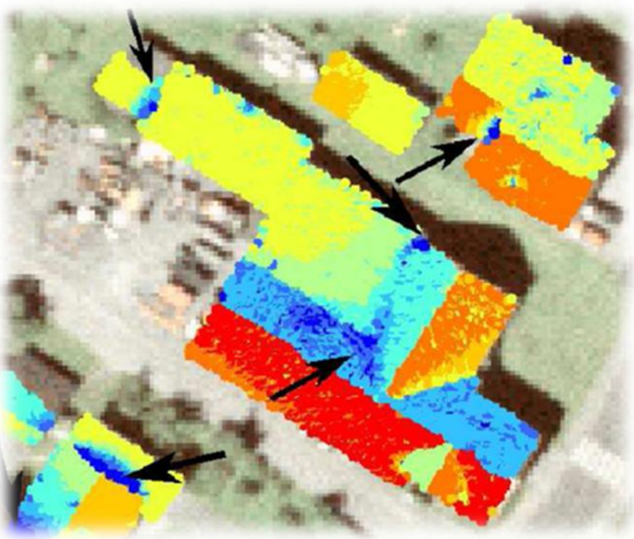
Technical Report

Initial Potential Capacity Assessment for the Implementation of a Scotland-Wide Solar Water Heating Systems Installation Plan in the Domestic Sector



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Important Notice:

This is a private & confidential technical report funded by ICARB (www.ICARB.org) and undertaken by a research team at the School of Built Environment of Heriot-Watt University for the Scottish Government. Its content, i.e. technical information, literature review, facts & figures, assumptions, calculations, results, analyses, discussions and conclusions, are the product of academic research only and aim to provide the Scottish Government with information and an indication of the possible potential capacity of renewable energy systems, more specific solar water heating, in the Scottish domestic sector. It is a draft study, done informally over a short period of time and cannot be considered as a definitive study.

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Executive Summary

This report proposes an initial estimate of the potential installable capacity of water heating systems (SWH) in Scotland to give decision makers a feel for the cost, energy and carbon emission reduction impacts of their mass installation. The related benefits of implementing a national scale solar plan to install SWH in suitable Scottish homes will:

a) Reduce Scotland's dependence on fossil fuels;

b) Reduce significantly carbon emissions from Scotland;

c) Reduce fuel poverty in Scotland;

d) Enhance energy security in Scotland by significantly increasing heat storage capacity across the Scottish grid in SHW tanks in homes and

e) Boost the Scottish economy by stimulating related industries across Scotland.

To highlight the scale of the potential for building level solar micro-generation in Scotland to achieve the above objectives, this study follows the "*Renewable and Low-carbon Energy Capacity Methodology*" published by the Department of Energy and Climate Change (DECC) in 2010 to provide some insight into the scale of the opportunities at hand to do so. The DECC methodology was designed for use at a regional and city level, to provide decision makers with renewable energy potential maps. The method introduces various assumptions for each renewable technology and suggests specific factors to be used in the renewable energy potential assessment.

However, the DECC methodology includes some constraints in its application and therefore a second revised scenario was investigated building on the findings of its early case study applications. This led to a dual approach of developing both a low and high level implementation scenarios of SWH technology in the Scottish domestic sector. These scenarios are:

<u>Scenario 1 (Low):</u> Standard use of the DECC methodology. The typical factors presented in the methodology are applied to the total number of Scottish dwellings and the suggested average SWH system capacity was counted per roof considered suitable for solar integration.

Scenario 2 (High): This is the optimistic/realistic scenario, developed in response to trial runs of the Scenario 1 method the figures of which proved to be underestimates. The results of Scenario 2 provide a far higher figure for the solar potential once the underestimation taken account of.

In the pessimistic (low) DECC scenario it was found that 732,000 rooftops are suitable for SWH integration with a total capacity of 1,464 MW_{th}. The total cost for a wide implementation of these scenarios is £1,385,676,000. This exceeds the generation capacity of Scotland's nuclear station in Scotland, Torness, with an installed capacity of 1,190MW. It would result in a CO_2 emissions reduction of around 397,000 tonnes of CO_2/yr for electricity displacement.

