

The Solar Commission

A bright future: opportunities for UK innovation in solar energy

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Prof. Alison Walker	University of Bath
Chris Coonick	BRE National Solar Centre / Innovate UK
Prof. Neil Greenham	Cambridge University
Katherine Vinnicombe	Foresight Group
Prof. Mike Walls	Loughborough University
Dr. Biljana Stojkowska	National Grid ESO
Dr. Robyn Lucas	Open Energi
Aleksandra Klassen	Solar Trade Association
Prof. Neil Robertson	University of Edinburgh
Prof. Phillip Dale	University of Luxembourg
Imran Agha	Siemens
Dr. Paul Warren	NSG
Dr. KT Tan	Viridian Solar
Sonya Bedford MBE	Stephens Scown
Dr. Louise Jones	Knowledge Transfer Network (Innovate UK)
Dr. Richard Dobson and Dr. Adam Thirkill	Energy Systems Catapult
Dr. William Burns and David Stoker	UKERC

Foreword

"If we could harness one 5000th part of the energy that the sun sprays on the Earth every 24 hours we could provide all the energy requirements of the entire human race."

Sir David Attenborough, BBC Newsnight 30 November 2015

"We say that all those solutions [to the climate crisis] needed are not known to anyone and therefore we must unite behind the science and find them together along the way."

Greta Thunberg address to the UK Houses of Parliament 23 April 2019



I undertake research into solar power. The most inspiring part of my role is working with young scientists and engineers who are motivated by the huge potential of solar power to provide solutions to the climate crisis. To do justice to their commitment, policy makers, energy providers and the public need to understand the scale of innovation in solar power and the potential to contribute to the UK's ground breaking net zero emissions target and the Paris commitment to limit global temperature rises to 1.5°C.

Dr William Burns from the UK Energy Research Centre and I worked with Regen to set up the Solar Commission. Its aim is to show how the UK's extensive innovation and industrial capabilities can be harnessed to enable the UK to play a leadership role in what will undoubtedly be one of the key energy generation technologies of the coming decades.

This report brings together insights from academic research and leading businesses to examine innovation in cell technology, applications, finance, systems integration and digitalisation and storage. Chairing the Commission has been an eye opener on the depth of engagement in solar power from all sectors of the UK economy and the potential to build on our strengths. I trust that you too, will share our enthusiasm.

Prof. Alison Walker, University of Bath

Introduction

Solar PV is at the heart of a revolution in how we generate and supply energy

The global energy system is undergoing a revolution. Centralised fossil fuel power plants are being replaced by decentralised renewable generation and smart, flexible operation of the system. This shift is being driven by rapid technological advances, business innovation, and the imperative to decarbonise our power supply to address the climate crisis.

The transformation of how we power our society is set to accelerate in the 2020s. Solar photovoltaics (PV) will be one of the key technologies driving this transformation. Solar PV has seen remarkable price reductions and there is now over 480 GW of installed solar PV capacity¹ across the globe. The International Energy Agency predict that global installed capacity will reach 1 TW by 2023² and a recent report by the independent Energy Watch Group predicted that solar could provide a remarkable 70% of the world's total energy by 2050³.

The UK is playing a key role in the energy revolution

This transformation of our energy system is both one of the great challenges facing humanity and one of the greatest opportunities for innovation and investment the world has seen. Playing a leading role in this transformation is key to the UK meeting its ambitious goal to achieve net zero emissions and to the success of our industrial strategy.

The UK has a strong position to build from. UK researchers working with businesses have played a key role in the innovation driving the remarkable cost reductions in renewable energy. UK investors are at the forefront in mobilising the capital needed to bring forward smart, zero carbon technologies.

Whilst the UK role in offshore wind is well known, the importance of the UK's role in the development of solar PV is less well understood. The Committee on Climate Change state that the UK has contributed to driving costs of solar down globally, through open markets and well-established financial institutions⁴. In 2018, solar generated 13 TWh, or nearly 4% of total UK electricity - a more than six-fold increase over just five years⁵. In 2019, solar PV is poised to surpass coal as a source of power in the UK⁶.

Solar PV is entering a new phase of innovation with significant opportunities for the UK

Far from being a mature technology, however, solar PV is on the verge of a series of technological and business innovations with the potential to cut costs, to lead to rapid deployment and to enable a broader range of applications.

UK researchers and businesses are at the forefront of developing innovative solar PV technologies, materials and applications including:

- New solar cell technologies that reduce costs per unit of energy generation and enable new applications.
- Development of storage systems that enable solar power to be stored off-peak and released at times of peak demand or system stress.
- Digital technologies that use algorithms and big data to maximise the value of solar PV to energy users and enable a smart more, flexible energy system.

- Building integrated technologies that enable solar to become ubiquitous in the built environment as part of the development of 'buildings as power stations'.
- New financing models that enable deployment of capital at the scale needed to finance a transformation of the energy system.

Despite the potential of solar PV and the UK strengths, the technology is not currently identified as an industrial priority by the UK government and its innovation agencies. The UK's Industrial Strategy makes only one mention of a technology that could be the key global energy source of the future.

The Solar Commission

The Solar Commission is a unique partnership of leading academics, system operators and industry, supported by UKERC and managed by Regen. The aim of the Commission is to examine areas where the UK could use its scientific and technical capabilities to play a leading role in the innovation and industrial strategy opportunities being created by the rapid, global emergence of solar PV as a major form of power generation.

This report presents the conclusions of the Commission, setting out:

- key areas of innovation in the solar PV value chain where the UK has competitive advantage.
- the UK's capabilities in these innovation areas.
- recommendations for UK to capitalise on the global growth opportunity.

