Part of the conference series
Breakthrough science and technologies
Transforming our future

Sci-Fi: bridging climate science and green finance

Held on 21 July 2021

Conference report

Supported by AstraZeneca

THE ROYAL SOCIETY

Introduction

On 21 July 2021 a conference was held exploring climate science and the technologies that show genuine promise towards net-zero emissions, as well as barriers to the flow of capital and solutions to funding such technologies.

This meeting was held by the Royal Society in partnership with the Green Finance Institute and brought together world-leading experts from industry, academia, policymaking, and the wider financial and scientific communities.

With this unique interaction between science and finance, the discussion delved into recent developments in low-carbon technologies across sectors which have been the target for 'green finance': hydrogen and ammonia, heating and cooling, batteries and energy storage, nuclear energy and digital. The meeting explored opportunities and challenges to commercialising these technologies and potential solutions to channel the world's finance into their widespread implementation.

This conference, supported by AstraZeneca, is part of a series organised by the Royal Society entitled Breakthrough science and technologies: transforming our future, which addresses the major scientific and technical challenges of the next decade. Each conference covers key issues including the current state of the UK industry sector, the future direction of research and the wider social and economic implications.

The programme was shaped by Dame Sue Ion DBE FREng FRS (Royal Society Science, Industry and Translation Committee), Professor Peter Bruce FRS (University of Oxford), and Sir Roger Gifford (Green Finance Institute and SEB). During the planning of this event, Sir Roger Gifford, a key member of the organising committee, sadly passed away. Sir Roger leaves a strong legacy in this important area of climate-linked financial services and contributed significantly during the development phase and to shaping the agenda and content of this timely event. The conference was held in dedication to him.

The conference series is organised through the Royal Society's Science and Industry programme which demonstrates the Society's commitment to integrate science and industry across its activities, promote science and its value, build relationships and foster translation.

This report is not a verbatim record, but a summary of the discussions that took place during the day and the key points raised. Comments and recommendations reflect the views and opinions of the speakers and not necessarily those of the Royal Society.

Executive summary

Achieving a net-zero carbon society that is both resilient to climate change and inclusive, bringing everyone in society along with it, requires the development and widespread deployment of both disruptive and existing technologies, supported by public and private funding.

Responding to climate change has historically been seen as the realm of government policy, however, there is rising expectation that the financial sector should contribute to managing the risks associated with climate change. Furthermore, closer integration is needed between the physical and social sciences, financial professionals and institutions, innovative start-ups and global industry to support a low-carbon future.

Key findings were:

- Public funding and state aid are necessary to reduce risk when investing in emerging technologies. Existing financial instruments in green finance, such as green bonds, are not fit for purpose to invest in early-stage risky technologies.
- Existing climate models have insufficient resolution to predict the short-term and localised climate extremes we are seeing today: greater investment, research and development is needed.
- Different low-carbon energy solutions are suited to different locations and must be implemented in a way that is fair and affordable for consumers.
- Even with successful development of emerging technologies, a robust, widely implemented digital system is necessary to bring them together onto one energy grid.
- A stable regulatory environment, that accounts for the transition that industry needs to go through, will accelerate the low-carbon transition. Developing regulation to unlock private and public capital will engender a whole-economy transition.

"If we are to decarbonise our economy fast enough to maintain global warming at or below 1.5°C, we must bring the technical and nature-based solutions together with the finance needed to see these solutions become a reality."

Professor Peter Bruce FRS, The Royal Society

KEYNOTE

Science and the City: climate, capital and collaboration

The proliferation of net-zero aligned commitments from public and private financial institutions attests to the growing acceptance that climate risk poses financial risk and the need to reallocate capital towards zero-carbon solutions. Dr Rhian-Mari Thomas OBE, Chief Executive, Green Finance Institute (GFI), gave the opening keynote talk.

Green finance, the application of climate and environmental science to financial decision making, is one of the fastest-growing areas within financial services. Of the world's central banks and financial supervisors, 83 are members for the Network for Greening the Financial System, representing two thirds of carbon emissions and committing to reducing them. The financial industries are used to seeing long-term cyclical trends, yet rapid change has been observed in recent years. Capital investments in long-term oil projects have fallen 60% at Goldman Sachs in the last five years. Meanwhile, the Global Sustainable Investment Alliance valued funds which require green screening at more than $30 trillion.

Credible plans are needed to adjust business models to transition to zero carbon, and investors increasingly demand transparency from companies. Climate Action 100+ represents >500 institutional investors demanding that the 161 highest-emitting companies publish strategies to meet medium-term decarbonisation targets – the largest ever investment engagement initiative on climate change.

Industrialisation has driven wealth but caused observable stress in the Earth's systems with anthropogenic greenhouse gases altering climate 5,000 times faster than any natural warming episode. The Fourth Industrial Revolution offers an opportunity to harness technologies and protect shared resources.

Scale of the challenge

According to Carbonomics, $16 trillion of investment is required by 2030 in key technologies to decarbonise the energy sector. Investment is also required to transition the transportation sector, including shipping, and harder to abate industrial sectors such as steel and cement production.

However, allocating capital to new technologies poses considerable risk to investors, with potential near-term disadvantages to first movers. It is a challenge to traditional providers of finance. Venture Capitalists rarely invest hundreds of millions in a single venture, but this is necessary in early-stage technologies. Pension and sovereign wealth funds represent $17 trillion of assets, but are conservative investors. Promisingly, green bonds invest in projects with positive environmental impacts and reached a new record of $170 billion to fund climate investments in 2020[1]. However, the bonds' financing solution appeals to pensions and insurers seeking long-term steady income – meaning this is not relevant when profit is uncertain. No single institution or financial instrument can meet the investment required: an ecosystem is needed.

> "There is now understanding that the shift to a sustainable economy must be underpinned by climate science, and the inviolable laws of physics."
>
> Dr Rhian-Mari Thomas OBE, Green Finance Institute.