In the optimistic scenario (high) the total capacity was found 3,953MW_{th} at a cost of around £3,741,514,500. This is near a half more as much energy as is generated at Scotland's largest power station (coal) at Longannet, that has a capacity of 2,400 MW. The current estimated price of the new nuclear power plant at Olkiluoto in Finland (10 years in the building) is now put at c.€10 billion, over three times the delivery price of €3 billion. It will generate around 1720MW, less than half of the installed capacity of solar thermal energy that would be generated under Scenario 2. It would result in a CO_2 emissions reduction of around 1,065,000 tonnes of CO_2/yr.

A discussion section reports on the identified methodological constraints and a more detailed and accurate methodology is described and proposed.

The current report is a product of ongoing research of the School of Built Environment in Heriot-Watt University of Edinburgh, on the potential capacity for, and impacts of, solar building integrated technologies in Scotland. It was produced in response to a request from the Infrastructure and Capital Investment Committee of the Scottish Government is intended for general information and consultation purposes only and it can be upgraded to a more circumstantial study if proper planning and funding become available.

1. Introduction

1.1 The Solar Cities Movement

The Large Scale application of solar systems at a city level began with the work of the International Solar Cities movement. Building integrated solar energy is the most suitable and reliable of any of the renewable energy generating technologies for application in built-up urban areas. A working definition of what a Solar City is can be found on the Solar Cities Scotland website [1]: "*A Solar City is an urban community that is committed to the development of sustainable energy to power its development, rather than the continuing reliance on fossil and nuclear fuels. It is a worldwide movement that seeks to share knowledge and best practice on tackling some of the major issues of the early 21st century - that of climate change and peak oil*". It is clear from this definition that the 'urban community' and the 'sustainable energy V. fossil fuels' are the key issues for the Solar Cities Movement. Appendix 1 provides more information on the movement and examples of two case study cities.

1.2 The multiple benefits of exploiting the solar potential of homes in Scotland

While cities with similar latitudes to Scotland, like Gothenburg in Sweden have already produced a city level solar map [2] Scotland came late to understanding its solar potential despite the fact that many parts of Scotland have weather that will produce good solar returns as recent research has shown [3].

The Scottish Universities Insight Institute has provided evidence to the Scottish Government of the benefits of solar technology in technical, social and economic terms [4] and the Scottish Institute for Solar Energy Research (SISER) produced a report on the opportunities for solar markets in Scotland in 2013 that dwelt largely on its photovoltaic potentials [5].

However such reports only deal largely with the costs and benefits associated with the installation and operation of the technologies. The huge employment impacts and knock-on economic benefits figure highly in such assessments as do the fossil fuel energy savings and their consequent carbon emissions reductions. The present authors with Professor Tapas Mallick at Heriot-Watt University undertook a detailed study for the city of Dundee that showed that solar energy potential exists within the city, given the right environment, to take about 5,000 households out of fuel poverty at a cost of around £67 million and a carbon emission reduction of some 4,443,781 kg of CO_2 [6]. Compare this cost to that of the Aberdeen Western Peripheral Route now under construction (£745 million) or the Edinburgh Tram (£776million) and factor in the enhanced job opportunities and reduced health and well-being costs of families taken out of fuel poverty and the scale of the limitations of current life cycle cost analysis approaches become clear. It is not only in cities that solar becomes important in taking families out of fuel poverty but also in rural areas where families often pay more to commute to work and no access to cheaper gas. The whole lifestyle costs then become a factor in determining the descent into fuel poverty of households [7].

Dundee is home to the Solar Cities Scotland (SCS) office. SCS was founded to promote renewable energy of all types in a micro scale in Scotland. Since 2008, SCS has opened the “Sun City House” to the public [8]. Sun City House is an effort from the SCS to inform Scottish people of the benefits of renewable energy use in Scotland. It is a refurbished house constructed in the 1960s with poor insulation, a good sample of many Scottish houses today. Nevertheless, the project has clearly demonstrated how solar systems can effectively perform under Scottish weather conditions.

There are plenty of strong arguments for investing in renewable and solar energy in Scotland, not least because perhaps the only way to put paid to the rising fuel poverty rates [6] is to put the means of producing a household’s own energy onto the roofs of the poor. The existing evidence is now clear enough on the benefits of building integrated solar systems that investors and scientists are now taking an active role in serious discussions for a change. This report provides a quick estimation, based on confidence developed through previous detailed research on the subject, of how much solar thermal building integration can take place in Scotland and an approximate cost for this. It is a very initial estimation and therefore deviation from realistic numbers is possible. At the end of the report a method of getting more robust estimates is proposed.