A key finding of the Commission is that the UK has strong capabilities in many of the disruptive innovations transforming the solar PV market. The UK's strengths in areas like innovative solar cell technologies, storage, information and communication technologies and finance have sometimes been obscured by a focus on China's domination of the manufacture of current generation crystalline solar PV panels.

Despite the lack of explicit focus on solar PV, the UK's Industrial Strategy is already going some way to aligning the policy and innovation framework to leverage UK capabilities and attract private investment in key areas of the value chain including green finance, digitisation and storage. In these areas the Commission is recommending building on the UK's competitive advantage. Key recommendations include a revenue stabilisation mechanism to unlock investment in solar PV and prioritising the work of the Energy Data Taskforce to open energy data to the market.

In other areas such as cell technology and building-integrated solar PV the UK has considerable capabilities, that are not sufficiently recognised or supported. In these areas the Commission is recommending much greater focus, particularly in government funding of research and innovation, to attract private investment.

The central conclusion of the Commission is that the key areas of innovation in solar PV are closely interlinked and that a systems approach is needed to maximise the UK's potential in the sector.

The Commission's overarching recommendation, therefore, is that government and industry should work together on a sector initiative that:

- Recognises the role of solar PV as part of a smart, decentralised energy system.
- Invests in the UK's capabilities to play a key role in solar PV innovation across the value chain.
- Secures business investment in solar PV in the UK.
- Coordinates investment in innovation in solar PV with that in complementary technologies such as storage and digital technologies to maximise the value of public and private innovation spending.

¹ https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/Mar/IRENA_RE_Capacity_Statistics_2019.pdf

² <https://www.iea.org/renewables2018/>

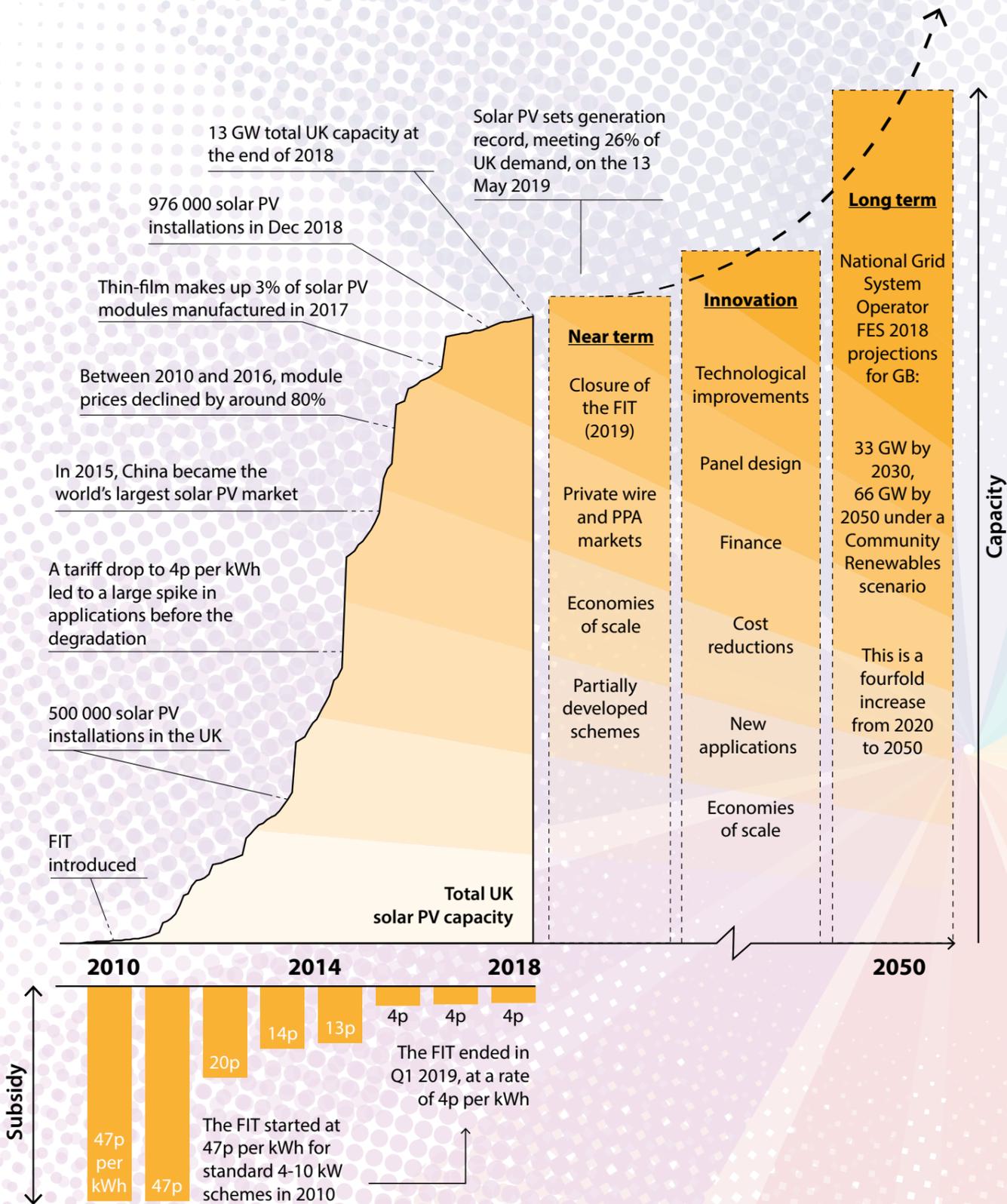
³ <http://energywatchgroup.org/new-study-global-energy-system-based-100-renewable-energy>

⁴ <https://www.theccc.org.uk/wp-content/uploads/2019/05/Net-Zero-The-UKs-contribution-to-stopping-global-warming.pdf>

⁵ <https://www.carbonbrief.org/analysis-uk-electricity-generation-2018-falls-to-lowest-since-1994>

⁶ <https://www.mygridgb.co.uk/coal-tracker/>

Story of solar power in the UK



Innovation areas



Cell technology

One of the most exciting areas of technological innovation in solar energy is the development of new solar cell technologies that have the potential to improve efficiencies. More efficient cells can reduce the total lifetime cost of solar PV projects and enable the technology to be used in a wider range of applications. Even relatively small cost reductions can be transformational in enabling solar PV projects to become viable in UK and international markets.

