etp Solar
Theme Group

ETP Review of Innovation and Opportunity in the Scottish Solar Energy Sector

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ETP Review of Innovation & Opportunity in the Scottish Solar Energy Sector

Scottish Solar Facts

Solar energy can make a substantial impact in Scotland in several areas including statutory decarbonisation targets, business innovation and social aspects such as fuel poverty. Key points relating to the solar opportunity in Scotland include the following:

- An estimate of roof-mounted photovoltaics (PV) in Scotland determines that 11 GW of solar could be installed across the country, providing nearly one third of Scotland's current electricity needs**.** This does not include ground-mounted solar PV, or floating solar PV.
- A typical domestic 4 kWp PV installation in Scotland can yield an average around 10 kWh per day, similar to the average electricity demand of a family house.
- The cost of PV continues to plummet worldwide; in Scotland it is already comparable to wind and predicted to drop by another one third by 2040.
- Solar can play a key role in alleviating fuel poverty at relatively low cost.
- Significant employment opportunities exist in the solar sector with the majority, around 17 jobs per MW attributed to installation and maintenance.
- There are innovation opportunities to develop intellectual property and products within Scotland, such as panels for building-integrated PV, components such as invertors, microgrid technology and advanced solar thermal.
- Scotland has substantial and diverse academic expertise in solar energy that can be mobilised to support industry and innovation.
- Solar output is complementary to wind, such that better grid stability and energy security can be achieved by combining both in the mix.
- As the most effective renewable technology in cities, solar can assist in achieving targets on sustainable buildings.
- Solar thermal technology, although of lower prominence than PV worldwide, can play a particularly important role in Scotland where decarbonisation of heat is the next priority.
- An average solar-thermal installation in Scotland can provide 40-50% of annual hot water requirements of a family home.

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1 Introduction

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) and solar thermal will be key technologies driving this transformation. Solar thermal technology has received less attention to date but will be instrumental in tackling the next big challenge to decarbonise heat in Scotland. Solar PV has seen remarkable price decreases and the global PV installed capacity at the end of 2019 was 627 GW[1], an increase of 115 GW in one year, and up from 23 GW a decade earlier (Figure 1).

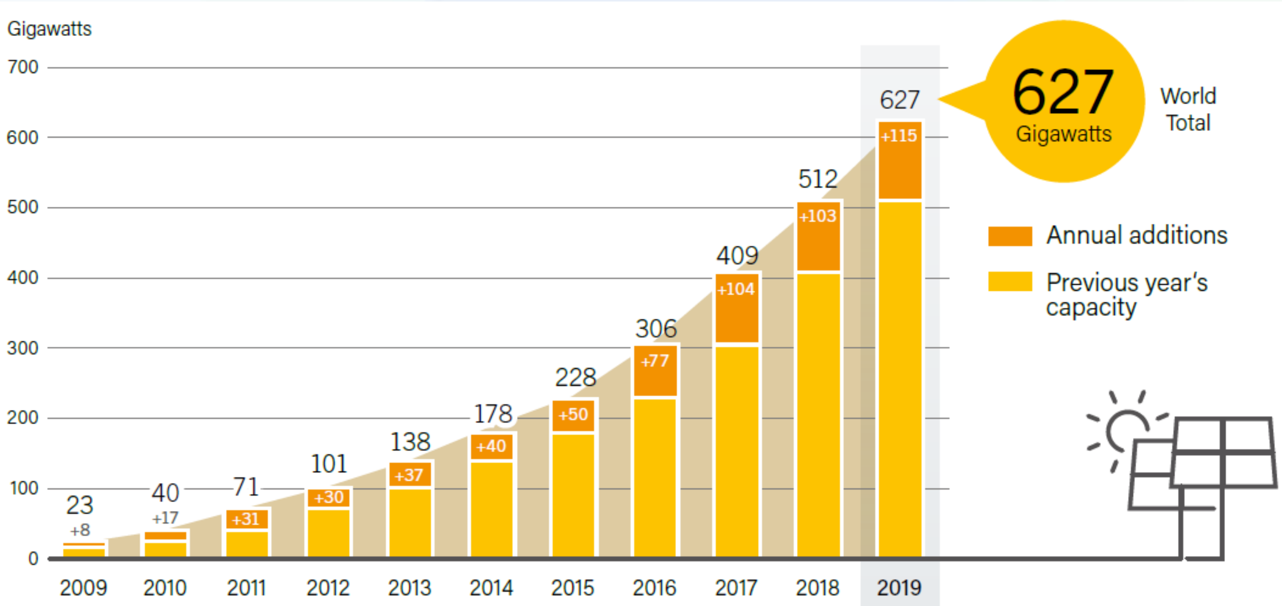

Figure 1: Solar PV Global Capacity and Annual Additions, 2008-2019. Source: REN21 (2020) "Renewables 2020 Global Status Report"

Scotland has been following a similar upward trend, with 364 MW of installed capacity by the end of 2019[2]. This generated 347 GWh of electricity in 2019, enough to power more than 80,000 Scottish homes. There is a further 356 MW of solar projects in the pipeline[3].

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[1] REN21(2020) "Renewables 2020 Global Status Report", Paris

[2] BEIS (2020) "Solar photovoltaics deployment August 2020", 24 September 2020

[3] BEIS (2020) "Renewable Energy Planning Database June 2020"