1 International Finance Corporation Green Bond Impact Report, Financial Year 2020.

Funding the gap

The GFI seeks to meet this funding gap by facilitating international dialogue between funding providers to invest according to their risk-return profiles. Public sector support and philanthropic capital is necessary to de-risk early technologies and create conditions for private finance. Technologies that provide a 'public good', like carbon capture and storage, make a clear argument for public funding. Co-designing incentives and financial solutions by sector, such as buildings, enables maximum crowding in of capital per investment. The new UK Infrastructure Bank has net zero as part of its mandate and will allow public and private sectors to work collaboratively, providing an opportunity for UK industry.

The UK has a world-class blueprint – or 'greenprint' – for how public support has unlocked green infrastructure and tens of thousands of jobs. Four technical interventions enabled government support for wind energy; now 40% of global offshore wind is off the UK coastline:

1. The Government provided financial incentives for 15 years through 'Contracts for Difference', providing a guaranteed minimum cost and predictable cash flows.
2. Bidding rounds for access and construction aligned land- and seabed-leasing processes.
3. Bidding rounds for offshore wind capacity created investment opportunities.
4. A dedicated national green investment bank overcame investment gaps.

Ensuring that the economy transformation is based on rigorous scientific guidance remains a challenge which no single type of financial institution, public or private, can meet. This indicates an opportunity for unprecedented collaboration between science, industry, policy and finance.

KEYNOTE

A CERN for climate change

Professor Tim Palmer CBE FRS, University of Oxford, explained what is unknown in state-of-the-art climate models and why there is a need for an international institute for climate prediction.

On the global scale we do not understand well how clouds will respond to increasing CO_2 concentrations – and yet this will determine how much the planet will warm. On more regional scales we have a poor understanding of the changing nature of extreme events, or of the possibility of passing irreversible tipping points. One way to address these issues, and their impacts, is to invest in an international institute for climate prediction – a CERN for climate change. At its heart would be exascale computing infrastructure, completely dedicated to climate change research.

Models give understanding of long-term climate trends from carbon emissions, but not local weather events, and rising atmospheric carbon appears to be affecting local weather dynamics. It has been argued that recent climate extremes – such as near 50°C temperatures in British Columbia, and recent flooding in Germany and China – have not been successfully simulated in climate models. This is largely because current climate models have relatively coarse spatial resolution. Climate models based on the physics of Newton, Planck and Clausius unpack into trillions of equations from planetary to microscopic scales. The size of computers dictates what equations can be solved. As a typical climate model will have a 50 km grid spacing, anything smaller cannot be resolved by the model. Recent extreme events were driven by thunderstorm cloud systems with scales less than 50 km – the Canada heatwave circulation patterns were forced in the Tropical Western Pacific by storm systems. Creating a model with a resolution of 1 km requires 10^{18} calculations per second, which is not currently available.

Even climate models on large scales have significant errors. When compared against 20th Century observations, model predictions are smaller than model errors and are therefore not reliable in predicting climate (figure 1). Because the error size is larger than the signal size, sometimes even the sign of the change in rainfall is unknown. In short: the current generation of models are incapable of simulating the observed extremes of climate.

Any climate mitigation and adaptation strategies should consider the developing world, where climate extremes can be even greater. Such regions are particularly threatened by climate-related risks – heat, storm, flood, drought, and so on. A dedicated computing facility for climate, a role similar to that of the European Organization for Nuclear Research (CERN) in particle physics, would allow nations to prioritise climate risks, mitigation and adaptation strategies.

CERN's budget is approximately €1 billion per year; a climate 'CERN' would require roughly €200 million per year, including the intellectual resource to build and understand climate. It would be producing societally-relevant information within five years. This would facilitate more detailed understanding of how close climate is to 'tipping points', after which carbon removal would be largely ineffective. Geoengineering should not be approached without a better understanding from models of its ramifications: a devoted centre would enable better understanding of these – for example, would the use of sulphuric acid particles in the stratosphere to reflect insolation also affect monsoon circulation.

> "Climate modelling needs to be given the same focus as particle physics. It is not only scientifically important but societally vital if we are to meet the future with any degree of confidence and certainty."
>
> Professor Tim Palmer CBE FRS, University of Oxford.

Climate modelling

Left column shows model error against observations; right shows model predictions. Current-generation climate models are imperfect simulators of climate as the errors are comparable with the signal of climate change.