Crystalline silicon cells have had a dominant market share for many years, however, advances in thin-film cells, organic compounds and hybrid cells (combining a new material and a traditional silicon cell) are changing the landscape.

Thin-film incorporates four main types of cell which have the potential to increase solar panel efficiencies above the theoretical limits of traditional crystalline silicon cells. Global Market Insights predict that the global thin-film market could be worth over \$30 billion by 2024⁷.

“ The UK is innovating in new technologies that can be added to silicon solar cells, increasing their efficiency above the current limits and thus reducing the cost of solar electricity. We can convert more light into electricity if we stack two solar cells on top of one another, where each separate cell takes a certain part of the colour spectrum. By absorbing the colours separately, we can use the light energy more efficiently and produce more electrical energy.

Professor Neil Greenham, University of Cambridge

What are the UK's capabilities?

The UK has world-leading capability in research and technology development in some of the fundamental science that underpins the development of new cell technologies, enabling UK researchers to lead the way in the development of materials for thin-film and other next-generation PV technologies.

The SuperSolar Hub is a consortium of universities set up to focus solar research and development capabilities, it provides training and skill development for researchers, an accreditation cell efficiency facility and a multidisciplinary network of researchers. Led by Loughborough University's Centre for Renewable Energy Systems Technology (CREST), the Hub comprises the Universities of Bath, Cambridge, Imperial College, Liverpool, Oxford, Sheffield and Southampton and incorporates the Solar Fuels Network.

The UK has built on this academic research expertise to develop industrial capability for the next generation of solar PV. The UK is home to both NSG, a world leader in the production of glass used in thin-film photovoltaics, concentrated solar power applications with interests in crystalline silicon photovoltaics, and Oxford PV, a spin-out from the University of Oxford, leading the development of perovskite technology.

“ The partners in the SuperSolar Hub are a complementary mix of researchers within the PV field in the UK. The members have internationally recognised expertise in the fundamental understanding of materials and architectures including thin-film technologies, silicon as well as the new perovskite solar cells. The Hub also offers expertise helpful to solar asset managers such as measuring and predicting solar resource, identifying degradation and developing improved strategies for anti-reflection and anti-soiling. With its deep expertise, the Hub was able to recognize the early potential of perovskites and back the new science with its flexible funding. The UK now enjoys a leadership position with strong IP in this breakthrough technology. Continuity is needed to fully exploit the UK's research position in a market with huge international potential.

Professor Mike Walls, Loughborough University

“ There is scope for development of technologies that allow more light into the solar cell – by modifying the glass and/or coatings above the solar cell. Opportunities here include the relatively straightforward use of advanced anti-reflective coatings or physically structured surfaces, through to more advanced concepts like photon-shifting or photon-multiplication. Looking further ahead, there is potentially a massive opportunity in PV integrated into other structures. In all cases we have world-leading R&D here in the UK: expertise in the physics of transparent conducting materials, C-based electronics, first-principles atomistic modelling for prediction of new materials, AI-based ways of speeding up material development and large-scale development of so-called 'active buildings'. This R&D effort needs to be fully supported to maintain critical mass in these and other, allied, areas.

Paul Warren, principal technologist, NSG

Spotlight on NSG

NSG is one of the largest glass manufacturing companies in the world. Employing nearly 1700 people in the UK, the company has developed various products for solar power applications – including coated glass for thin-film PV and is also strongly involved in Building Integrated Photovoltaics (BIPV). The first generation of products has been produced with Solaria – using silicon strings embedded in glass. More recently a joint development agreement with Ubiquitous Energy has been announced - targeting the development, manufacture and integration of their ClearView Power™ technology into architectural window glass.

This is a thin-film organic PV technology – and is thus truly transparent: one then has the potential to produce solar electricity for buildings – whilst also reducing solar gain into the building.



Photo credit: NSG

⁷ <https://solarmagazine.com/thin-film-solar-cells-market-to-grow-at-16-cagr-from-2016-to-2024/>

Spotlight on Oxford PV

Oxford PV was established in 2010 to commercialise the perovskite solar cell material from Professor Snaith's lab at the University of Oxford. Today the company is the technology leader with the largest team globally, exclusively focused on developing and commercialising a perovskite-based solar technology. Oxford PV employs over 90 people and has a R&D site in Oxford, UK and an industrial pilot line near Berlin, Germany. Oxford PV's perovskite-on-silicon solar cell technology has set a certified world record efficiency, surpassing the record for silicon. In 2019, it announced plans to move into volume manufacturing.

In their recent funding round, Oxford PV raised over £60 million from shareholders and are moving into commercial production.



Photo credit: Oxford PV



Where should the UK focus?

The UK has invested in key areas of research needed to develop solar cells. To capitalise on the opportunities in solar cell innovation, the Commission recommends that the UK government and its innovation agencies focus on developing the UK's capabilities in next-generation solar technology. This includes:

- Provide sustained funding for solar research and development in the UK, spanning fundamental research in PV materials and processes, focussed research on novel PV devices, and industry-led development for new applications.
- Support collaborative PV research within the UK to maximise the international competitiveness of the strong, but distributed and diverse, research base in thin-film PV.
- Renew efforts to develop the next generation of PV researchers, through focussed Ph.D. funding.
- Make innovation in solar panel design a key feature of a sector initiative with the solar sector, including commitment by industry to invest in UK-based R&D in next-generation solar technology.
- Review how government can create market pull for next-generation solar through its purchasing power – for example, by testing its application in trial projects on the public estate.