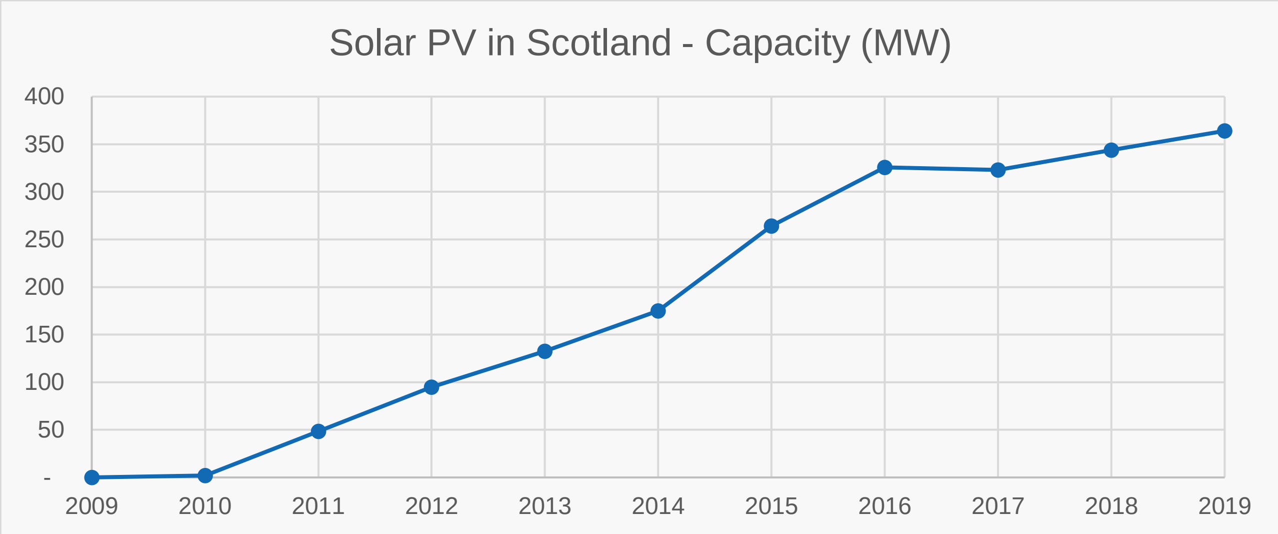

Figure 2: Solar PV Installed Capacity in Scotland 2009-2019. Source: BEIS Renewable Electricity Capacity and Generation statistics, September 2020.

The very conservative International Energy Agency (IEA) predicts that global installed capacity will increase by 700 GW to reach 1.2 TW by 2024[4], and a recent report by the independent Energy Watch Group predicted that solar could provide a remarkable 69% of the world's total energy by 2050[5]. Installed capacity of solar PV has grown near exponentially since the 1990s, approximately doubling every two years since 2000[6]. Remarkably, continued growth at this rate would provide 100% of current electricity needs from solar alone by 2028. This is driven by the year-on-year reduction in cost of solar panels and is comparable to other electronic goods such as phones and laptops. The Learning Curve (or Experience Curve) of PV modules over the last 38 years is 24%, where the price of PV modules decreases by 24% with each doubling of cumulative production due to economies of scale and technological improvements[7]. Since 2014, the global average cost of PV electricity has fallen into the fossil fuel cost range, with the UK cost dropping by 50% from 2013 to 2019. New solar PV are expected to increasingly cost less than the marginal operating cost of existing coal fired power plants[8]. The UK Government Department for Business, Energy & Industrial Strategy (BEIS) has predicted that by 2025, large-scale solar PV in the UK could cost as little as £39/MWh, lower than onshore and offshore wind and around half as much as combined-cycle gas turbines (CCGT), continuing to fall further in the years beyond to around £28/MWh by 2040[9]. Already the price of solar compares favourably with other energy, and is currently comparable with wind, as can be seen in Figure 3:

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[4] IEA "Renewables 2019" October 2019

[5] Energy Watch Group, Paris "Global Energy System Based On 100% Renewable Energy", April 2019

[6] https://www.solarpowerworldonline.com/2016/03/futurist-ray-kurzweil-predicts-solar-industry-dominance-12-years/

[7] Fraunhofer ISE "Photovoltaics Report November 2019", 14 November 2019

[8] IRENA, "Renewable Power Generation Costs in 2019", June 2020

[9] BEIS, "Electricity Generation Costs 2020", August 2020

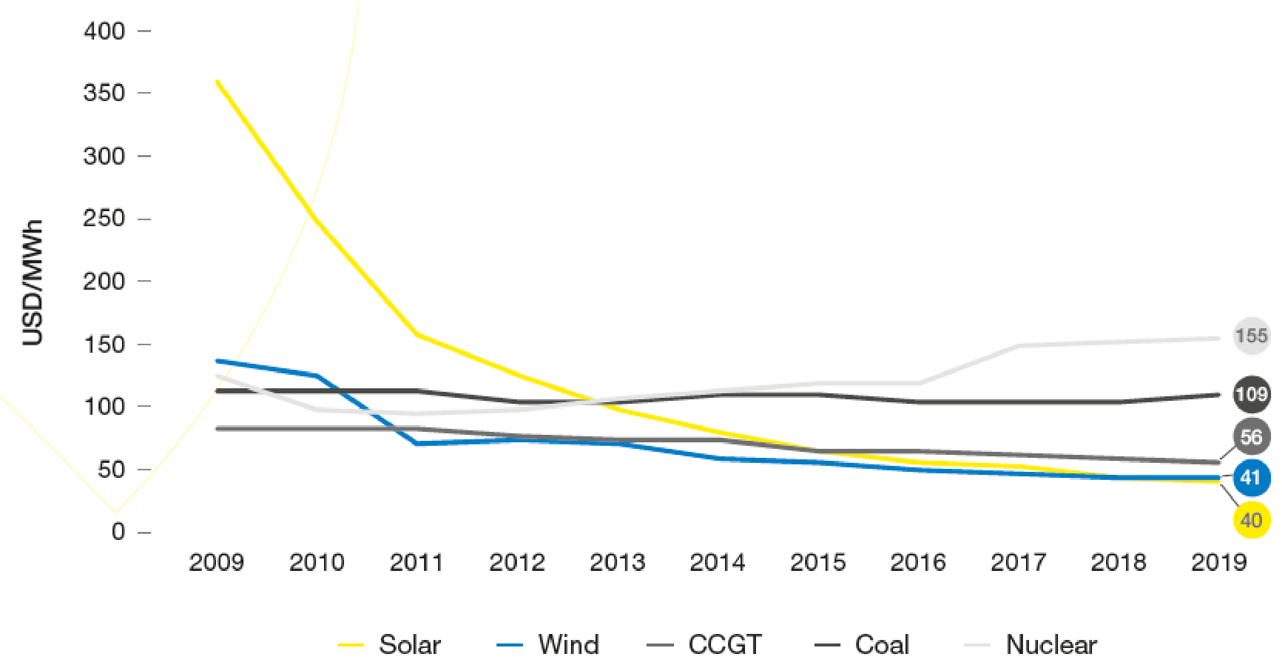

Figure 3: Solar Electricity Generation Cost in Comparison with Other Power Sources 2009-2018. Source: Solar Power Europe "Global Market Outlook for Solar Power 2020/2024", June 2020

2 The Case for Solar Energy in Scotland

A number of policy and contextual factors are itemised in Section 6 Policy, Markets & Finance relating to solar in Scotland. These demonstrate the strong decarbonisation ambitions of Scotland and mention solar as a contributing factor in the future energy mix. It would be fair to say, however, that the true potential of solar has yet to be fully recognised by government, industry or wider society and that stated expectations remain lower than could be achieved with a more systematic and strategic focus. For example, the Scottish Government Energy Strategy 2017 states that "there is enough capacity in Scotland to power the equivalent of over 50,000 homes." This however, is a remarkably low and unambitious estimate: indeed, it is even lower than has already been achieved (see Section 1 Introduction). In contrast, a simple calculation shows that Scotland's entire annual electricity consumption of 36 TWh could be met with 20%-efficient PV panels covering around 0.27% (216 km^2) of the country's area (the area of Glasgow = 175 km^2). Utilising all of this may not be straightforward in practice, but it serves to illustrate the enormity of the resource.

