utilising the power generated by renewable energy is important for generating electrolytic hydrogen, the efficiency of the local generation system and future decarbonisation goals, with the prospect of removing over 2,700 tonnes of direct CO2 emissions (diesel equivalent), if deployed over a 30-year lifetime.

Advanced Carbon Capture Usage and Storage

Carbon capture, usage and storage (CCUS) technologies are one of the key options to minimise carbon emissions from hard-to-abate sectors. For example, certain metallurgic processes require very high-temperature heat which, at present, can only be obtained with fossil fuels. The UK government aims to capture 20-30 MtCO2 per year by 2030 utilising this technology, including 6 MtCO2 of industrial emissions (HM Government, 2021).

The CCUS Innovation 2.0 and the Accelerating Carbon Technologies 3 programmes seek to remove barriers to CCUS uptake by supporting the development of second-generation CCUS technologies, ranging across all stages of the supply chain, from capture and utilisation to transport and storage. The objectives are to bring down the cost of capturing and sequestering CO2 and help the UK CCUS industry develop and deploy the next generation of CCUS technologies from 2025.

The **Accelerating Carbon Technologies 3** programme continues the work of the previous two rounds of funding[9], to support international collaboration across 14 countries including the UK. In April 2022, the programme awarded £5 million in grant funding up until March 2025 for CCUS developers to expand on their research and development and to push their technologies to higher technology readiness levels. The £5 million provided by the UK contributes to a total funding pot of around £40 million, including £25 million provided by international partners.

In July 2021, the **CCUS Innovation 2.0** programme awarded over £12 million across 8 innovative projects, constituting a combined industry and government investment of almost £26 million in next generation CCUS innovation. These projects, now in their planning and feasibility stage, seek to improve the cost-effectiveness of next-generation carbon capture technologies for deployment from 2025. Their results will provide further clarity and direction about which technologies show the greatest potential for future development.

In April 2022, the findings from a techno-economic analysis and technology review paved the way for a second call of the programme. Launched in July 2022 with an additional £7 million of funding, it targets both early- and late-stage innovation projects, funding pilots and feasibility studies. Winning projects are in a due diligence process ahead of funding awards.

[9] Through the UK and its international partners, Accelerating Carbon Technologies 1 and 2 provided a total of £58 million, of which 15 UK projects received a total of £13 million.

Case study: Advanced Carbon Capture Usage and Storage

Econic Technologies

Econic Technologies and Unilever have teamed up to demonstrate how waste carbon dioxide can be converted into valuable products.

Sustainable sourcing of key ingredients for consumer goods is fundamental to Unilever Home Care's Clean Future Strategy, which aims to create products made from sustainable ingredients in sustainable packaging.

In this project Econic Technologies are using their pioneering technology to integrate waste CO2 into a widely-used chemical building block. The project funds a dedicated lab-scale reactor to create, assess and identify sustainable non-ionic surfactants, replacing up to 40% of the material's weight with CO2. These products will then be commercialised for use in Unilever's products.

> "We're very grateful for the support received by this grant. The capabilities we will have with the new equipment will be instrumental in allowing us to design and scale the new and exciting molecules we are developing in partnership with Unilever."

Dr Michael Kember, Econic co-founder and Head of Research & IP

Funding from NZIP has been essential for Econic Technologies to rapidly upscale materials, enabling parallel-track evaluation activities to identify functionally superior molecules for fast moving consumer goods. Unilever's global reach means new materials can be deployed quickly and at scale around the world.

Greenhouse Gas Removal

Greenhouse gas removal (GGR) technologies will be essential for reaching net zero—balancing residual emissions from hard-to-decarbonise sectors while providing new economic opportunities as part of our Green Industrial Revolution. The UK is well positioned to be a global leader in the development and deployment of GGR technologies, with world-class engineering expertise and access to geological storage sites. In the Net Zero Strategy, we committed to developing and deploying GGR technologies at scale. This included an ambition to deploy at least 5 megatonnes CO2e of engineered removals per year by 2030, potentially rising to around 23 megatonnes CO2e annually by 2035.

GGR technologies are not yet ready for commercial deployment in the UK – a key barrier currently being the prohibitively high cost of removing CO2. NZIP's **Direct Air Capture and Greenhouse Gas Removal** innovation programme aims to develop approaches to removing CO2 and other greenhouse gases from the atmosphere, with the longer-term aim of reaching MtCO2e per year scale and costs below £200 per tonne CO2e removed. The programme's central objective is to deliver at least one first-of-a kind demonstration plant by the middle of the decade.