In addition to these reasons to review current attitudes to the imperative for SHW is another new and compelling driver. Solar hot water systems include, within their hardware, large solar hot water tanks. Tanks containing between 250 – 400 litres of stored hot water are typical of such installations. If many Scottish homes, as described below in scenarios 1 and 2, had such tanks in them this would lead to over 200 million litres of heat storage being available across the country into which excess energy could be dumped when superfluous to demand (e.g. from wind), or which could provide hours of heat buffer in winter, effectively shaving the spiking peak load demand that government now fears may well turn the lights off in winter. So the thermal storage aspect of installing universal solar hot water systems across the housing stock may be an effective way to avoid building new power stations to meet the peaking demand during those fleeting peak load hours in winter.

In a warming world the emphasis on achieving real reductions in carbon emissions is escalating. Rather than relying on large scale, often fragile plants (four nuclear power stations and one coal fired power station are currently off line for some time in the UK) the resilience of the whole energy supply system is enhanced by embedding the potential to achieve carbon emissions at the level of individual buildings. The figures below show that the installation of SHW systems across Scotland could have a major impact on the energy demand of the whole nation and importantly its carbon emissions.

1.3 Solar City Mapping

Besides the Asian 'solar revolution' being played out in China and South Korea, there are many cities worldwide that have shown significant interest in maximally exploiting their own solar potential. One of the results of this interest is the production of local and regional solar maps.

Over last two decades GIS systems and aerial photogrammetry technology have greatly developed, and using them, cities have begun to build solar maps in order to be able to estimate the solar potential at their territory. A major solar mapping exercise was undertaken by the EU and led by the Joint Research Center (JRC) in 2001. The online tool is called "PVGIS" and it provides data for solar irradiation on horizontal or inclined surfaces as well as PV system potential energy generation throughout whole Europe [9]. It should be noticed, however, that the PVGIS shows solar potential is generally measured by land surface area without taking into account building integration suitability in cities.

Solar mapping as a technique for renewable energy assessment at the building level has been promoted by some individual city councils which have produced their own solar maps. Common characteristic of these projects is the examination of which building roofs can be used for solar systems installations. Jouri

Kanters et. al. [2] have researched several solar mapping case studies worldwide and identified 19 different situations which they analyzed. According to this study, the majority of all other solar city maps assessed followed the same process of at least one of these 19 models. Total system annual output in kWh and area per roof, heritage limitations and considered technologies were some of the parameters that Jouri Kanters et. al. compared between the 19 cases. Among these cases studied was the city of Bristol.

1.4 The case of the city of Bristol

Bristol is probably the only city in the UK that has applied solar energy research for building integration at an advanced level. The Bristol City Council, funded by the DECC, has produced its own solar map using LiDaR technology. The map identifies unshaded rooftops in the whole city and gives an output in the form of total solar irradiation available, unshaded roof area, PV system size and generation, CO_2 savings and other information per rooftop, all in annual sums (fig. 1).