2.1 How Well Does Solar Work in Scotland?

Installing solar power in Scotland has tremendous potential even though it doesn't receive as much solar irradiation as places such as Africa, India or Southern Europe. Solar power potential in the UK and Scotland is not dissimilar to Germany, the largest PV market in the world, which already had 24.7 GW of PV installed by 2011[10].

At the individual level, "a typical domestic rooftop 4 kWp system in Scotland can generate about 3,400 kWh of electricity a year – that's similar to the amount of electricity used by one family house and the same amount of electricity as it takes to turn the Falkirk Wheel 2,200 times. It will save approximately 1.3 tonnes of carbon dioxide every year."[11]

In fact, Scotland has a very similar solar radiation profile to the rest of the UK (Figure 4). The University of Edinburgh has carried out research into the solar resource across Great Britain taking 10-years of weather data into account[12]. From this, a comparison of the potential output of a typical domestic solar installation (a 4 kWp roof-mounted array) between various representative conurbations in the UK has been produced:

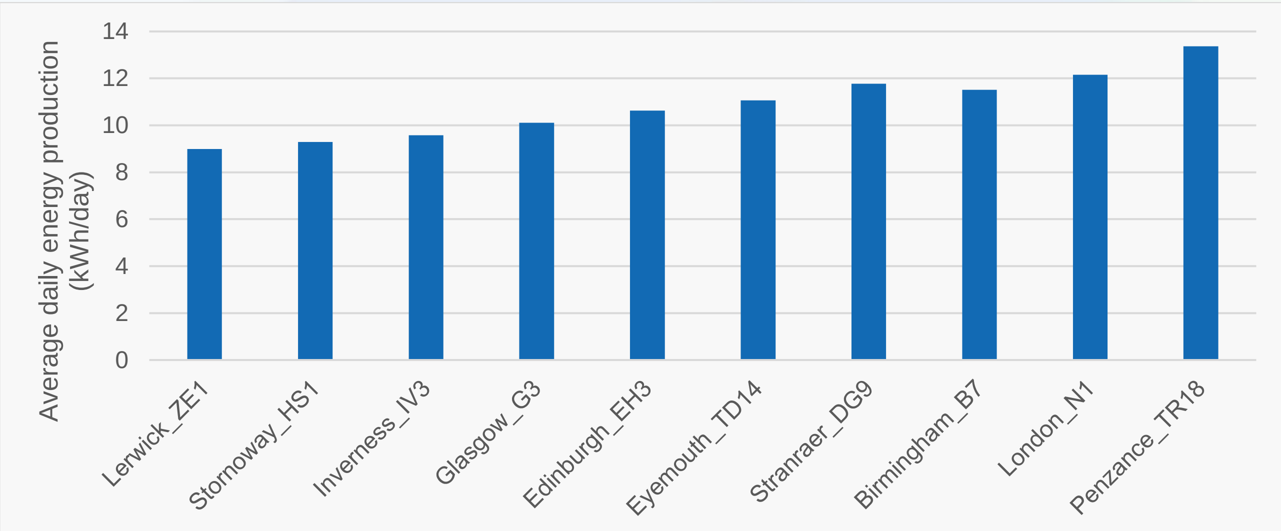

Figure 4: Average daily energy production of a typical domestic array across selected postcodes

As can be seen from Figure 4,the average energy output of a domestic installation in Edinburgh is 10.6 kWh/day, which is only 13% less than London, at 12.2 kWh/day.

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[10] European Photovoltaic Industry Association (EPIA) (2012) "Market Report 2011"

[11] https://energysavingtrust.org.uk/renewable-energy/electricity/solar-panels. Accessed 17 February 2020

[12] Thomson, R, Sun, W & Harrison, G 2019, 'Developing a spatially and temporally explicit solar resource dataset for Great Britain', *The Journal of Engineering*, 2019 18 5269-5273. https://doi.org/10.1049/joe.2018.9264

Another question that arises with regards to solar power in Scotland is the seasonal and temporal variation. This has also been investigated, with a particular focus on London and Edinburgh.