In its 2021 Phase 1 competition, the programme selected 23 projects to assess the practical and technical feasibility of GGR technologies and processes and to prepare detailed designs for piloting. This phase supported 129 jobs and came to an end in January 2022. The outputs of each project were published and helped to inform both private stakeholders and future GGR policies.

In July 2022 the 15 most promising projects were awarded a total of over £54 million to implement and test their innovations in real-world conditions. Over the next year, these projects will be installing the equipment for their prototypes, with the final year leading to March 2025 focused on the commissioning and demonstration of the direct air capture and GGR solutions.

The programme has also expanded the UK's international cooperation in the sector by joining Mission Innovation's Carbon Dioxide Removal Launchpad.[10] This is a coalition of governments that have agreed to work together to accelerate the pace of carbon removal advancements through large demonstration projects and to share data and experiences.

[10] See http://mission-innovation.net/missions/carbon-dioxide-removal/

Case study:
Greenhouse Gas Removal

Lapwing Reverse Coal Project:

Novel engineering of a natural solution will enable the removal of CO2 from the atmosphere to lock it back in the ground.

The Lapwing Estate sits on lowland peat which has been historically drained and farmed for organic food production. These practices have degraded the soil and led to greenhouse gas emissions as the peat oxidises (lowland peat is responsible for 3% of UK GHG emissions).

Reverse Coal was awarded nearly £3 million through NZIP's Greenhouse Gas Removal and Direct Air Capture innovation programme. To capture carbon dioxide and abate existing emissions, they will rewet the peat and establish fast growing willow crops which will be chipped and dried and then fed into a high temperature pyrolysis plant. This plant converts the willow (biomass) into a solid form of carbon akin to coal, called 'biochar'. The biochar is then expected to be buried for long term storage of CO2. The heat and power generated from the biochar production are directed into controlled-environment agriculture, for example heating greenhouses for more sustainable and secure food production.

> "We are grateful to BEIS for backing us to develop our novel Reverse Coal approach as a pioneer in this space. This support extends beyond the pure financial investment and associated boost to credibility, to project oversight through regular reviews, extending our networks and enhancing our collective knowledge."
>
> **CEO James Brown**

This project is exploring an innovative new way to sustainably intensify production of high quality, healthy food, whilst at the same time supporting the government's target for net zero by 2050.

Homes and Buildings

The UK has around 30 million buildings that are collectively responsible for 30% of national emissions, with the vast majority of buildings emissions resulting from demand for heating (BEIS, 2021a). The UK aims to reduce these emissions by improving buildings' energy efficiency, for example through better insulation, and replacing heating systems with low carbon alternatives. Currently, cost, technological challenges and low uptake from commercial and private building-owners and occupiers are key barriers in the journey to net zero.

The two programmes of the Built Environment theme target deployment approaches, consumer engagement and costs. The up to £60 million **Heat Pump Ready** programme tests how domestic heat pumps can be made more accessible, deployable and attractive to the consumer. The up to £20 million **Green Home Finance Accelerator** develops new consumer finance models to make the initial capital required for building energy efficiency measures more accessible.

Heat Pump Ready focuses on three different problems. Stream 1 aims to identify and address issues affecting efficient high-density mass roll out of heat pumps in local areas through learning-by-doing. Stream 1 has delivered its first phase, in which 11 projects tested the feasibility of their proposed approaches for high density heat pump deployment. The programme is currently selecting the most promising of those projects to run real-world trials in local areas.

Stream 2 projects are developing tools, technology and processes which overcome specific barriers to domestic heat pump deployment, for example developing better 'heat pump readiness' assessments for potential customers. To date, 24 projects have been selected for funding.

Stream 3 shares the learning from the other two streams, maximising knowledge exchange between the projects, as well as providing guidance, tools and training, so that learning from the programme can inform a wide range of actors, including improving installer and customer experience.

Since its start in late 2021, Heat Pump Ready has supported 108 full-time equivalent jobs across the UK.

The **Green Home Finance Accelerator** supports lenders to develop and pilot innovative, commercially viable green finance products and services (such as home improvement loans), which incentivise domestic energy performance improvements. It seeks to improve lenders' skills, encourage partnerships between lenders and energy efficiency and other providers, and help lenders understand what drives consumers to invest in energy efficiency and low carbon heating. This will unlock private finance support to help as many UK homes as possible to reach Energy Performance Certificate (EPC) C by 2035.