Application

The major applications of solar PV to date have been in large-scale, ground-mounted 'solar farms', and roof-mounted systems. However, the innovations in cell technologies, development of storage technology and new business models are opening up a wide range of new applications from floating solar to solar roads and solar car parks with electric vehicle charging. These developments also open up multiple opportunities to use solar PV in a more aesthetically pleasing manner.

The Commission concluded the key opportunity for the UK in developing new applications for solar PV is building-integrated photovoltaics (BIPV). The term BIPV includes building facades, solar tiles and other architectural items that can also generate power. Bloomberg's latest projection is that the global BIPV market is likely to expand from USD 6.7 billion to USD 32.2 billion by 2024, a compound annual growth rate of 23.4%⁸.

Turning buildings into power stations could transform the energy use of cities and cut bills for energy users, including those in fuel poverty.

Thin-film solar cells require less material and less energy to make than traditional silicon solar cells, meaning they have a lower environmental footprint when making them. The active materials within thin-film solar cells are around fifty times thinner than silicon cells, but convert similar amounts of light energy to electrical energy. The thinness enables them to be deposited on flexible substrates. The lightweight nature, and the ability to be curved means that they can be placed on, for example, warehouse roofs without worrying about the strength of the roof, and can easily follow contours.

Dr. Phillip Dale, University of Luxembourg



What are the UK's capabilities?

The 2016 Solar Technology Innovation Needs Assessment identified the UK's extensive strengths in BIPV as part of an overall approach to sustainability in the built environment⁹.

The UK is investing in developing buildings that use dramatically less energy through the Transforming Construction initiative which will invest £170 million of public money over a period of four years as part of the Industrial Strategy Challenge Fund.

Examples of UK organisations playing a leading international role in the sustainability of buildings include BRE National Solar Centre which provides expertise to support the use of PV in the built environment. Companies such as the NSG Group, Viridian, Polysolar and Romag all have UK-based capabilities in manufacturing, research and development of panels and cells for BIPV projects.

⁸ <https://www.bloomberg.com/press-releases/2019-04-25/global-building-integrated-photovoltaics-bipv-market-to-witness-a-cagr-of-23-4-during-2018-2024>

⁹ https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/593465/Solar_PV_Thermal_Technology_Summary_Report_March2016.pdf



BIPV provides an opportunity to integrate renewable energy generation seamlessly into the built environment, delivering multiple functions from a single building material (i.e. weather protection, sound proofing, thermal insulation/control, structural support, modulation of daylight and electrical generation). Historically BIPV technologies were specified for exemplar low carbon new construction projects and special architectural or historical building refurbishment projects, however with the dawn of the digital construction age and technological/manufacturing advances, BIPV is becoming more accessible and cost effective.

Chris Coonick, BRE National Solar Centre and Innovate UK

Spotlight on The Active Building Centre

The Active Building Centre (ABC) is one of the centres of excellence funded by the Transforming Construction programme. The ABC will help to transform the UK construction and energy sectors, through the deployment of Active Buildings. An Active Building supports the energy network by intelligently integrating renewable energy technologies for heat, power and transport. The centre will look at energy generation, storage and release technologies and ways to commercialise and increase adoption of this approach. The ABC seeks to revolutionise the way the UK designs, constructs and operates buildings by realising the potential for the integration of innovative renewable and storage technologies with state-of-the-art digital design. Building performance will be monitored through standardised data collection. Active Buildings have the potential to substantially reduce both the operational costs of buildings and their demand on the UK energy infrastructure.



Photo credit: ABC



40% of world energy use is associated with buildings and current glazing systems give rise to 60% of energy losses from a building, making this an essential challenge to address. Photovoltaic glazing has the potential to combine energy generation with good aesthetics, and thermal insulation, using for example low-cost technology such as amorphous silicon solar cells.

Professor Neil Robertson, University of Edinburgh

Spotlight on BIPV in retrofit housing

Energiesprong UK is working with Viridian Solar, based in Cambridge, to provide an innovative approach to whole-house retrofit demonstrating the role of BIPV in retrofit housing and new builds. The Energiesprong approach is to work with social landlords, such as the demonstration project in Nottingham which uses Viridian Solar's Clearline Fusion technology.



Rooftop BIPV is beginning to gain traction in the new build market – there are many areas for UK professions to innovate in this sector, for example, structural strength, fire safety, weathertightness, and durability issues. Once these areas have been tackled properly, then the solutions are likely to be applicable for the overseas market. We have a great potential to add value to these areas and enhance the export market.

Dr. KT Tan, chief technical officer, Viridian Solar



Where should the UK focus?

Developing UK expertise in BIPV will require measures both to increase market pull, and to ensure the UK stays at the cutting edge of innovation and expertise in sustainable buildings. Significant investment is already going into this sector, including through the Transforming Construction initiative. The Commission recommends this is built on by:

- Industry and the UK government making BIPV a key feature of a sector initiative with the solar sector, including a commitment by leading industry players to increasing BIPV R&D in the UK.
- A BIPV and construction sector taskforce should be set up to address how solar and construction standards can be better integrated.
- The government driving zero-carbon new homes through building regulations, and promoting solar PV as an intrinsic element of sustainability in the Modern Methods of Construction (MMC) approach.
- The government providing support for large-scale market development exercises in net-zero energy retrofit for housing, starting in the social housing sector.
- The government using its purchasing power to drive sustainability in offices and commercial buildings, requiring high standards in all buildings it owns or rents.
- Local authorities should use their powers to set higher standards than Part L of the Building Regulations. This can include improving the energy efficiency of buildings and specifying targets for renewables.