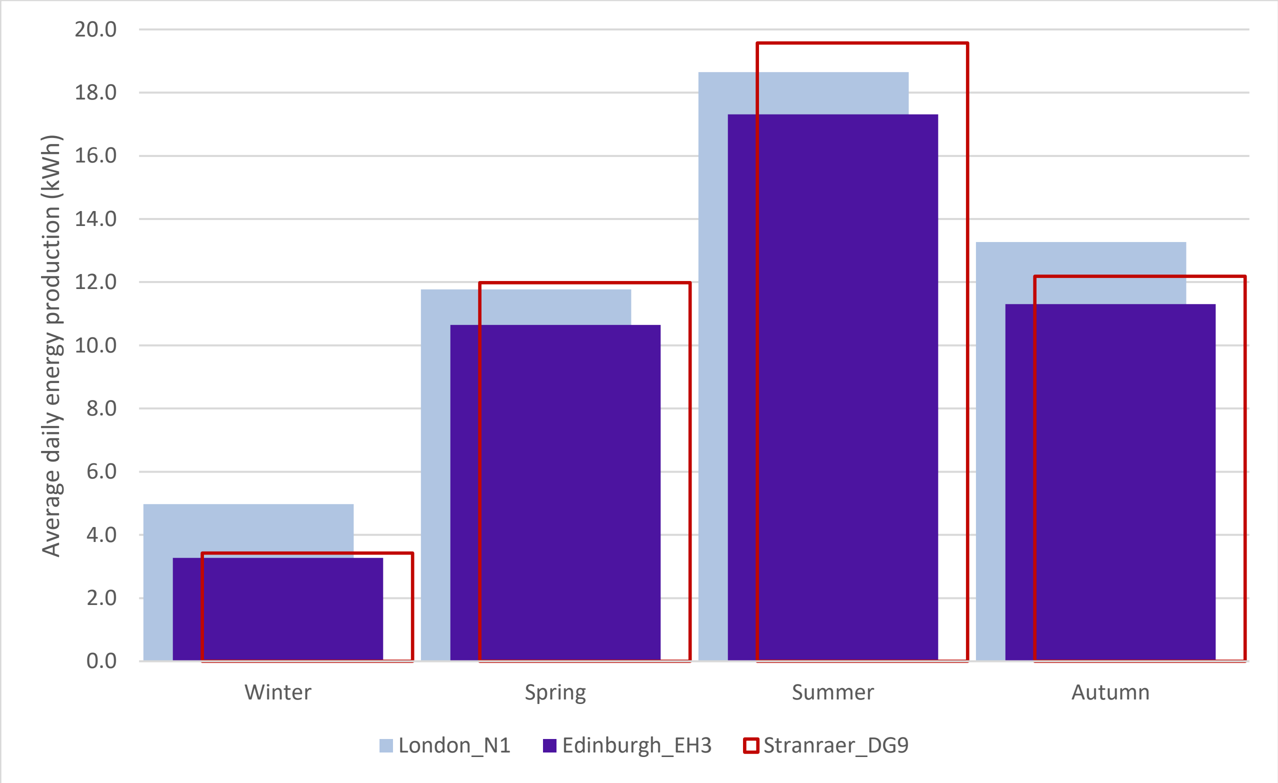

Figure 5: Average seasonal energy output of a typical domestic array in Edinburgh, London and Stranraer

It can be seen from Figure 5 that the seasonal fluctuations in Scotland are similar to those experienced in London. The efficiency of a solar panel in London will be similar to one in Edinburgh. Denmark, with a comparable latitude, climate and population to Scotland, expects to increase solar PV from 955 MW (2018) to 2015 MW (2023)[13], which is five times Scotland's current capacity.

[13] SolarPower Europe (2019) "EU Market Outlook for Solar Power / 2019 – 2023", 2019

2.2 How Much Electricity Could Solar PV in Scotland Produce?

There are two parts of this question. The first is the available solar resource, as already discussed, and the second is about how many Solar PV panels (the maximum potential capacity) could be installed in Scotland. These considerations can then feed into realistic targets for solar PV deployment in Scotland, something that is currently lacking.

It is challenging to accurately estimate the maximum potential capacity of solar PV in Scotland. Existing estimates for the UK are largely based on modelling studies augmented by available data on buildings and land-use. Based on a preliminary review of available published estimates for maximum potential solar PV capacity in the UK [14] [15], adjusted values have been calculated for Scotland. The most optimistic estimates for potential practical solar PV capacity in Scotland are *(p = peak power output):*

- 8 GWp for domestic roof-mounted solar
- 3 GWp for commercial roof-mounted solar
- 21.5 GWp for ground-mounted solar farms, per percent of Scotland's land devoted to solar PV

The available solar resource can be described in terms of an average capacity factor for Scotland (estimated to be 10.7%, 10.8% and 11.3% for domestic, commercial and ground-mounted arrays respectively)[16], which allows the potential annual energy production to be calculated:

- 7.5 TWh/yr for domestic roof-mounted solar
- 2.8 TWh/yr for commercial roof-mounted solar
- 21.3 TWh/yr for ground-mounted solar farms, per percent of land devoted to solar PV

On the above basis, Scotland's entire electricity demand equivalent (36 TWh/year) could be met using domestic and commercial roofs, plus 1.2% of land area.[17]

These figures provide context for any proposed solar PV deployment target for Scotland. The "Net Zero Technical Report" of the Committee on Climate Change (May 2019)[18] states that over the period to 2035, up to 54 GWp solar PV could be needed in the UK and that further deployment is likely to be needed over the period to 2050. If Scotland captured 10% of this UK growth, that would lead to 6 GWp capacity by 2035, which is clearly achievable within the maximum capacities outlined in this section above.

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14 UKPVMA 2020 "A vision for UK PV: An up to date and accurate analysis on the investment case for solar photovoltaics (PV) in the UK", 2009. UK Photovoltaic Manufacturers Association.

15 MacKay D, "Sustainable Energy-without the hot air", UIT Cambridge, 2008.

16 Thomson, R, Sun, W & Harrison, G, 'Developing a spatially and temporally explicit solar resource dataset for Great Britain', The Journal of Engineering, 2019 18 5269-5273

17 Scottish Government, "The Scottish Energy Strategy: The Future of Energy in Scotland", December 2017

18 Committee on Climate Change "Net Zero Technical Report", 2 May 2019

3 Solar Photovoltaics: Innovation and Socioeconomic Impact

A 2019 report at UK level by the Solar Commission noted that "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."[19] The Solar Commission further emphasises that "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." Studies have shown that PV **installation and maintenance** generates double the jobs (ca. 17/MW) compared with manufacture (ca. 7/MW) such that the country of installation benefits most, irrespective of where manufacturing takes place[20]. This analysis is further supported by similar studies observing employment in the solar industry providing 20 jobs/MW for rooftop and 7 jobs/MW for solar farms[21].

Nevertheless, **conventional silicon PV manufacturing** may also become attractive in Scotland as costs drop and transportation from East Asia becomes a larger component of overall cost. Local manufacture will also remove reliance on imports as well as reduce carbon footprint by 30 times. This is based on data showing the Scottish energy generation carbon footprint is currently 0.024 $kgCO_2(e)/kWh$[22], while China has an electricity emission factor of 0.753 $kgCO_2(e)/kWh$[23].

It is important to recall that within a few decades solar is expected to be the dominant source of energy on the planet and that even "niche" products could address an enormous international market demand. Although ground and rooftop mounted PV will continue to be essential (*see above*), a much more diversified market of ubiquitous solar is emerging, including building-integrated PV (BIPV), combined PV & storage, PV-powered internet-of-things, solar-assisted electric vehicles and more. This requires new technologies and new product ideas that exploit embedded solar. For example, Bloomberg projects that the global BIPV market will grow to USD 32.2 billion by 2024.[24] BIPV is very relevant to Scotland's Energy Efficiency Programme (SEEP), which aims to make Scotland's buildings near zero carbon, wherever feasible by 2050. Solar can play a key role as the best renewable technology for integration into buildings and cities and provide a simple and cost-effective way of meeting those targets.