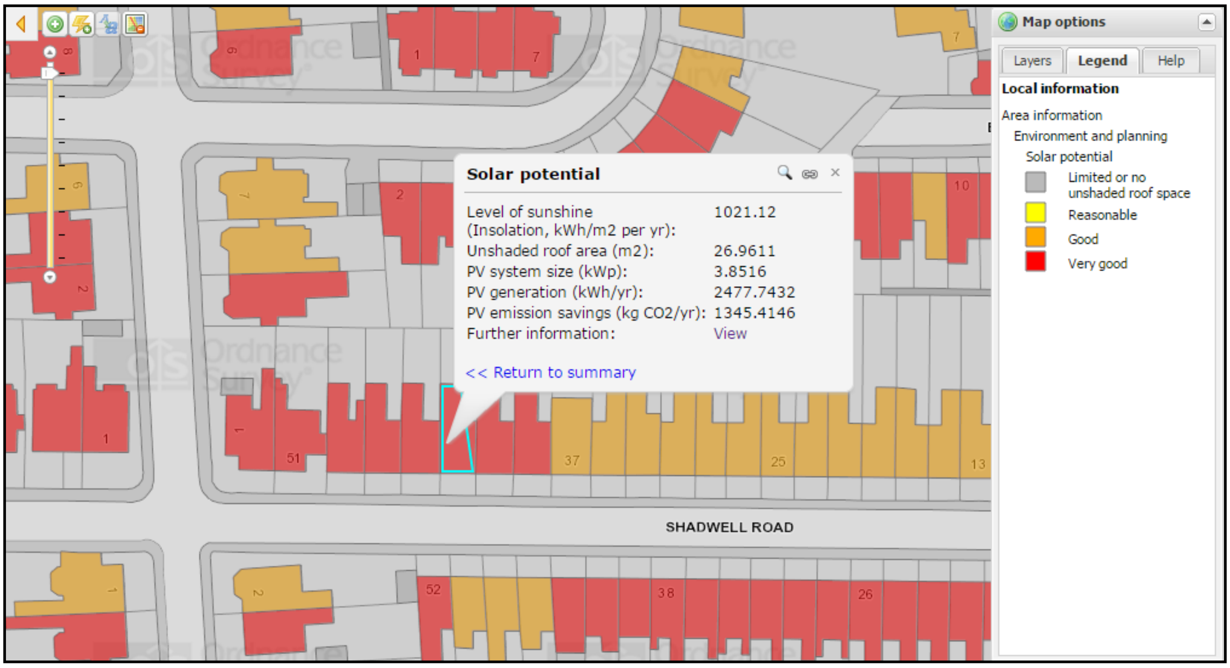

Figure 1 Bristol solar map detail [10].

The solar energy assessment carried out by the Council estimated that about 80,000 rooftops, a third of all in Bristol, are suitable for solar systems installation. This means that 605 MW of PV, 63% of the capacity of Scotland's nuclear Hunterston B power station, is feasible if these rooftops are to be used for building integrated PV (BIPV) [11].The final result above was produced after the initial Bristol solar map findings were checked by 5 PV installers. Those identified the overestimates of the map findings and gave advice to the Council on what they believed a more realistic outcome should be.

Other regions have also used the DECC methodology for renewable energy capacity estimation, like West Midlands. However, in the council published report, a total number of PV and SWH capacities are only shown per district and no further details were given [12].

2. SWH capacity assessment in Scotland

2.1 The DECC methodology

The "*Renewable and Low-carbon Energy Capacity Methodology*", prepared and published by the DECC in 2010, is a simple guide for addressing the renewable energy capacity over wide areas, such as cities [13]. It is a quick but also consistent technique for English communities to calculate how much PV power for example can become available if all suitable rooftops in a city turn to solar roofs (see the Bristol case in §1.3)[a]. Emphasis is nevertheless given on the scope of the methodology: of the total seven stages for developing a comprehensive evidence base for renewable energy potential, only the first four are covered by the methodology. These are:

1. **Naturally available resource**
2. **Technically accessible resource**
3. **Physical environment constraints of high priority**
4. **Planning and regulatory constraints**

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5. Economically viable potential
6. Deployment constraints (supply chain)
7. Regional ambition – target-setting

Concentrating on the solar energy potential, the suggested assessment of the DECC methodology is presented in table 1. For stages 1 and 2, the Scottish House Conditions Survey (SHCS), prepared by the Scottish Government, has been used as the resource data [14]. This survey provides all the essential information about the population of the dwellings in Scotland and their construction period.

As it can be seen from table 1, the end result that the DECC methodology suggests comes of very rough. It is a 'rule of thumb' for an initial estimation of the renewable energy capacity in a region. This is anyway the purpose of this report, the data and results of which are presented in the next paragraph.

[a]The methodology is targeted for the English regions. No further directions have been published by the DECC for the rest of the UK. As there are no other consistent methods available the DECC methodology is currently used in this report for the Scottish regions.

Table 1 Detailed assessment of opportunities and constraints for solar energy (table 3-8 in the DECC methodology, §3.24)

No	Parameter	Description	Assessment requirement	Where to resource data from
Opportunity assessment – natural and technically accessible resource				
1	Existing roof space	Number of roofs suitable for solar systems	Apply the following assumptions for number of suitable roofs: • Domestic properties - 25% of all properties (including flats) • Commercial properties - 40% of all hereditaments • Industrial buildings - 80% of the stock	CLG Statistics English Housing Survey (EHS) ONS data
2	New developments	Number of new roofs suitable for solar systems	Assume that 50% of all new domestic roofs will be suitable for solar systems	RSS new housing provisions
3	System capacity	Average generation capacity of an individual system kW	Apply the following assumptions for average system capacity: • Domestic - 2kW (thermal or electric) • Commercial - 5kW (electric only) • Industrial - each region use their own assumption	no data required
Constraints assessment – physically accessible and practically viable source				
4	n/a		No specific parameters have been defined as most constraints have already been taken into account in the assumptions applied for the parameters above.	no data required

2.2 Results

The key findings of the SHCS are given in table 2 below.