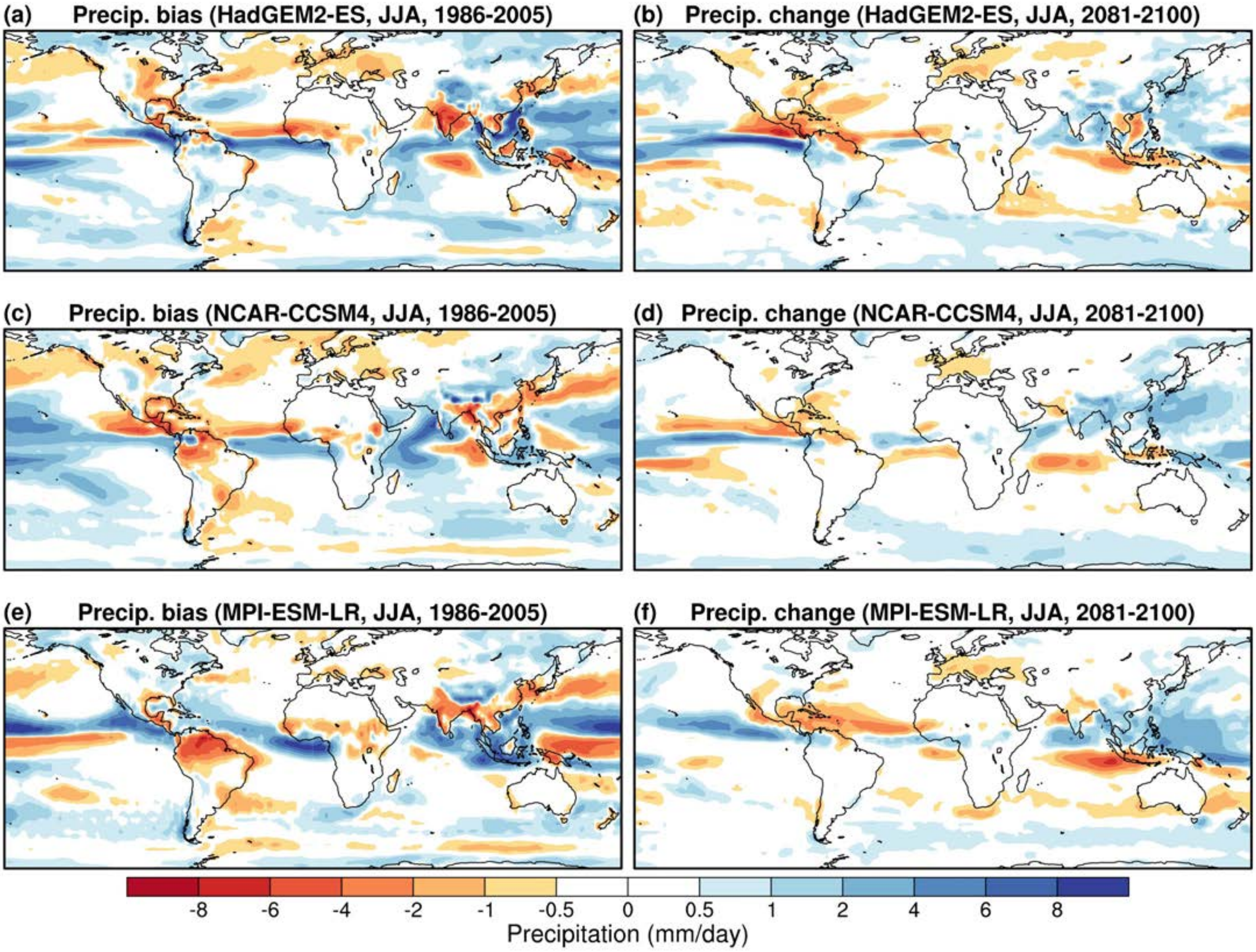


Image credit: Palmer and Stevens, PNAS 2019.

Five technologies for a low-carbon future: the role of hydrogen and its derivates in the achievement of the climate targets

Professor Christopher Hebling, Co-Director, Division Energy Technologies and Systems and Director, Business Division Hydrogen Technologies of Fraunhofer ISE, spoke about the role of hydrogen to achieve the climate targets as well as materials challenges of developing the hydrogen energy vector.

Fraunhofer is the largest organisation for applied research in Europe, comprising close to 30,000 scientists, engineers and students across 75 institutes in Germany. One of the seven dedicated strategic areas of Fraunhofer is hydrogen technologies.

Globally, around 75% of greenhouse gas emissions stem from the energy sector. Green hydrogen and its derivatives are expected to help realise a defossilised energy system based on renewable energy, as well as helping to replace fossil molecules for the chemical sector with synthetic chemicals.

There is increased pressure to mitigate climate change: in Germany, a federal constitutional court judgement against the Federal Climate Change Act[2] in April 2021 concluded that "one generation must not be allowed to consume large portions of the CO_2 budget…if this would involve leaving subsequent generations with a drastic reduction burden and…comprehensive losses of freedom". The German government has since shifted its target of net-zero carbon emissions from 2050 to 2045.

Funding for hydrogen

Hydrogen has seen an unprecedented development in 2020 including the release of many of the 35 National Strategies for hydrogen. Germany has devoted €9 billion to realise the targets of its national hydrogen strategy. The costs of photovoltaic and wind energy have now fallen to \$0.01/kWh and \$0.02/kWh levelised costs of electricity, respectively. This is leading to large private investments in hydrogen technologies - totalling over \$300 billion globally up to 2030. Australia is seeking to introduce 150 GW of solar photovoltaic and wind energy by 2030 in order to produce 15 million tonnes of hydrogen annually. Meanwhile, Saudi Arabia's ambitious Neom smart city deal commits \$5 billion to build the world's largest green hydrogen and ammonia plant. In addition, it is expected that the European Green Deal and European Commission 'Fit for 55' package will accelerate development of hydrogen technologies.

> "Nobody knows exactly what climate neutrality by 2050 means in terms of cost and challenges – normally it takes 20 years to build a road around a city."
>
> Professor Christopher Hebling, Fraunhofer Institute for Solar Energy Systems, ISE

2 Federal Constitutional Court Judgement against the Federal Climate Change Act, April 2021.

Technical challenges

The German primary energy sector consists of less than 25% of electricity, the rest is molecular based (transport, high and low temperature heat). The challenge is to transform the energy system such that the fossil molecules (coal, natural gas, oil) are replaced either by green electricity (eg in electric vehicles or in heat pumps) or by synthetic fuels and chemicals. Such synthetic fuels are made of hydrogen from water electrolysis, as well as either nitrogen from the air, or carbon molecules from biomass plants or industrial exhaust gas streams (figure 2). Hydrogen will play a key role in the future energy system, because transforming green electrons to green molecules enables storage, transportation and usage of energy in different forms (known as 'Power to X', eg Power to Gas, Power to Liquid).

Other challenges for hydrogen include:

- Scaling production of hydrogen for heavy industries: hard to decarbonise sectors comprise >75% of global energy demand. Hydrogen will need to be produced at scale, as green production of steel in Germany requires 2.4 Mt/annum of hydrogen (~20 GW electricity), while industrial high-temperature heat needs <6 Mt/annum.
- Reducing costs: production costs are determined by both investment costs (CAPEX) and operational costs (OPEX). Research and development can help to reduce the CAPEX cost, but the total costs of ownership are dominated by the OPEX costs which are mostly defined by the electricity price. Public funding will help reduce early costs.
- Research challenges: much more fundamental science and technology is required, especially in the field of hydrogen production, storage and transport of hydrogen at low temperatures and high pressures as well as safety technologies for all materials systems involved in the whole value chain.