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19 The Solar Commission, "A Bright Future: Opportunities for UK Innovation In Solar Energy", July 2019

20 Fragkos P, Paroussos L, "Employment creation in EU related to renewables expansion", Applied Energy 230 (2018) 935–945

21 DECC, "UK Solar PV Strategy Part 2: Delivering a Brighter Future", April 2014

22 The Scottish Government, "The Scottish Greenhouse Gas Emissions Annual Target Report for 2017" October 2019

23 Li X, Chalvatzis KJ, Pappas D, "China's electricity emission intensity in 2020 - An analysis at provincial level", Energy Procedia 142 2017, 2779–2785

24 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

Within this context, some representative examples of current and future innovation, technology-development and business opportunities in Scotland are outlined below.

Combining storage with wind and solar PV presents a valuable solution for the energy system as a whole, offering the potential for demand to be managed locally. This is perfectly illustrated by Mackie's of Scotland who added a 1.8 MW solar array to complement their wind turbines since these vectors peak at different times and can more effectively use their grid connection[25]. A recent study has shown that such complementarity between renewables can enable the network to host more renewable generation capacity and increase total energy export[26], linked also to the adoption of smart grid technologies, systems integration and digitalisation. These factors help meet Scotland's renewable generation ambitions, relating to the forthcoming review of energy standards under Building Regulations, and the development of the next National Planning Framework.

Integrating solar PV into the game changing technology of **Electric-Vehicle-to-Grid** means demand-side response of the vehicle-owner can play a significant role in balancing the grid with benefits also to the vehicle-owners by allowing them to sell electricity to the grid[27]. The need is to develop viable business models to support government policies where electric vehicles can be used as virtual power plants to ensure grid stability. This can be achieved by returning power to the grid from its storage during peak hours and be charged back from the grid during off-peak hours or when output from solar radiation is maximum. This kind of flexibility and control will be important with the uptake of heat-pump assisted electric heating and as electric vehicles become an integral part of the transport system.

Furthermore, the integration of solar PV into power networks near to the load centres can help to reduce congestion on distribution networks coping with increasing demand from the electrification of the heat and transport sectors. This can be exploited to further mitigate some of the need for upgrades on distribution networks.

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25 https://www.mackies.co.uk/our-farm/our-environment/making-electricity.html, accessed 12 October 2020

26 Sun W, Harrison GP, "Wind-solar complementarity and effective use of distribution network capacity", Applied Energy Volume 247 2019 89-101

27 Sovacool BK et al, "Actors, business models, and innovation activity systems for vehicle-to-grid (V2G) technology: A comprehensive review", Renewable and Sustainable Energy Reviews, 131 2020

Floating PV (FPV) systems present a significant opportunity for Scotland. These can be installed in water bodies like oceans, lakes, lagoons, reservoirs, irrigation ponds, waste-water treatment plants, wineries, fish farms, dams and canals, thereby reducing the opportunity cost on land, and reducing evaporation and operating costs for power generation expenses[28]. Europe's biggest floating solar panel array has been installed on the Queen Elizabeth II Reservoir, London. Just over 23,000 solar PV panels have been floated on the reservoir, utilising a normally redundant and wasted suburban space on the surface. With a surface area of 57,000 m^2, the solar array covers less than 10% of the reservoir but is able to generate 5.8 MWh/year, enough to power 1,800 homes[29]. Floating PV systems use otherwise-wasted space, can be built with less planning permissions in the UK than those on land, are simpler to build and assemble and on reservoirs they can be near hydropower stations with readily available grid connectivity[30] [31]. The total number of Scotland's controlled reservoirs that are in operation and are currently registered with SEPA is 671.

Another innovative example is **bifacial photovoltaics** for increased on-site generation to reduce the need for expensive investment for grid upgrades and to complement standard south-facing PV by generating during the morning and evening demand peaks. High-latitude, snowy climates are particularly favourable for bifacial systems and therefore can contribute to Scotland's renewable energy diversity.

Emerging technologies, such as organic and perovskite PV, are reaching maturity and offer complementary applications to the incumbent silicon technology. These opportunities include flexible and visually attractive solar panels for BIPV, electric vehicles, portable power, and ultra-low-cost power generation. This offers a context for Scotland to develop high-value contributions to final products and to the supply chain in new markets and high-value manufacturing. Currently, there are strengths in Scottish Universities in emerging PV technologies, working with international companies in the field. However, although ETP has 2 programmes which support the development of sustainable energy technologies (the Energy Industry Doctorate Programme, and the Knowledge Exchange Network), neither programme includes solar within its scope, thereby severely hampering opportunity in this sector.

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28 Farfan J et al, "Combining Floating Solar Photovoltaic Power Plants and Hydropower Reservoirs: A Virtual Battery of Great Global Potential", Energy Procedia 2018 155 403–411

29 https://www.lightsourcebp.com/uk/stories/qe2/

30 Sahu A et al, "Floating photovoltaic power plant: A review", Renewable and Sustainable Energy Reviews 2016 66 815–824

31 Chudinzow D et al, "Vertical bifacial photovoltaics – A complementary technology for the European electricity supply", Applied Energy 264 2020

4 Solar Thermal: Innovation and Socioeconomic Impact

Solar thermal offers a huge opportunity for Scotland to provide affordable, renewable heat to households across the country, helping to tackle renewable heat and fuel poverty which is a significant problem in Scotland. Building-integrated solar systems, including both solar thermal and solar PV, have demonstrably already taken some families out of fuel poverty in Scotland[32].

Whilst renewable electricity deployment figures continue to receive widespread praise, the elephant in the room is incomparable progress toward renewable heating. Over 50% of the energy consumed in Scotland is used to heat and cool buildings and processes. Although renewable electricity is close to meeting the Scottish Government target of 100% by 2020, the target for renewable heat is only 11% by 2020[33], recognising that this is where the majority of future effort must go.

Solar thermal deployment was on a steady incline until 2010 when it began to decline across the UK[34], largely attributed to the introduction of the FiT for solar PV. With around 85% of all UK households currently heated by gas[35] and with UK having gas prices around 34% cheaper than the European average[36], solar thermal has struggled from lack of incentive or business case.