Table 2 Number of Occupied Dwellings by Age Band and Type (Table 2, §2 in the SHCS)

Age of dwelling	Dwelling Type					**Total**
	Detached	*Semi-detached*	*Terraced*	*Tenement*	*Other flats*	
pre-1919	122,000	69,000	60,000	188,000	64,000	503,000
1919-1944	48,000	78,000	35,000	33,000	90,000	284,000
1945-1964	35,000	131,000	170,000	111,000	81,000	527,000
1965-1982	102,000	117,000	190,000	86,000	33,000	529,000
post-1982	211,000	94,000	48,000	151,000	38,000	542,000
Total	**518,000**	**490,000**	**503,000**	**569,000**	**306,000**	**2,386,000**

It should be noticed that the type of the dwellings have no impact in the DECC calculation. What is more, the Scottish dwellings built after 1982 were considered as new developments in this study.

For the assessment below the SWH system studied in Ref.[6] was taken into account. The system capacity is $2kW_{th}$, has an area of $3.3m^2$ ($0.61\ kW_{th}/m^2$) and is suitable for a family dwelling.

2.1.1 Scenario 1 (low)

Here the DECC methodology factors are applied to the total number of dwellings (before and after 1982, i.e. existing and new developments, respectively). The average SWH system capacity according to the methodology is $2kW_{th}$. This is indeed an average system for a family house which can cover more than 50% of hot water use in the house annually. Therefore:

Existing roof space

No.rooftops suitable for solar integration:

1,844,000 No.dwellings X 25%DECC factor = 461,000

SWH system capacity:

461,000 X $2kW_{th}$ = 922 MW_{th}

New developments

No.rooftops suitable for solar integration:

542,000 No.dwellings X 50%DECC factor = 271,000

SWH system capacity:

271,000 X $2kW_{th}$ = 542 MW_{th}

Totals

732,000 No.rooftopswith a total **1,464 MW_{th} SWH capacity**.

Energy yield and CO_2 savings (not covered by the DECC methodology)

1,049[b] kWh/system/yr X 732,000 systems = 767,868,000 kWh

CO_2 for electricity displacement

767,868,000 kWh X 0,517 kgCO_2/kWh = **396,988 tonnes of CO_2/yr savings.**

The number above corresponds to **542.33 kg of CO_2** saved per system per year.

CO_2 for gas displacement

767,868,000 kWh X 0,198 kgCO_2/kWh = **152,038 tonnes of CO_2/yr savings,**

And **270.7 kg of CO_2** saved per system per year.

2.1.2 Scenario 2 (high)

Unfortunately, there is not any official feedback survey of how accurate the DECC methodology is. The Bristol case was the only study available at an advanced level that compared realistic findings against what DECC would suggest. It was thus found that DECC methodology underestimated the Bristol solar map findings by 63 – 81%. This is a significant number and means that from the total SWH system capacity that DECC indicates this should be increased to achieve a more realistic figure. This study cannot ignore this evidence and it seemed useful to include it as a second, more optimistic scenario (high). Hence, with the lower underestimation factor of the range the optimistic result is:

1,464 MW_{th} SWH capacity X 2.7 [c] = **3,953MW_{th} SWH capacity**.

The enhanced capacity above corresponds to 6,480,328 m^2 of SWH collector systems. Hence, following the same steps as in Scenario 1, the rest of the figures are:

2.06 GWh/yr and a) 1,065,000 tonnes of CO_2/yr savings for electricity displacement, b) 407,872 tonnes of CO_2/yr savings for gas displacement.

To have a better understanding of the magnitude of these two SWH capacities it can be said that the largest nuclear station in Scotland, Torness, has an installed capacity of 1,190MW [15] and the largest power station (coal), Longannet, has a capacity of 2,400 MW [16].Therefore, the capacities in Scenarios 1 and 2 are,

[b] Energy produced by the SWH system in ref.[6] with an average annual solar irradiation in the main Scottish cities of 880kWh/m^2yr.