FIGURE 2

The efficient conversion from sustainable feedstock to advanced products remains a challenge.

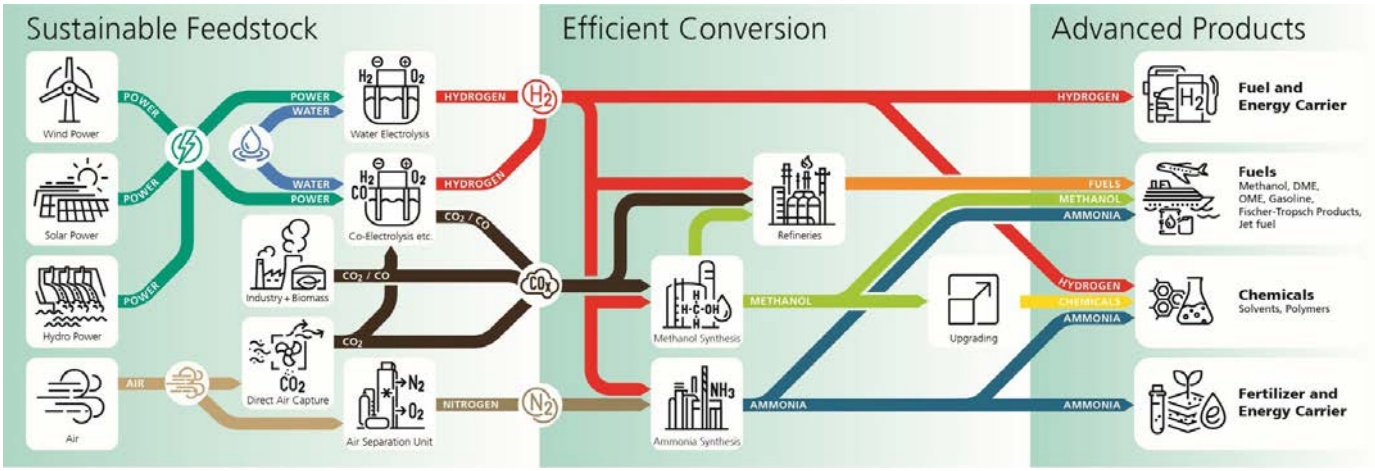


Image credit: Fraunhofer ISE 2020.

Balancing risk and reward in the Faraday Institution's energy-storage research portfolio

Professor Pam Thomas, Chief Executive, The Faraday Institution spoke about the Institution's approach to application-inspired energy storage research and analytical methodology to assess early-stage commercialisation.

The Faraday Institution is the UK's independent flagship organisation for electrochemical storage research, skills development, market analysis and early-stage commercialisation. It brings together over 450 research scientists from 20 universities and 50 industry partners to work on projects in areas that show promise in providing tangible benefits to the UK battery and transport sectors (figure 3). The Institution's work model represents a Government intervention as part of the Industrial Strategy Challenge Fund's Faraday Battery Challenge.

> "We see ourselves in collaboration – not competition – with the energy ecosystem and want to develop porous boundaries across energy technologies."
>
> Professor Pam Thomas, The Faraday Institution.

FIGURE 3

Technical targets set by industry and pursued by the Faraday Battery Challenge.

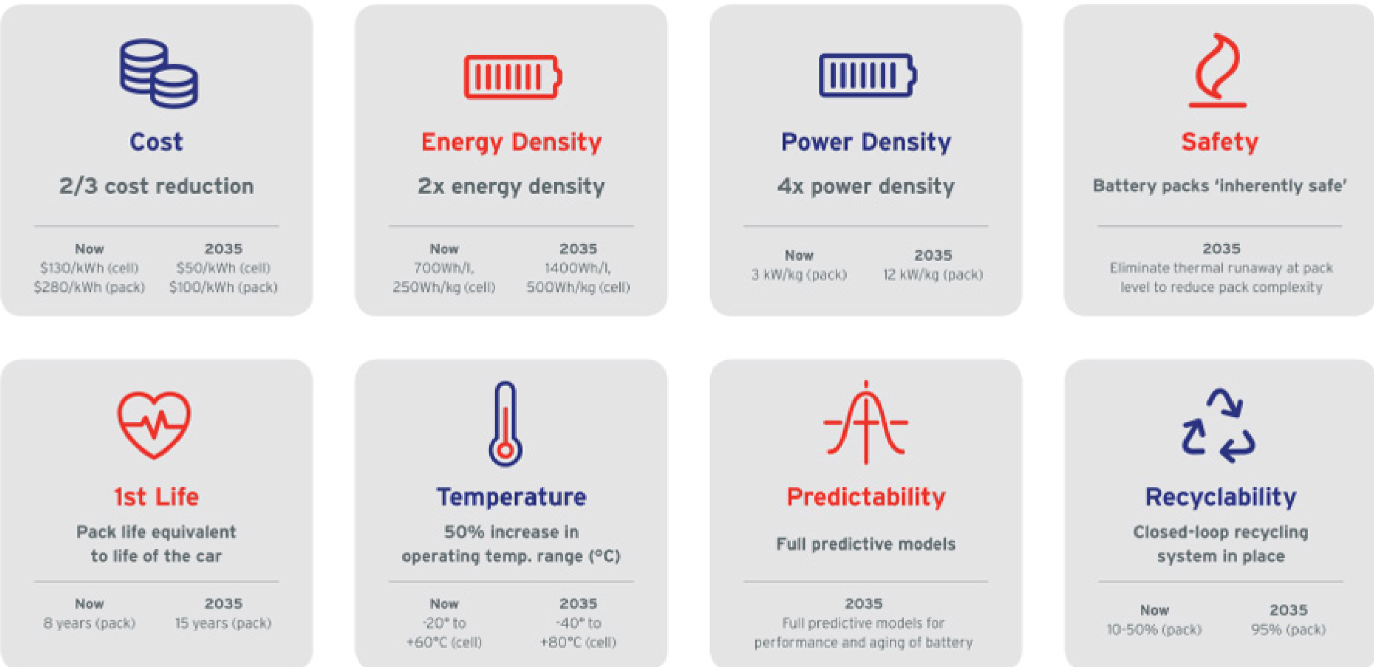


Image credit: Faraday Battery Challenge, 2018.