However recent policy for new homes to be built with low carbon heating and plans to move off the gas grid opens up a huge opportunity for solar thermal on the domestic scale in Scotland. This gradual shift in policy focus to heat and the decline of cheap gas create a huge opportunity for increased solar thermal deployment. Evidence for this can be found from other European countries with higher gas prices and similar climates. Figure 6 shows the UK accounted for only 0.9% of the European market for new installations in 2015, with no significant progress since then. There is clearly an imperative to catch up, and exceed, successful European neighbours.

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32 Andreadis G et al, “Tackling fuel poverty with building-integrated solar technologies: the case of the city of Dundee in Scotland”, Energy and Buildings 59 2013 310-320

33 Scottish Government “Renewable Heat Action Plan for Scotland”, 4 November 2009

34 IEA Solar Heating & Cooling Programme “Solar Heat Worldwide - Edition 2020”, May 2020

35 OFGEM “Insights paper on households with electric and other non-gas heating”, 11 December 2015

36 https://ec.europa.eu/eurostat/statistics-explained/index.php/Natural_gas_price_statistics, accessed 27 October 2020

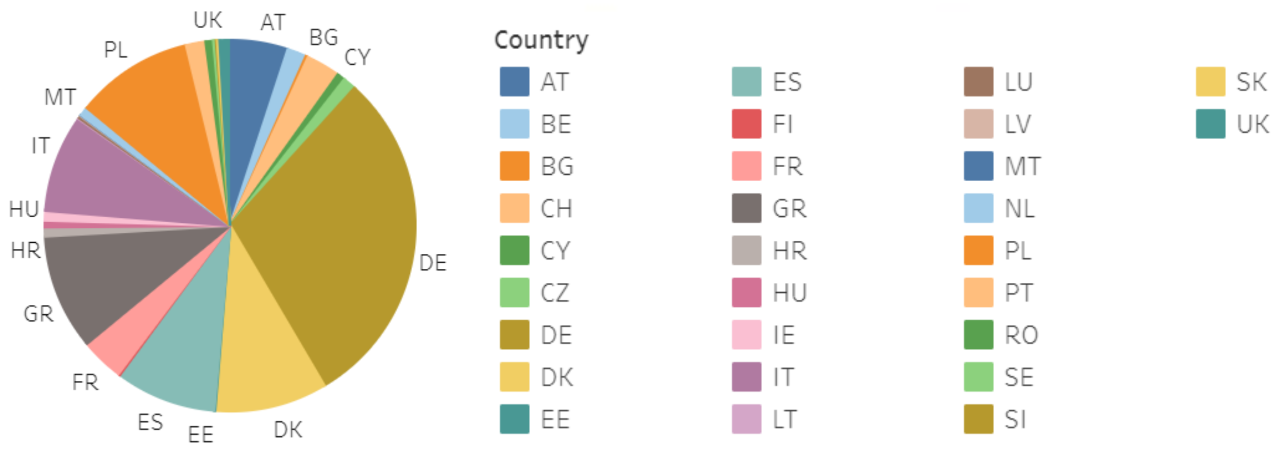

Fig 6: Shares of the European solar thermal market (newly installed), 2015[37]

Solar thermal has the ability to work as a compliment to other renewable heating solutions, such as heat pumps and biomass, increasing the lifespan, reducing the fuel requirements and further reducing the costs. This impact can be even greater in northern colder climates such as in Scotland[38]. A factor which makes solar thermal such an effective complimentary system is the ability to preheat water in colder months but to provide the majority of the hot water demand in summer when space heat is not required and other heat systems will perform at lower capacity.

Whilst solar thermal is widely recognised as a mature technology there is a huge amount of innovation occurring around the UK, from unique combined PV and thermal collectors created by English pioneers Naked Energy[39], to Senergy's use of high temperature polymers to develop low cost collectors in Northern Ireland[40]. Scotland equally continues to innovate in this sector, with freeze tolerant solar collector of Soltropy winning Business Insider Inventor of the year[41] and Scottish manufacturer AES Solar being chosen as the solar specialist in a Europe wide project for solar assisted heat pump technology[42]. More recently in 2020, Scottish based start-up, SolarisKit, became the first Scottish company to be listed on '1000 solutions to change the world', by the Solar Impulse Foundation. This was for their innovative low-cost flat-pack solar thermal collector[43].

37 http://solarheateurope.eu/publications/market-statistics/interactive-statistic/, accessed 27 October 2020

38 Carbonell D et al, "Potential Benefit of Combining Heat Pumps with Solar Thermal for Heating and Domestic Hot Water Preparation", Energy Procedia, 2014, 57, 2656-2665

39 https://www.nakedenergy.co.uk/news/2020/3/21/case-study-virtu-pvt-active-office-swansea, assessed 27 October 2020

40 https://www.senergyinnovations.co.uk/, accessed 27 October 2020

41 https://www.soltropy.com/stuart-wins-made-in-scotland-inventor-of-the-year/, accessed 27 October 2020

42 https://www.heat4cool.eu/about/consortium/, accessed 27 October 2020

43 https://solariskit.com/news/solariskit-solar-collector-labelled-one-of-1000-solutions-to-change-the-world, accessed 27 October 2020

As well as solar heat on domestic and industrial scales, Scotland also presents a huge opportunity in Solar District Heating (SDH), providing heat to a whole community or district, often with other technologies and often with daily or seasonal storage. This can be evidenced by continued growth of SDH across Europe in countries with similar climates such as Denmark, Germany, Austria and Sweden. The current, worldwide, installed collector area of large-scale solar heat systems (>350 kWth; 500 m) is around 1.8 million m^2 (339 systems in total)[44]. Further analysis of the potential for low cost SDH has indicated that the UK may have one of the highest potentials across Europe[45]. Given Scotland's great challenge ahead in meeting renewable heating targets, the move off gas grid and other rising concerns such as fuel poverty, exploring the potential of SDH can be an important component of the heat challenge.

5 Policy, Markets & Finance

There are a number of relevant contextual policies in Scotland[46] [47] [48] [49] [50] [51] [52] [53]: however, these generally contain little specific mention or consideration of solar, which is *largely overlooked in Scotland's national policies*.

In most countries throughout the world renewable energy technologies such as solar are supported by a mixture of policy instruments, often in the form of market incentives such as a feed-in-tariff (FiT), subsidies, financing arrangements, and certificate trading schemes, as well as research and development incentives[54]. Policy instruments to assist with purchase and installation costs are useful for the promotion of renewable energy systems that have substantial upfront costs, often considered a principal barrier to the adoption of such systems. These programs can include monetary support in the form of upfront payments or rebates as well as other types of aid.