The competition launched its £4 million "Discovery Phase" in October 2022 and grants are now being awarded. During this phase, projects will develop ideas and proposals and can then apply in September 2023 to the £16 million "Pilot Phase", where the best proposals can obtain up to £2 million to test and improve their products with customers.

Case study:
Homes and Buildings

City Science

Regional studies and modelling to accelerate the deployment of high-density heat pumps across the UK.

Heat pumps are a key solution for decarbonising homes and have a critical role to play under all pathways to net zero. City Science have been awarded through the Heat Pump Ready programme, including £498,000 to run a study which will transform current understanding of heat.

This project will roll out a financing support package for combined heat pump and retrofit solutions designed to accelerate heat pump deployment at the lowest cost to the consumer. The project also seeks to develop tools to better predict building energy consumption, thereby improving building owners' understanding of their buildings' energy requirements. Finally, it will develop a trial of solutions and methodologies to deliver high-density heat pump deployment in locations across the UK.

> "The funding provided under the NZIP Heat Pump Ready programme has allowed us to significantly accelerate our research and development into cutting edge technologies and delivery models."
>
> **CEO Laurence Oakes-Ash**

This project has been able to analyse multiple layers of heat pump deployment, which has allowed them to collaboratively tackle key barriers to large scale heat pump deployment, and positively contribute to the UK's decarbonisation objectives. In addition to carbon savings, this work will result in supporting up to 14 jobs across this and other Heat Pump Ready projects, with exploitation of this innovation aiming to create many more new, high-skilled jobs over the next five years.

Disruptive Technologies

The Disruptive Technologies theme captures new, uncertain technologies which show potential to support decarbonisation and where there is industry support for accelerating innovation as well as providing support for entrepreneurs and smaller-scale innovators.

There are three distinct programmes under this theme. The **Energy Entrepreneurs Fund** (EEF) was set up in 2012 to support the development and demonstration of energy efficiency, power generation and heat and electricity storage technologies, products and processes, and in particular to assist small- and medium-sized enterprises. Through its first seven rounds under the Energy Innovation Programme and predecessors, the EEF supported 156 projects with £72 million. Round Eight launched in February 2021 under NZIP, providing 53 projects with £30 million in grant funding. Round Nine launched in September 2022, selecting 37 projects. The projects anticipate increasing their technology readiness, as measured by the Technology Readiness Level (TRL) scale, by three TRLs, bringing them closer to being commercially deployed at scale.

The £3 million **Space Based Solar Power (SBSP)** programme explores to what extent, how and at what costs future energy could be provided from space using orbiting solar power stations. The programme launched in July 2022 and is working with partners to create opportunities for UK companies to participate in relevant international programmes, in particular the European Space Agency SOLARIS programme. The programme will support projects across 4 different streams of innovation (power beaming, space solar panels, network integration and space mission construction) as soon as April 2023. This initiative has been ramping up international and UK collaboration in SBSP development, through events and knowledge sharing with 63 partnerships and this is expected to continue through 2023.

The **Artificial Intelligence for Decarbonisation** programme aims to stimulate further innovation in artificial intelligence (AI) and drive growth, whilst helping the UK and others decarbonise. The programme has contributed £500,000 to the creation of a virtual AI Centre of Excellence. This Centre will promote the UK's AI knowledge base and drive collaboration across the decarbonisation and AI sectors. The programme also runs a £1 million grant-based competition which opened in November 2022. It will fund projects to help address three major decarbonisation challenges with the help of AI: enable a faster transition to renewable generation in the electricity system, decarbonise UK industry by improving energy productivity or enabling fuel switching, and decrease agricultural CO2e emissions through improving the efficiency of processes.

Case study:
Disruptive Technologies

LiNa Energy

Novel sodium battery project offering alternative to traditional lithium-ion batteries for long-term energy resilience.

Battery energy storage is becoming increasingly important in the transition to a net zero energy system. Effective energy storage solutions will help boost the UK's long-term energy resilience and reduce reliance on fossil fuels. LiNa Energy, a spin-off from research at Lancaster University, received a grant of £862,000 through NZIP's Energy Entrepreneurs Fund Round 8 and have been able to develop a safe battery system that is a first-of-a-kind technology.