Translation

Research breakthroughs are challenging to anticipate, the timescales involved between lab-based breakthrough and deployment in a commercial product are often long, and development cycles rarely track product roadmaps. Typically, it takes 10 to 15 years to generate a critical mass of intellectual property (IP) for hard technologies from research to product.

Research is directed toward multiple industrial targets: reducing cost, increasing energy and power density, improving safety, prolonging first life, extending temperature range, enabling predictability of properties, and ensuring recyclability. Current research focusses on automotive as a large sector but has many spill-over benefits, from electric rail to marine and the grid. £75 million of research funding has been spent across the UK since 2018 and a further £25 million is committed for 2021-2022. The ten multi-institutional projects centre around three streams:

- Lithium-ion: optimising existing lithium-ion battery technologies for nearer-term challenges, including recycling and reuse of materials for circular economy.
- Beyond lithium-ion: higher risk, higher reward project that require considerable research including materials discovery, for battery types including solid state and lithium-sulfur.
- Battery characterisation: developing new characterisation techniques to provide world-leading tools to accelerate understanding of battery materials and performance.

The early-stage commercialisation potential for each project is continuously assessed and any interventions needed are identified. This helps tailor commercialisation approaches for each project to prioritise resources, back likely winners and convene consortia around advancements that are investment ready. An example is innovation in solid-state batteries, a next-generation technology for electric vehicles that promises 50% increased energy density, greater range, improved safety and faster charging over current generation lithium-ion batteries. The Institution is working as a consortium across the supply chain to develop foreground IP, enable rapid translation, and attract investment from corporates and other collaborators. A further challenge is in storing energy from multiple sources to be deployed when needed to the grid, with a large piece of integration work required.

Heating and cooling

There is much debate about the 'right' zero carbon heating technology. Professor Malcolm McCulloch, Associate Professor and Group Leader, University of Oxford offered three guiding principles to evaluate in what contexts different solutions could be successful.

Domestic and commercial heating produces ~20% of the UK's emissions, a proportion consistent across high-income countries. However, only 5% of homes use low- carbon heating, generally biofuel. Many low-carbon technologies offer part of the solution but all come with risks: hydrogen supplied directly to the home may cause an explosion, heat pumps only achieve excellent coefficients of performance if managed well and there is public concern about whether smart technologies are 'smart' for the consumer or the digital company. Identifying winning technologies is challenging. Instead, three principles can be applied when investing in heating and cooling:

1. Only heat what you need

- Smart zonal heating: heating individual rooms by detecting people or syncing to booking systems can reduce energy use 30-50% in commercial buildings. Companies include EcoSync.
- Smart hot water: whole-tank temperature sensors give the option to heat only the water that is needed, saving 30-40% of energy use. Companies include Mixergy.
- Other: insulating buildings reduces parasitic heat loss but comes with a high 'hassle factor'; meanwhile very localised heating to heat or cool a chair can substantially widen a person's tolerance to air temperature.

"Many technologies claim to be silver bullets to achieve low-carbon energy. As the world warms, cooling will start climbing up the agenda."

Professor Malcolm McCulloch, University of Oxford.

2. Location – some technologies are better suited to particular locations

- Generation 5 heating network: appropriate for high density housing and buildings that require significant cooling, like supermarkets. This comprises a twin low temperature network with a cold (2-12°C) and a hot (12-20°C) line. Heat pumps adjust temperature for heating and refrigeration, recycling excess heat and cold water back into the system.
- River source heat: rivers offer substantial untapped heat. Per year, 10-20 TWh of heating can be extracted from the River Thames without pushing environmental conditions beyond their normal boundaries, but bringing the risk of environmental fouling.
- Other: ground source heat pumps work for properties with gardens, while radiative cooling to space suits buildings with roof access.

3. Minimise the 'hassle factor' – technology that is easy to use will be more swiftly deployed

- Heating as a service: developed by the Energy Systems Catapult, customers pay a fixed rate for warm rooms while the service provider handles installation, paperwork and system management. This improves customer experience, uptake of low-carbon heating and reduces energy demand.
- Green spaces: the natural environment can manage temperature without active elements for heating and cooling, as implemented in Chicago City Hall.

These principles can guide the understanding of the potential market size. Aggregating all low-carbon energy services will be the final step for convenient heating and cooling.

Nuclear energy = low-carbon energy. Why aren't we seeing more of it? Lost opportunity or new dawn?

Dame Sue Ion DBE FREng FRS, Chair of the Royal Society Science, Industry and Translation Committee, explored how science and engineering has led to major progress in nuclear energy. The talk focused on two UK systems: Small Modular Reactors (SMRs) based on traditional water-cooled technology, and advanced nuclear systems using high-temperature, gas-cooled technology with potential for both electricity and heat production and a possible role in producing green hydrogen.

Nuclear energy has the lowest lifecycle carbon emissions of all current energy technologies alongside wind – solar's emissions are 4 times higher and gas 40 times higher. Countries with the highest proportion of nuclear and hydroelectric power in their energy mix have the lowest carbon intensity, as in Norway and France, yet all of the UK's nuclear fleet except Sizewell B are scheduled to close this decade. Nuclear progress has been halted by the historic high upfront costs of reactor systems: Hinkley point C will cost £23 billion. Most costs are dominated by non-nuclear elements, particularly construction and shielding (figure 4). As nuclear is not eligible for ESG[3], it means that even newer systems are difficult to progress. Government could offer more policy support to enable cheaper borrowing of funds for such projects.