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44 IEA Solar Heating & Cooling Programme "Solar Heat Worldwide - Edition 2020", May 2020
45 IEA Solar Heating & Cooling Programme "Solar District Heating Trends And Possibilities", June 2018
46 Scottish Government "Scottish Energy Strategy: The Future of Energy in Scotland", 20 December 2017
47 Scottish Government "Climate Change Plan: The Third Report on Proposals and Policies 2018-2032", 28 February 2018
48 Scottish Government Climate Change (Emissions Reduction Targets) Bill (23 May 2018) and amended bill (June 2019)
49 Scottish Government "Annual Energy Statement 2019", 15 May 2019.
50 RSE Enquiry "Scotland's Energy Future", 17 June 2019
51 Scottish Government "Greenhouse Gas Emissions 2017", 11 June 2019
52 Committee on Climate Change "Net Zero: The UK's contribution to stopping global warming", May 2019
53 Committee on Climate Change "Reducing emissions in Scotland 2019 Progress Report to Parliament", December 2019
54 Hosenuzzaman et al, "Global prospects, progress, policies, and environmental impact of solar photovoltaic power generation", Renewable and Sustainable Energy Reviews 41 2015 284-297.

The introduction of the FiT in the UK in 2008 stimulated growth towards the present figure of around 10 GW installed capacity, of which 0.35 GW is in Scotland. The FiT is no longer available to new subscribers, and in the absence of this incentive during 2019 solar deployment stalled somewhat. However, from 1 January 2020 BEIS introduced the **Smart Export Guarantee** (SEG), under which all licenced energy suppliers with 150,000 or more customers must provide at least one SEG tariff. Smaller suppliers can offer a tariff if they want to. All suppliers can also choose to offer other means of making payments for exported electricity, separate to the SEG arrangements.

Under the SEG regulations suppliers must offer a tariff greater than 0p/kWh. At present the SEG tariffs on offer vary greatly between suppliers, with some as high as 5.6 p/kWh and others as low as 1.5 p/kWh. The arrangements are not constrained, and in future are likely to encompass 'brown' electricity, from storage systems, as well as 'green' electricity direct from the generator. With the advent of smart metering and greater supply/demand dialogue such a system could facilitate small-scale renewable energy trading in a manner that might suit smaller communities in Scotland.

A further incentive may arise from **peer-to-peer trading**[55]. This facilitates the trading of energy surplus as a virtual commodity. SonnenCommunity[56] is an example of peer-to-peer trading between domestic PV generators who possess a Sonnenenergie battery-based system. Members cover their own energy needs on sunny days, and any surplus is audited by a software-based virtual energy pool that is available to other members of the scheme who are generating insufficient energy. The role of the conventional energy provider is redundant in such a system. Again, this mode may favour smaller like-minded communities linked by the desire to trade green energy, of which PV is one option.

Such a diverse and changing landscape calls for much further analysis of the market growth of the industry as a result of effective policy introduction (e.g. **Renewable Heat Incentive** for solar thermal) and understanding of initial investment by government (e.g. FiT, RHI) vs final gain, such as total generated income through installation and manufacturing, corporate tax gain, carbon reduction etc. This would greatly assist government to optimise policy and examples of other policy tools are available from around the world.

Policy programs, such as the **Residential Solar Photovoltaic Dissemination** (RSPD) program in Japan, provide assistance with costs related to the purchase and installation of solar energy systems. The **California Solar Initiative**, which was initiated with the goal of accelerating the deployment of solar energy within the state, is one of the largest rebate schemes in the United States[57]. Some researchers have found that upfront rebate schemes such as the California Solar Initiative act as effectual policy instruments for the promotion of residential solar energy systems.

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[55] Zhang et al, "Review of Existing Peer-to-Peer Energy Trading Projects", Energy Procedia 2017 105 2563

[56] https://sonnenbatterie.co.uk/sonnencommunity/

[57] Dong C et al, "Incentive pass-through for residential solar systems in California", Energy Economics 72 2018 154-165.

Other prevalent policy mechanisms include financing arrangements and tax credit initiatives. In the United States, examples include **tax exemptions, tax credits, and loans** with preferential terms. The Energy Policy Act of 2005 authorized the United States Department of Energy to issue **loan guarantees** to help finance renewable energy projects, including solar energy systems that meet certain criteria. The United States has also provided favourable **depreciation deduction programs** designed to accelerate cost recovery related to solar energy systems.

Policy instruments known as **renewable portfolio standards** that require electricity suppliers to produce a specified percentage of electrical generation from renewable sources have been successfully implemented in numerous countries throughout the world. In addition to reducing carbon dioxide emissions, rationales often cited include energy security and job creation. In the United States, over thirty state governments have implemented renewable portfolio standards. Renewable portfolio standard legislation has been credited with significantly advancing the renewable energy industry in Japan.

Renewable portfolio standards often coincide with a renewable energy certificate trading scheme, under which a renewable energy certificate, also known as a green certificate in some countries, is issued for each MWh of electricity produced from a renewable source, which can then be sold or traded in the marketplace. In the UK, renewable energy certificates are issued under the **Renewable Energy Guarantees of Origin** (REGO) scheme. REGOs are issued for every MWh renewable electricity generated by accredited installations and can be traded in the marketplace for between 10p to 20p per certificate.

In addition to market incentives, many countries also provide **research and development incentive** programs to facilitate researchers and innovators in the development of technological advancements related to renewable energy systems. Numerous pioneering innovations are developed in Germany, a state among the largest research and development spenders in the world. It is important to achieve an optimal balance between public spending devoted to the deployment of existing technologies and investments dedicated to research and development.

6 Scotland's Business & Research Landscape – Present & Future

Figure 6 highlights the innovation, manufacturing, deployment and operation chain for solar PV and thermal in Scotland. Underlined segments indicate Scottish capacity and capability. The industry is strongly supported by the research and innovation carried out by Universities. For solar PV we import panels: however, all other aspects of the industry are active in Scotland. Solar thermal devices are produced locally such that the complete chain is represented locally. Figure 6 shows specific examples of the various elements.