Finance

The governors of the UK and French central banks recently wrote an open letter to the finance sector setting out that delivering the Paris climate change targets requires “a massive reallocation of capital”¹⁰.

According to the Global Commission on the Economy and Climate Change, \$93 trillion of green infrastructure investment will be needed between 2015 and 2030 to meet global climate change commitments¹¹. The Committee on Climate Change (CCC) has estimated the total investment needed to meet the UK’s fifth carbon budget at approximately £22 billion per year (1% of GDP)¹².

Rising to the challenge of shifting investment from fossil fuels and high carbon investments into renewable energy and low carbon technologies represents a major challenge to the financial sector as well as a huge opportunity. According to Bloomberg NEF, in 2018 \$139.7 billion was invested globally in solar. By 2050, this is expected to increase by a further \$4.2 trillion dollars.

What are the UK’s capabilities?

Given the strength of the UK finance sector, green finance is an obvious area for the UK to focus. In September 2017, the government established an independent taskforce to accelerate growth of green finance and the UK’s low carbon economy. The Taskforce report concluded that “London is already a world-leading hub for green finance – backed by deep and liquid capital markets and a strong reputation for innovation”¹³. The Taskforce also, however, concluded the shift of capital is not fast enough.

The Green Finance Initiative records that green bonds listed on the London Stock Exchange have raised in excess of \$25.3 billion in seven currencies and that investment in the UK’s clean energy sector has surpassed £100 billion since 2004. This represents 12.6% of all new investment in clean energy in the EMEA region¹⁴. The UK also has a developing social capital sector, for example Community Owned Renewable Energy LLP is a £40m investment programme targeting operational solar farms in England.

Further innovation will be required to deploy finance into low carbon energy at the scale required to meet UK and global climate targets. A developing area of innovation is in corporate power purchase agreements where power from renewable energy projects is sold directly to large energy users, providing long-term revenues for investors. This market is, however, shallow and will not drive the level of investment in renewable power generation needed for the UK to meet its net-zero emissions target. An electricity market revenue stabilisation mechanism will be required to facilitate the scale of private investment that is needed.

Local or green power purchase agreements have always been popular with community energy companies, but they are now becoming more mainstream. Businesses or local authorities seeking to meet their targets or act on climate emergency declarations can “adopt” renewable energy generation by entering into a green power purchase agreement. The generator obtains an income for the site and the end user has guaranteed renewable energy. Innovation in power purchase agreements comes from the pricing methods, length of term and variable options for generators to engage with suppliers.

Sonya Bedford, partner and head of renewable energy, Stephens Scown

¹⁰ <https://www.bankofengland.co.uk/news/2019/april/open-letter-on-climate-related-financial-risks>

¹¹ <http://greenfinanceinitiative.org/new-ceo-green-finance-institute-appointed/>

¹² <https://www.theccc.org.uk/wp-content/uploads/2017/03/The-infrastructure-needs-of-a-low-carbon-economy-Committee-on-Climate-Change-March-2017.pdf>

¹³ https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/703816/green-finance-taskforce-accelerating-green-finance-report.pdf

¹⁴ <http://greenfinanceinitiative.org/facts-figures/>

Spotlight on Foresight

Foresight Group is a leading independent infrastructure and private equity investment manager which has been managing investment funds on behalf of institutions and retail clients for more than 30 years. They have over £2 billion of energy infrastructure assets under management and currently manage more than 140 renewable energy assets worldwide, including more than 1.1 GW of solar (100 projects) .



Foresight is headquartered in London with regional offices in Manchester, Nottingham, Milton Keynes, Leicester and Guernsey and international offices in Sydney, Rome, Madrid and Seoul.

Foresight used its experience of structuring complex deals to close a corporate 10-year fixed price power purchase agreement in Spain for two projects, due to be operational later in 2019, built without subsidies.

We are excited to be exporting our finance and engineering capability worldwide including Australia and Spain where our first subsidy free solar projects have recently entered operations.

Katherine Vinnicombe, senior investment manager, Foresight Group

Where should the UK focus?

The government’s Industrial Strategy sets an intention to make the UK the global standard-setter for finance that supports clean growth. The UK took a step back with the privatisation of the Green Investment Bank, but is implementing actions including working with the British Standards Institution and the City of London’s Green Finance Initiative to develop green financial management standards¹⁵.

To develop the UK’s capabilities in solar finance, the Commission recommends:

- Government provides net-zero cost revenue stabilisation methods to enable further investment into solar in the UK. This could be in the form of a floor price or debt guarantee.
- Department for International Trade focus on exporting of green finance skills from the UK to overseas markets.
- The government and industry implement the recommendations of the Green Finance Taskforce paper “accelerating green finance”¹⁶. In particular, establishing early stage accelerators and venture capital funding to build on the innovation supported by Innovate UK.

Since the Green Finance Taskforce report in 2018, several progressive market players have pushed forward proof of concept pilots. In July 2019, the Government published their ‘Green Finance Strategy’. This includes a £5 million fund to help the financial sector develop green mortgages, as well as other green finance products, which are aimed at encouraging householders to upgrade the energy efficiency of their homes.

Aleksandra Klassen, business development manager, Solar Trade Association

¹⁵ https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/664563/industrial-strategy-white-paper-web-ready-version.pdf

¹⁶ <http://greenfinanceinitiative.org/wp-content/uploads/2018/04/Report-of-the-Green-Finance-Taskforce-1.pdf>



Systems integration and digitalisation

The transformational effect digital technologies have had on many sectors of our economy are now being felt in the energy sector. New methods of data communication, analysis, visualisation and smart infrastructure technology provide the tools to intelligently manage supply and demand of energy. The International Energy Association found increased digitalisation can help save 5% of annual power generation costs¹⁷.