"It does not matter which high-temperature reactor is taken forward. The underpinning science and evidence are the same and we can have confidence that they are investible systems."

"Nuclear can be seen as nuclear business, not just nuclear project, and should be given the same facilities for green finance as wind and solar."

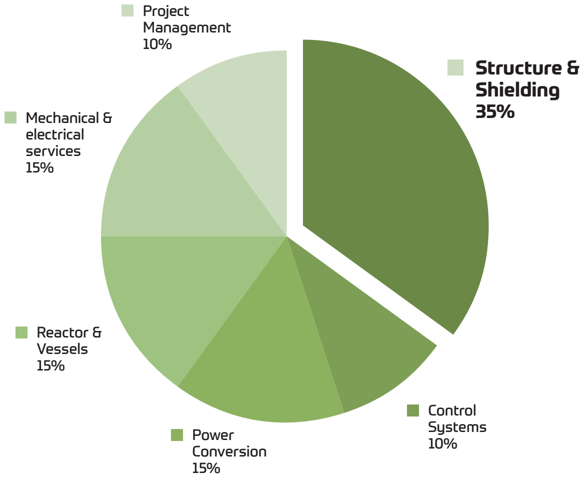
Dame Sue Ion DBE FREng FRS, Chair of the Royal Society Science, Industry and Translation Committee.

3 Environmental, Social and Governance (ESG) criteria are used as standards for a company's operations. Some investors use these for screening.

FIGURE 4

SMR cost breakdown

Large nuclear reactor capital and finance costs.



Small Modular Reactors (SMRs)

SMRs are factory built, then transported to site for assembly, adopting practices that support volume manufacturing and ensure build certainty. Harnessing the latest science and engineering, all-part kits are supported by factory simulation and digital twins. A significant breakthrough is that the sites are fully covered, meaning that building can take place all year round. Rolls-Royce has led the concept of building a holistic nuclear factory rather than just the nuclear reactor. Key component factories are available and ready for modification for SMR production, minimising the skilled labour needed. Meanwhile, predicted costs are lower than Hinkley Point at £35-50 per MWh.

The Nuclear Innovation Programme, backed by the UK Government with research and development at the Nuclear Advanced Manufacturing Centre at Rotherham, has made significant steps to commoditise the nuclear power station. Research has sought to quantify material properties to ensure that the systems are serviceable for the 60-80 year life cycle of a nuclear plant. One pilot achieved a 41% reduction in machining time to efficiently build nuclear components. Meanwhile, use of laser tracking systems during heat exchanger assembly allowed automation of processes to ensure alignment[4], reducing time by 50% and providing validation that was historically missing. Further automation offers an 80% time reduction.

Advanced nuclear systems: nuclear cogeneration

Nuclear cogeneration[5] is where the heat generated by a nuclear power station is used, not only to generate electricity, but to address 'difficult to decarbonise' energy demands. High-temperature nuclear reactors could be used for electrolysis to split hydrogen from water. It has the capacity to produce similar quantities as 'blue' hydrogen (hydrogen made from a fossil fuel) while delivering it like 'green' hydrogen (using renewable electricity, producing no CO_2 at all stages of the process). Higher temperatures could even enable thermochemical processes. The UK is pursuing a high-temperature reactor technology platform as part of its strategy for advanced modular systems. The Urenco Group's U-battery has been under development for some time and reached the point where many of the key major components are at the test phase. High-temperature advanced modular reactors take advantage of the inherent safety of the TRISO[6] fuel they are powered by. The UK's National Nuclear Lab has taken the first steps in developing a fuel production line capable of making TRISO fuel.

Going forward, there is a need for government policy that affords nuclear its role as a legitimate low-carbon energy source and, the same subsidies for green finance as wind and solar energy.

4 Each baffle cage has 5,000 6mm tubes which historically were inserted by hand.

5 royalsociety.org/topics-policy/projects/low-carbon-energy-programme/nuclear-cogeneration/

6 TRi-structural ISOtropic particle fuel.

The digital energy system of the future

Digitalisation is seen as an essential enabler of the energy transformation, from production to distribution and consumption. Nick Winser CBE FREng, Chair, Energy Systems Catapult, explored society's increasing dependency on digital systems and how digitalisation can help enable the future energy system.

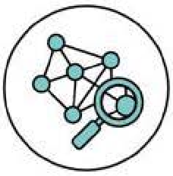
Society is increasingly dependent on digital technologies and the digital sector continues to experience innovation, bringing transformations of the infrastructure, operations, and use of digital systems. Alongside this, the energy sector is entering a period of profound change driven by several factors, including the need to decarbonise, the ageing state of networks and increase in demand. The energy system will need to support more intermittent generation from renewable sources, with architecture that is more distributed and supports two-way power flows.

New digital technologies – from the internet to artificial intelligence – must be brought into the energy sector to integrate markets and technologies and to run a stable, data-driven and efficient system. This is particularly urgent given rising assets for energy generation, storage and demand. If used effectively, digitalisation creates opportunities and enables known risks to be mitigated (figure 5).

> "So much focus is on big energy technologies, but the future energy system will require integration in a multi-vector, complex way. If we don't digitalise, it will impact the stability of the system and security of supply."
>
> Nick Winser CBE FREng, Energy Systems Catapult.

FIGURE 5

Opportunities and risks of digitalisation.



Opportunity:
Transformation and optimisation

- Digitalisation can transform the industry through **new markets and business models**.
- **Optimisation** not consumption.
- **Customer centric products** and services that **mitigate complexity**.
- Enable consumers to be **rewarded**.
- Unlock the value of **storage and flexibility**.
- **Stability and security** through visibility and interactions.
- Enabling more **effective investment** in Net Zero.