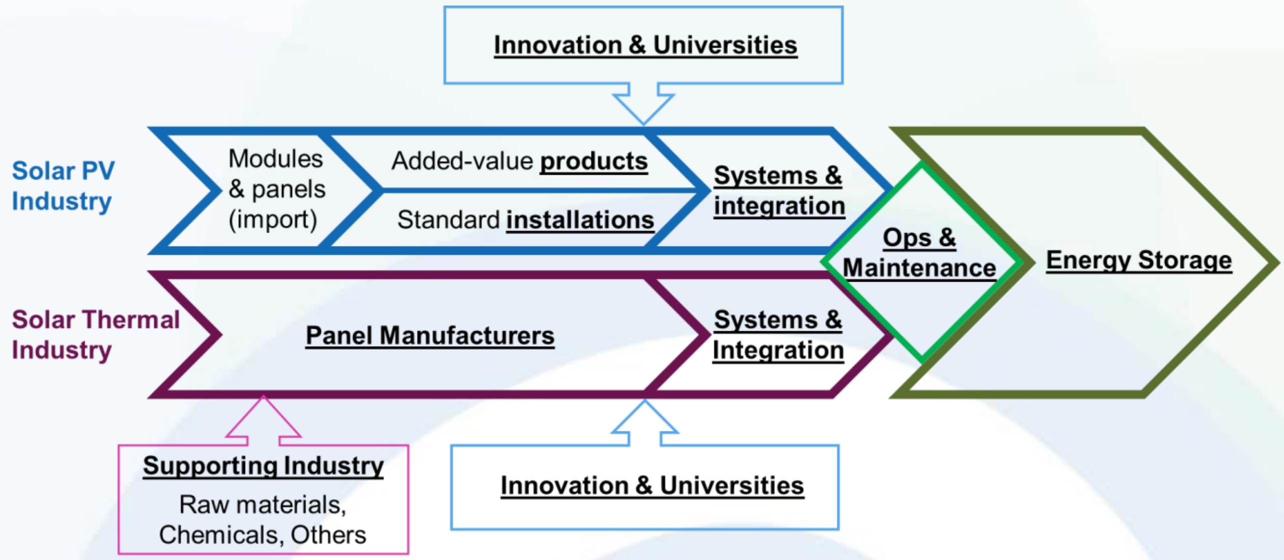

Figure 6: Scottish Solar Industry Supply & Innovation Chain – underlined segments indicate Scottish Capacity & Capability

Solar thermal panel development and manufacture is carried out by companies such as AES Solar, Soltropy and SolarisKit. The development of innovative **solar PV** products over the last 15 years has seen several companies aiming to address various niche aspects of the market. These have included new solar cell innovations e.g. Power Textiles Ltd, Solway PV, or incorporation of pre-made cells into novel products e.g. Grid Post Ltd, Daima Energy, AllSolar, Puurgen. Although a consistent spin-off eco-system has remained elusive in Scotland, the continued global market expansion for solar products offers opportunities that can be seized with a supportive environment.

Growth of installations, in line with future low-carbon targets, will provide substantial growth in the need for **installation** as well as **operation and maintenance**. In addition, developments are required in **systems and integration** to optimise solar PV and solar thermal to the electric and heat grids respectively. Solutions to these challenges are location specific and it is essential that Scotland grows its capacity in the engineering, financial, business and policy expertise required to deliver an integrated low-carbon system.

Scotland's Universities are well-placed to contribute to all of the above challenges. Substantial expertise is established in emerging PV technologies, materials, manufacturing, solar thermal systems, complementary renewables and storage, systems modelling and integration, and the supportive policy landscape. ETP and other initiatives have played an important role in networking this community and providing small-scale funding, however there has been insufficient national support or strategy to coalesce the community towards a solid framework for future innovation and local industry partnership.

7 Conclusions & Recommendations

7.1 Energy Generation

Solar PV and solar thermal can both play a significant role in Scottish energy decarbonisation and their implementation should be supported by removing barriers. The complementarity of solar to other technologies will help provide grid stability and flexibility. Scotland should set a target for solar PV installation: we suggest 6 GWp by 2035 as a realistic goal in line with UK level analysis[58].

7.2 Innovation and Economy

Scotland has world-leading indigenous solar thermal and heat storage companies, supported by research and innovation in universities. We should therefore support innovation and growth in solar heat as part of a larger heat strategy.

For PV, there are huge new opportunities beyond the high-volume panel manufacture established in Asia. The sector will massively expand and diversify worldwide, requiring innovative products bespoke for more northern countries and that can be embedded in electricity-driven daily life. Solar technologies can lead to significant job creation in installation and maintenance, as well as high-value jobs in research, product development, supply chain and components. Solar PV innovation in Scotland has, historically, suffered from lack of critical mass. Solar should be included in the ETP the 2 programmes which support the development of sustainable energy technologies (the Energy Industry Doctorate Programme, and the Knowledge Exchange Network). Not only will this develop the skills base and critical mass, but it will bring international companies to Scotland

58 Committee on Climate Change "Net Zero Technical Report", 2 May 2019

7.3 Government Policy

The Scottish Government should put in place a bold and ambitious Solar Action Plan for Scotland as part of an integrated path towards Net Zero 2045, engaging with the relevant trade bodies (STA, SR) to form a strategy on barriers and incentives to unlock step-change progress.

The re-establishment of Pot 1 technologies in the next Contracts for Difference round (taking place in 2021) can provide a route to market for large-scale solar in Scotland. Projects could be up and running from the mid-2020s if successful.

Scottish Government should use their policy levers to incentivise development of solar (particularly small-scale now that FiT is gone) e.g. through additional government support, business rates relief or more favourable planning frameworks (particularly increasing permitted development rights). Public bodies could also be encouraged to enable solar installations on their own buildings/land, and it should become part of buildings regulations that new-build should have solar built-in.

Policy should also take account of the potential for solar energy to substantially address fuel poverty in Scotland, working with local authorities and housing providers.

7.4 Research and Development

A key observation of this report is that Scotland-specific research and development is needed across all key areas of solar PV and solar thermal. The solar resource, the balance of other renewables, energy demand and socioeconomic factors are unique in every country and local understanding and insight is essential. R&D needs and opportunities include development of niche solar PV technologies; improved solar thermal products; novel products that incorporate solar PV for portable, transport or autonomous power; resource modelling; solar within electricity systems both on and off grid; solar coupled with storage; optimal use of policy levers; economics and market modelling; social attitudes and technology adoption.

There is significant expertise and capacity in Scotland's universities and innovative companies to tackle all of these diverse factors, but it is fragmented and lacks support or a central strategy for coordinated action. Systematic funding for an integrated **Scottish Solar Research Hub** (virtual or physical) is needed to avoid missing out on what will inevitably become the largest energy sector on the planet.