The emergence of digital technology is fundamentally altering business models in the energy sector, enabling more flexible and decentralised models to outcompete existing centralised generation and supply. New companies are emerging using data science, artificial intelligence and distributed ledger technologies to deliver better value to customers.

More flexible technology is also key to efficient integration of decentralised renewable energy generation into a secure grid, maximising the value of solar PV. The 2016 National Infrastructure Commission's Smart Power report concluded that smart power (incorporating flexibility, storage and interconnection) could save consumers up to £8 billion a year by 2030¹⁸.

“ The huge increase in solar sites, and the connections to the network they require, now represent a huge opportunity for digitalisation. By co-locating storage, PV sites gain the ability to make the very best use of the solar energy produced.

Using advanced machine learning and artificial intelligence techniques to enhance short and long-term forecasting of consumption, generation and price, as well as real time asset characteristics via secure, fast data connections, automated optimisation and dispatch technology can produce a significant uplift compared to a standard solar power purchase agreement.

Dr. Robyn Lucas, head of data science, Open Energi



What are the UK's capabilities?

The UK has established itself as a global leader in the still emerging smart energy technology sector, based on its leading position in digital technology, public and private investment in smart energy innovation and a supportive policy environment. The UK's technology sector is ranked the third most innovative in the world with London seen as a major hub for data science, fintech and digital technologies¹⁹.

A combination of regulatory support, innovation funding and new revenue streams has created opportunities for UK-based start-up smart technology companies, working to maximise the value of distributed energy assets from domestic to utility scale. There is a now highly competitive market of aggregators and platform providers. This remains, however, a challenging market with companies working to find viable business models and grappling with frequent changes to how flexibility is valued on the energy system.

There are also opportunities for more established power electronics companies in sectors of the market, such as the development and design of inverters, which can be developed to provide services such as reactive power to system operators and networks. This is an area of the market where significant investments will be made in the coming years and there are opportunities for the UK to use its skills base and open markets to position itself to attract investment.

¹⁷ <https://www.iea.org/digital/>

¹⁸ <https://www.nic.org.uk/wp-content/uploads/Smart-Power.pdf>

¹⁹ KPMG's 2019 Technology Innovation Hubs report

Spotlight on Optimisation through digitalisation

At a distribution centre near Birmingham, a 500kW, 1MWh Tesla battery, funded by Guinness Asset Management, sits next to a 3.811 MWp rooftop solar array.

By co-locating storage at an industrial site with PV generation and using cloud based data-driven optimisation technologies, significant savings can be made. At various points through the day, Open Energi combine close to real time forecasts of the available solar resource, site demand, and the price of electricity to generate an optimal schedule for the battery to follow. Local adjustments deal with solar intermittency, and the system also provides ancillary services to the grid such as Firm Frequency Response²⁰. Over winter 2018/2019, these actions saved the site more than 20% of its electricity bill.



Photo credit: Open Energi

Spotlight on FLATLINE

The FLATLINE project, funded by BEIS and led by Sero Energy, aims to provide typical domestic energy consumers with set-price heat and power fuel bills through an innovative integration and management structure between the collaborators' systems.

Stable monthly bills will be possible by using a combination of domestic DSR and demand shifting (for both heat and electricity) across networked districts of homes, operating to control domestic appliances, heating, photovoltaic generation and battery storage in combination. In aggregate across the homes, the energy load will be managed between generation, supply and demand times as well as energy forms, with the goal of achieving a flat line energy demand placed on the Distribution Network Operator and better value to the consumer.

FLATLINE's phase 1 feasibility study concluded that there is a strong, viable and well-evidenced case to suggest that the FLATLINE project can deliver meaningful Domestic Demand Side Response services to the National Grid, whilst achieving very significant fuel bill reductions to residents (up to 64%), in an economically sustainable business model.

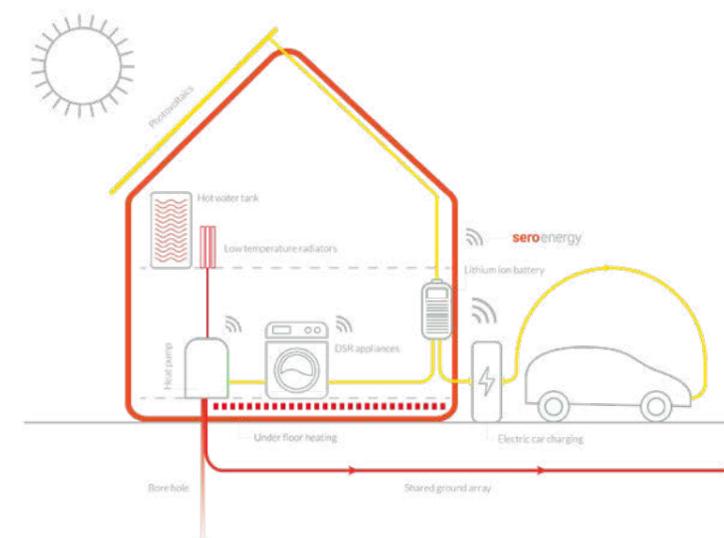


Photo credit: FLATLINE

²⁰ Firm Frequency Response is a paid for service provided to reduce demand, or increase generation, to help balance the grid and avoid power outage

Spotlight on Power Potential

Power Potential is the UK's first reactive smart grid project and is a joint National Grid and UK Power Networks innovation trial. The project, could save consumers over £400 million by 2050 and generate up to an additional 4 GW of capacity in the south east, is investigating ways of providing flexibility through the establishment of a new reactive power market for energy companies to generate additional capacity for distributed energy resources, including solar PV through the use of their inverters. It provides a framework to allow distributed energy to provide electricity onto the network when and where there is demand, and to be remunerated for this service.