> "This funding helped LiNa to raise investments from private sources and create permanent jobs. The award of this grant provided additional confidence to investors in our ability to advance our technology towards commercialisation and reach our net zero goals."
>
> **Mark Boland from LiNa**

This year-long project was undertaken mainly in Lancaster. LiNa Energy's system claims superior safety through its inherently safe chemistry; greater sustainability, as the battery contains no critical elements like cobalt or lithium; and the promise of significantly lower costs compared to traditional lithium-ion batteries.

The project has contributed to the creation of nine positions in Lancaster and the company has already successfully secured £3 million of follow-on funding to scale. This battery offers the potential to store energy more cheaply and safely, increase job creation potential and could help make the energy system more flexible, supporting the UK pathway to net zero.

Next Steps

NZIP aims to bring innovative, clean energy ideas closer to reality. Over the coming years, projects will progress from a conceptual phase to one in which real-life demonstrators and prototypes are built, enabling the department to demonstrate the practical viability of the projects whilst enhancing their commercial value. Innovation is central to the UK's approach to delivering net zero and strengthening energy security and NZIP projects will be key to proving the technologies, business models and systems that will be needed in the transition to net zero.

The key focus for the department is to ensure the continued delivery of the projects, alongside effectively collecting and disseminating key learnings. To this end, a robust monitoring and evaluation framework has been developed.
Key features of this framework are below.

- Systematic and comprehensive monitoring of progress and impacts of programmes. This includes project completion reports and the reporting against a set of common key performance indicator (KPI) metrics to provide robust and systematic evidence of outcomes across the portfolio.
- Evaluations (at a theme level) across NZIP programmes to provide both an understanding of what we have learned through the portfolio and evidence of impact, including on carbon emissions, on cost of energy and energy security, and on UK jobs & economy. Interim and early impact findings will be produced throughout the remainder of the NZIP lifecycle to 2025, and final impact and economic evaluation reports are expected to be published by 2028.
- Synthesis of evidence from KPIs, evaluations and other data to demonstrate outcomes and impacts at a portfolio level. It is expected that an interim synthesis of the NZIP portfolio will be published in 2026 and a final synthesis in 2028.

As well as measuring the performance of the portfolio, evidence and learnings accumulated from evaluating NZIP (and its predecessor, the Energy Innovation Programme) will be integral to the design of future government net-zero innovation portfolios. The KPI data collected determines whether programmes achieved their intended outcomes, including technology and commercial readiness progression and follow on funding, which will help the department develop robust expectations and assumptions for future investment decisions.

Learnings from programmes will be disseminated regularly and widely, through a number of mechanisms including GOV.UK, formal reporting and stakeholder events. This will enable NZIP evidence to feed into departmental policy and to add to the knowledge base of the wider innovation community in government, industry and academia, to help deliver the cross-government Net Zero Research and Innovation Delivery Plan (HM Government, 2023).

NZIP and ANF programmes

Theme	Programme
Energy Storage and Flexibility	Flexibility Innovation Programme Sub programmes: Interoperable Demand Side Response, Vehicle 2 X, Smart Meter Internet of Things, Alternative Energy Markets, Automatic Asset Registration, Inclusive Smart Solutions, Smart Meter Energy Data Repository, Energy System Digital Spine, Non-Domestic Smart Meter Tariff Comparison, Flex Markets Unlocked[11]
	Longer Duration Energy Storage
Future Offshore Wind	Floating Offshore Wind
	Windfarm Mitigation for Air Defence
	Composites
Advanced Nuclear	Small Modular Reactor programme
	Advanced Fuel Cycle programme
	Advanced Modular Reactor programme
	Advanced Nuclear Skills and Innovation Campus
	Engage programme
Bioenergy	Biomass Feedstocks Innovation
	Hydrogen from Bioenergy with Carbon Capture and Storage

[11] Announced but not yet launched

Theme	Programme
Industry	Industrial Fuel Switching 2
	Red Diesel Replacement
	Green Distilleries
	Industrial Energy Efficiency Accelerator
	Industry of Future
Hydrogen	Low Carbon Hydrogen Supply 2
	Industrial Hydrogen Accelerator
	Hydrogen skills and standards for heat
	Hydrogen heating
Carbon Capture Use and Storage	Accelerating Carbon Technologies 3
	CCUS Innovation 2.0
Greenhouse Gas Removal	Direct Air Capture and Greenhouse Gas Removal
Built Environment	Heat Pump Ready
	Green Homes Finance Accelerator
Disruptive technologies	Energy Entrepreneurs Fund 8 and 9
	Space Based Solar Power
	Artificial Intelligence for Decarbonisation

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