Risk:
Vulnerability and system dominance

- **Consumer detriment** from service failure, mis-selling or data misuse.
- Some **consumers could be left behind** and face higher or more uncertain costs.
- **Digital monopolies** skew markets and business models.
- New digital roles and functions may be essential to system operation but fall **outside of existing governance**.
- Unforeseen cumulative actions **risking system stability and security**.
- **Algorithm discrimination**.

Image credit: 2021 Energy Systems Catapult.

In October 2018, the Energy Data Taskforce was established to provide a set of recommendations on how data can assist with unlocking the opportunities provided by a modern, decarbonised and decentralised energy system at the best value to consumers. In June 2019, the taskforce published 'A Strategy for a Modern Digitalised Energy System' presenting five key recommendations that will modernise the UK energy system and drive it towards a net-zero carbon future through an integrated data and digital strategy throughout the sector, including:

- Embedding into policy and regulation
- Cross-government support for innovation
- Increasing skills and data literacy

The new Energy Digitalisation Taskforce will consider the market design, digital architecture and governance of a modern digitalised energy system.

To harness emerging energy technologies, the future energy system will require complex integration at substantial cost. This must be supported by substantial digitalisation which could include smart handheld devices, as in the modern communications system. Understanding and optimising energy use down to within-house scales will help reduce waste. A plethora of technologies will be required to decarbonise future homes, with products and services that some may be unable to afford (figure 6). The new energy system must care for the vulnerable, be affordable and accessible. A bottom-up approach will be critical to ensure fair consumer experience.

FIGURE 6

The plethora of technologies required to decarbonise future homes must be affordable and accessible.

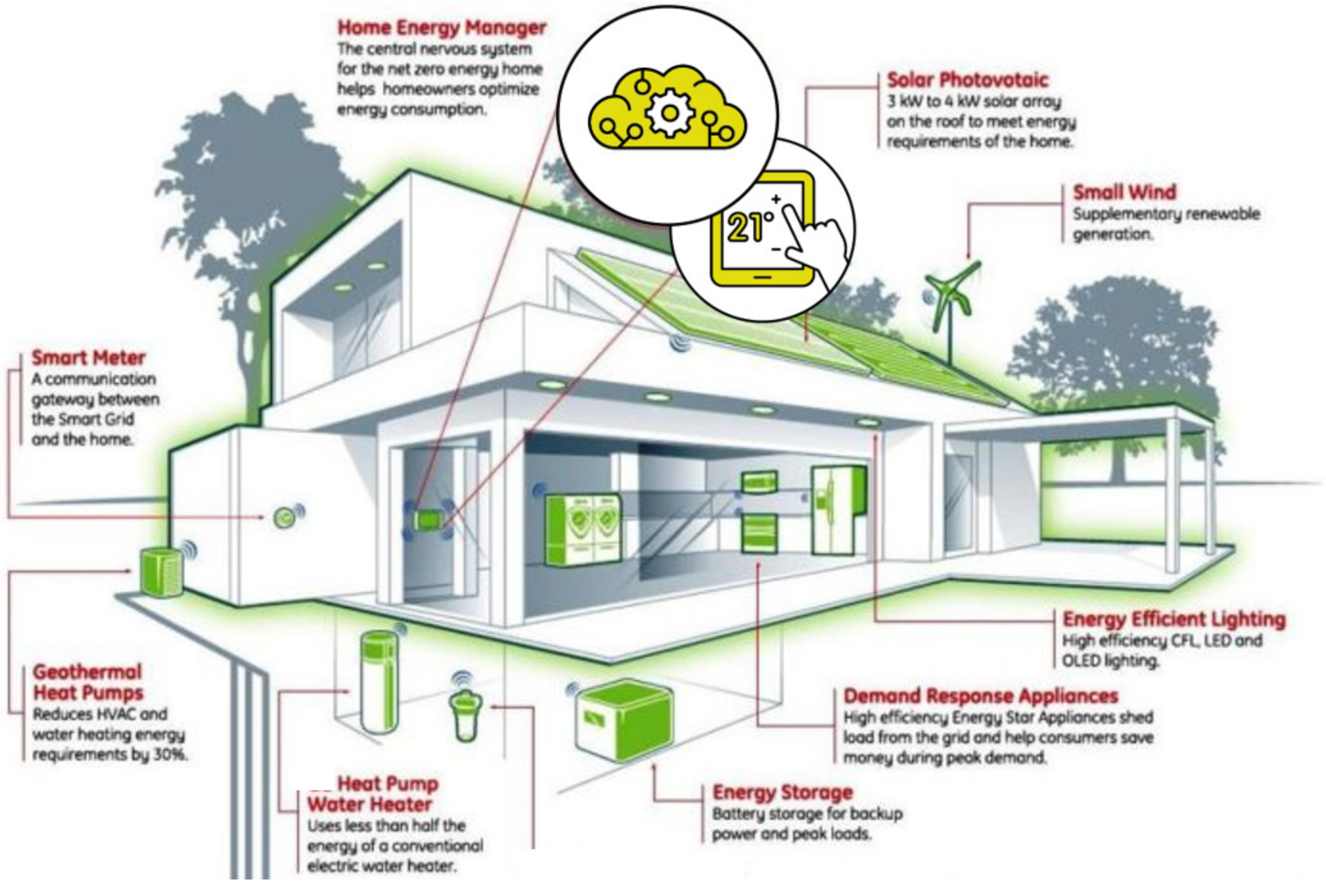


Image credit: 2021 Energy Systems Catapult.