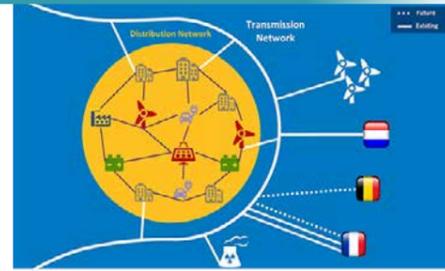


Photo credit: Power Potential project

Power electronics is one of the company's core technologies at Siemens. Power electronics holds the potential to transform worldwide markets through automation, digitalisation and the Internet of Things. The commercial and residential PV inverter market is set to grow up to €6 billion by 2022 as the uptake of renewable energy ramps up worldwide. Working with our global functions, the UK, with its rapidly growing capabilities in design and manufacturing of cutting edge power semiconductors can play a key role in developing novel PV inverter solutions for this growing market in turn, securing and creating additional R&D and manufacturing jobs in the UK.

Imran Agha, head of product innovation – research and development, Siemens

Opportunities for revenue from system services, particularly reactive power, are huge and the Power Potential project trials (which will begin in summer 2019) are excellent opportunities for solar power generators to understand how the future reactive market could work and where further revenue opportunities will be.

Dr. Biljana Stojkovska, power potential project lead, National Grid ESO



Where should the UK focus?

BEIS and Ofgem's Smart Systems and Flexibility plan has set out a supportive environment for smart energy technology. Measures to address regulatory barriers and significant innovation funding are being put in place alongside the development of markets where distributed energy resources can sell flexibility services to the energy system. To build from this strong base, the Commission is recommending:

- Accept and implement the recommendations from the Energy Data Taskforce, in particular, the focus on the need for standardised, open and accessible data.
- Ensure ESO and DSO markets for flexibility are fully open to small decentralised energy resources.
- Enable peer to peer energy trading and customers to select multiple suppliers through Ofgem's review of the 'Supplier Hub' model.
- Ensure Ofgem's reform of how we pay for the electricity system provides clear signals to support the value of flexibility to the network and to decarbonisation.
- Develop (following the end of the FIT) a register of all distributed energy resources.
- Focus Department for International Trade resources on supporting the global development of the UK's smart energy sector and inward investment in power electronics.
- Facilitate technology transfer from more advanced fintech and digital sectors into the energy industry.



Electricity Storage

Electricity storage technologies have a vital role to play in a smart decentralised energy system, providing system stability, security of supply and a level of flexibility that is central to enabling decarbonisation of the system. The Commission has, therefore, looked at the role of electricity storage as a key technology working alongside solar PV and other forms of generation, to decarbonise power and minimise costs.

There are a wide range of electricity storage technologies suitable for different applications. The development of electric cars has seen extensive investment in lithium battery technology dominating the market, leading to rapid price drops. In March 2019, Bloomberg New Energy Finance reported the levelised cost of energy of these batteries had fallen by 35% since the first half of 2018²¹. There is also investment in longer duration storage.

The latest report from Bloomberg New Energy Finance suggests that the global energy storage market is one of the most exciting areas of the market and could grow to 942 GW installed power capacity, storing 2,857 GWh of power, attracting USD 620 billion worth of investment by 2040²².



What are the UK's capabilities?

The UK government has identified electricity storage within its Industrial Strategy Challenge Fund programme, "Prospering from the energy revolution", and has committed £246 million through the Faraday Challenge for the development of batteries (storage and electric vehicles) to support the commercialisation of novel storage and battery technology "which can provide the right infrastructure for our growing renewables industry"²³.

This commitment recognised that the UK has a tradition and strong capabilities in electricity storage. The Electricity Storage Network was established over a decade ago in 2008 and has provided policy support and direction, including developing the definition of storage adopted by BEIS and Ofgem.

The ESO and DSOs are focused on creating open markets at transmission and distribution level for flexibility services that can provide value to the electricity system through energy balancing, frequency response and constraint management. Storage providers are working with aggregators and smart digital platforms to maximise the value of their assets in these markets. Raising investment for new storage assets remains very challenging in this emerging market. However, Regen's research show that there are now over 450 MW of battery storage capacity installed in Great Britain and a pipeline of over 5 GW of projects with accepted grid connection offers.

Spotlight on Storage and solar PV

Clayhill Solar Farm, located in Milton Keynes, developed by UK based Anesco consists of a 10 MW solar array located with 6 MW of energy storage. The project was fitted with an innovative inverter of 1500 V (standard used is 1000 V) which means that the cost of the balance of system was reduced as fewer inverters were required. A combination of an innovative inverter and the inclusion of a battery meant that part of the project could be deployed without subsidies.



Photo credit: Anesco, Clayhill site

We want a diverse electricity system that supplies our homes and businesses with secure, affordable and clean power. That means developing low carbon sources of electricity that are both cheap and clean, taking into account wider system impacts for all sources of generation. It also means upgrading our electricity system, so it is smarter (using data to provide greater control), more flexible (providing energy when it is needed) and takes advantage of rapidly developing technologies such as energy storage.



UK government, Clean Growth Strategy update, April 2018



Where should the UK focus?

The UK has established a positive support framework for electricity storage, tackling key barriers through BEIS and Ofgem's Smart Systems and Flexibility Plan and investing hundreds of millions in technology innovation. To build on this, the Commission recommends:

- Setting a clear government vision for the role of flexibility on the electricity system to give a clear, strong and sustained signal to the market and investors as to the value of this asset class.
- Implementing the commitment to define electricity storage in primary legislation, using the Electricity Storage Network's definition.
- Reforming the Capacity Market to recognise that speed and flexibility of response to system challenges could be as important in the future as duration.
- Broadening the Industrial Strategy focus on storage to include investment in research and innovation in how storage and digital technology can maximise the value of solar PV to the UK and global energy system.