Connecting science and finance: how to catalyse green technology investment and real-economy transition

Chaired by Dr Rhian-Mari Thomas OBE, Chief Executive of the Green Finance Institute, this panel comprised Sam Gyimah, Non-Executive Director, Goldman Sachs and former Science and Innovation Minister; Caroline Haas, Head of Sustainable Finance, NatWest; and Huw van Steenis, Senior Advisor to the CEO, UBS. Speakers discussed mobilising public and private capital at scale, data-based disclosure, and regulation including a new science-based Green Taxonomy for the UK.

Barriers to rapid investment

- Green technologies represent a substantial but complex investment opportunity for capital providers. It will require interaction and collaboration between science, industry, academia, policy and finance.
- An estimated £3.5 trillion per year is needed for a whole-economy transition. There is a need for support from both capital markets (private capital, providing efficient funding) and government (public funds, to support high-risk technologies).
- In financial parlance, innovation is synonymous with taking risk. To satisfy ESG, investors and lenders must quickly become comfortable with taking risk. Substantial ESG finance in the commercial sector needs de-risked conditions in order to invest, especially in emerging and middle-income markets.
- Most institutional and retail money follows particular investment mandates. These could be changed to become greener.
- To implement green finance at scale, there is a desire to shape the mandates of world banks so that investors see themselves as creating new asset classes and taking first loss risk. The European Bank for Reconstruction and Development is an example of a bank with a mandate that helps change infrastructure at speed in developing countries as well as in developed nations.
- The previous 10-20 year timescale for the cost of borrowing to be reduced, as for solar and wind energy, is too long for current needs.

Mobilising private capital

- Despite having strong venture capital funds, the UK lacks a deep-growth market and start-ups are often lost to investors in the US. The top investors for scale-ups are in Canada and the Middle East.
- Climate finance is traditionally a very small part of philanthropic funding but more is emerging, with some even taking risk capital positions too.
- Setting up races between companies could incentivise technology development. Meanwhile, in the USA, 500 businesses are putting a small amount of their revenue to fund carbon capture and storage in a novel way to finance the technology.
- Innovation clusters and accelerators offer substantial promise not only for scaling technologies but for job opportunities. There is argument for accelerators to combine on a national scale, building joined-up capacity across the devolved regions, rather than working in isolated clusters. Collaboration and partnership will drive success in this space.
- Lenders need to be nimbler with capital as with carbon capture and storage in the North Sea. This will require risk capital available within a short timeframe.
- Start-ups should incorporate ESG design from the outset as they will be increasingly asked about it by investors and lenders as they progress. NatWest helps support start-ups financially as well as providing education on how to develop business models, win financing, develop pilots and provide mentoring.

Mobilising public capital

- Before private and philanthropic capital is raised, there is a gap when technologies are pre-revenue to be funded through grant funding or public capital that does not expect a return.
- There is a clear role for public impact funds for good ideas that are pre-revenue. The Green Finance Institute recently supported the Department for Environment, Food and Rural Affairs and the Environment Agency in the development of the Natural Environment Investment Readiness Fund, which is giving initial capital to nature projects so they can develop to the point they can attract private investment.
- Government support in the UK will unlock funds and support growth, including through transparent regulatory processes and fast administrative processes.
- As well as pension funds, the Government must have a role in public funding for risky research and development, such as through the former Green Investment Bank, and instruments such as tax credits that enabled high-risk ideas to develop in the technology sector.
- The British Business Bank's Future Fund, set up during the pandemic, is a Government scheme supporting UK-based innovative companies with Government funds ranging from £125,000 to £1 million. A similar fund could be set up for green technology, tailored to that specific kind of risk, business maturity and cost.
- The US Offices for Special Initiatives have ringfenced money for trial and error, learning by experimentation. Setting up an entrepreneurial 'sandbox' environment in the UK would allow interaction between scientists and financiers to finance ideas, as done for fintech.
- Partnerships in the life sciences between government, universities and private companies give precedents of how public funding of research and development on a large scale has been done well.

"You have to get on board very quickly with innovation and rapid change, and in financial parlance taking on innovation is about taking on risk."

Caroline Haas, NatWest.

"Financing the low-carbon economy is one of the greatest challenges of our age. The quantum of money required is vast and we must be open to the pace of change."

Huw van Steenis, UBS.

"I'm an advocate of setting up entrepreneurial 'sandboxes' to interact with scientists and the City, ringfencing money for trial and error and learning by experimentation."

Dr Rhian-Mari Thomas OBE, Green Finance Institute.

"We need support from regulation, to be nimble with capital, and the spirit of adventure. By using public funding for innovation, the UK taxpayer subsidises an experiment for the rest of the world."

Sam Gyimah, Goldman Sachs.

Policy, regulation and disclosure

- As well as encouraging banks and companies to be greener, there is a need to measure outcomes. This includes work like the Taskforce for Climate-Related Financial Disclosure (TCFD) which is now mandatory for all public companies in the UK and for some companies in New Zealand and Canada. Work is to be done to make TCFD mandatory more broadly, making disclosure compulsory for private as well as public companies.
- As part of disclosure there will be a fundamental shift in how credit is understood, requiring scrutiny not just of the top line but the underlying assets including their geographic distribution.
- Over a thousand different ESG standards can apply to the financial services sector, making it hard to find comparable data. Finance is global and there is a need for one shared standard rather than individual, fractured metrics. The Taskforce for Voluntary Carbon Markets is doing interesting work to develop the right standards.
- Investment in very established markets can be as bureaucratic as innovative markets. There is concern that taxonomies stifle innovation as they are so difficult to meet, even for established companies: the EU Green Taxonomy is already 593 pages long and younger companies will struggle to abide by these rules. A strong taxonomy framework for the UK that avoids greenwashing, is embedded in science, and is flexible enough to move with the frontier of science is essential.
- Data science can help build understanding of the efficacy of green finance, and work must be done using the imperfect data currently available. Supernational companies can help build collated open data sources.
- The UK can take a lead on effective regulation. If developed well, this will naturally unlock capital to catapult new technologies.

Acknowledgements

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