²¹ <https://about.bnef.com/blog/battery-powers-latest-plunge-costs-threatens-coal-gas/>

²² <https://about.bnef.com/blog/energy-storage-620-billion-investment-opportunity-2040/>

²³ https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/756051/ssfp-progress-update.pdf



Asset management

As the amount of Solar PV deployed increases, the role of asset management in maximising the value of the billions of dollars invested in solar assets is becoming vital. Solar PV systems require monitoring, cleaning and maintenance in order to function at their optimal potential and to sustain 25 plus year operational lifespans.

Advances in information and communication technologies have enabled data-driven asset management to maximise solar system availability and output. This is particularly the case for utility-scale solar installations (both commercial and industrial rooftop projects and ground-mounted solar parks), which constitute the majority of the UK's total PV capacity. The current size of the UK O&M market is approximately £65million per year²⁴.



What are the UK's capabilities?

Ownership of large-scale solar PV projects in the UK is now dominated by less than ten large scale asset owners. This highly competitive market structure has helped enable focus and investment in improving the performance of the asset base. Over the past decade, several UK companies have emerged as global leaders in solar operation and maintenance and asset management. UK asset managers are pioneering artificial intelligence to analyse data to forecast output, optimise preventative maintenance and minimise downtime. New technologies such as drones for monitoring and inspection, and robotics for cleaning panels are being developed.

Based on this experience, the UK solar industry is leading international efforts to standardise best practice and develop export opportunities, bringing its expertise in asset management to other markets.

Spotlight on Advanced aerial thermography with drones

Founded in 2015, Colchester-based Above Surveying was one of the world's first companies to develop an accurate and consistent solar monitoring and inspection system using drone-collected data, delivering aerial inspection and software solutions to the international solar market. The company is currently working with Loughborough University and CREST on a study on early identification of solar panel degradation.



Photo credit: Above Surveying

Spotlight on Robotics

In addition to being one of the UK's leading solar PV maintenance companies, Telford-based Clean Solar Solutions currently operate in Ireland, Australia, France and Belgium. Founded in 2013, last year the company became the first in the UK market to incorporate robotics into panel cleaning. Clean Solar Solutions' lithium battery-powered robots are capable of cleaning up to 5,000 m² of solar modules in a day.



Photo credit: Clean Solar Solutions

Spotlight on Artificial Intelligence

London-based Quintas Energy are world leaders in data-driven solar asset management, operating in Ireland, Spain, Italy, the USA and Australia. Working alongside Microsoft's artificial intelligence team, Quintas are harnessing the power of data to confront challenges of output forecasting, managing balancing costs and predictive analytics to optimise preventative maintenance and repairs and minimise site downtime.



Photo credit: Quintas



Where should the UK focus?

Solar asset management is an emerging field in which the unique structure of the UK solar PV market and strengths in artificial intelligence, data analytics and robotics have placed UK companies in a strong position. With the extraordinary scale and growth of the installed solar PV asset base across the world, this is an opportunity for the UK to build on an area of competitive advantage. The Commission recommends seizing the opportunity by:

- Including solar PV asset management in a sector initiative between government and industry with a shared commitment to invest in innovation.
- UK industry playing a leading role in developing international standards and best practice.
- Ensuring overseas trade missions are focused on solar PV capabilities.

Our mission

Regen is a centre of energy expertise and market insight whose mission is to transform the world's energy systems for a zero carbon future.

Regen offers independent expert advice and market insight on all aspects of sustainable energy delivery. We use our technical expertise, industry research and policy knowledge to support a range of public and private sector organisations to make the most of their clean energy opportunities. We have three impact priorities:



Pioneering new energy models at the cutting edge of the energy transformation



Transforming policy and regulation



Championing a diverse, engaged and democratic renewable energy sector

We know we can't deliver this mission alone, so we want to work with you, our members, to be a strong, informed and independent force for change.



Regen's storage report launch event was a great opportunity to meet and talk to a cross section of parties, providing me with direct feedback on challenges and opportunities they face, allowing me to take that back to National Grid and feed it into our future strategy.

Claire Spedding,
head of business development,
National Grid Electricity System
Operator



Join us

Get plugged into the transformation of the energy system through our policy and market insights, sector knowledge and extensive network developed through ground-breaking research and pioneering projects.



Membership benefits

Have influence



- ▶ Opportunities to engage in our influencing and policy work, and contribute to thought leadership papers and consultation responses. Input from our members helps us to influence government to set the right policy for the industry.
- ▶ Set the agenda by joining our forums and working to address barriers to change such as outdated policy and regulation, working closely with BEIS, Ofgem, National Grid, DNOs and local authorities.

- ▶ Reach industry talent by posting your job vacancies on our networks and [website](#) for free.
- ▶ Access to our [Entrepreneurial Women in Renewables network](#).
- ▶ Free use of the [Engine Shed Business Lounge](#) in Bristol.

Stay informed



- ▶ Receive timely policy and regulatory updates from our unique and talented team, along with expert market insights through online articles, webinars and regular email bulletins.
- ▶ Discounted exhibition space at [Renewable Futures](#), our major conference and exhibition and [Smart Energy Marketplace](#) the biggest smart energy technology and renewable energy generation show in the south west, to raise your profile and generate new business.

Get connected



- ▶ Showcase your business with exhibition space and network at our events with our 200 members, innovators, influencers, potential partners and customers. Our forthcoming events are listed [here](#).
- ▶ Listed [online](#) as a member; this is a frequently used resource and encourages business relationships between our members.

If you aren't yet a member please contact Rachel Hayes, head of networks and development, Regen rhayes@regen.co.uk

Regen, Bradninch Court, Castle Street, Exeter EX4 3PL
+44 (0)1392 494399 www.regen.co.uk

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