[c] Bristol figure is underestimated by 63%, or equally: DECC figure = 0.37*Bristol figure, therefore 1/0.37=~2.7

respectively, much more compared to the capacities of these two very large scale conventional plants. Furthermore, the energy estimated in the optimistic scenario (2.06 GWh) has a proportion of 21.65% of all renewable energy produced in Scotland in 2010 [17].

2.3 Cost assessment

DECC does not cover economic assessments and costs in the methodology. It is obvious that the cost estimation of such a huge investment is really complicated and many regulatory bodies and investors will have to contribute to come to financial consensus. However, as the purpose of this report is to provide initial cost estimation, only the price of an average SWH system will be considered. As the vast majority of the systems will be installed in main cities in Scotland the transportation cost as well as labor cost is assumed to be included in the total price of the individual system.

The SWH system used in Ref.[6] has a cost of £1,893 (system kit consisting of the flat-plate collector, water tank, pipes, antifreeze, etc.). Following the results found for the two scenarios we arrive at a cost estimation as shown below:

Scenario 1 (low)

732,000 No.systems X £1,893 = **£1,385,676,000**

Scenario 2 (high)

3,953MWth / 2kWth = 1,976,500[d]No.systems

1,976,500 No.systems X £1,893 = **£3,741,514,500**

2.4 Discussion

As already stated in §2.1.2, the accuracy of the DECC methodology has not been officially evaluated yet. Moreover, it is not known to the authors how the factors suggested in the methodology that SQW energy prepared for the DECC have derived. It is therefore really difficult to judge how much the two assessment scenarios presented here are close to reality. Bristol Council had the opportunity to

[d] See sub-note e; the total no. Systems can be more than one in large residential buildings such as tenements.

consult 5 different PV installers, compare their data against Bristol's solar map findings and realize that the DECC methodology is significantly underestimating the total capacity which the Council gauged in the end. This is why this report presented a more optimistic scenario.

The main limitation of the DECC methodology is thus the determination of how many roofs are suitable for solar systems integration. The 25% and 50% approach for existing and new developments, respectively, is a very rough rule of thumb and it does not take into account parameters like object shading (e.g. nearby trees or buildings), roof structure and space suitability (windows, chimneys, antennas, etc.) and dwelling type/roof area available for system sizing[e]. Planning and regulatory constraints (stage 4, table 1) should also be considered. Edinburgh for instance is known for its constraints on any architectural intervention of the Georgian tenements in the city centre as this is protected by UNESCO's world heritage manifest. This kind of constraints has a strong impact on the renewable capacity potential in a city and should be definitely considered.

The SWH potential capacity can be even more if commercial buildings are also included in the study. Most new and refurbished commercial buildings make use of solar energy for hot water. This is a usual renewable energy option proposed by the building regulations to manage to reduce the CO_2 emissions in building energy consumption and increase energy performance[f]. However, the DECC methodology does not include SWH capacity calculations for the commercial sector (table 1, stage 3). This is an important limitation of the methodology when it comes to a point that this capacity must be estimated.

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[e]In realistic terms different types/sizes of dwellings will have different system capacity. A detached house for example, in which only one family lives, will need one system. A semi-detached with two families will need two. In larger buildings (tenements, blocks, residential towers) the problem becomes more complicated. Needless to say, that DECC assumes that even these buildings will get only one system with average capacity ($2kW_{th}$). This is an obvious underestimation and that is why Bristol Council has come to the comparison results discussed already. The problem is eliminated if GIS and LiDaR technologies are used to determine physically how much roof area is suitable for solar systems integration.

[f]See the current Part L Building Regulations for more information.

3. Conclusion and future work

The Bristol case in the UK demonstrated that solar energy potential mapping is feasible, if organized studies are prepared and published under the auspices of local or central governments.

The DECC methodology has been used in this report to calculate the SWH potential capacity in Scotland in the domestic sector. Two scenarios have been examined.

In the pessimistic (low) scenario, in which the DECC methodology was applied, it was found that 732,000 rooftops are suitable for SWH integration with a total capacity of 1,464 MW_{th}.

In the optimistic scenario (high) the total capacity was found 3,953MW_{th}. This was 2.7 times higher than the figure estimated in Scenario 1, following the findings of the Bristol showcase on the DECC methodology underestimation of determining the total solar potential capacity realistically. Both two scenarios give a total installed (solar thermal) capacity greater than some of the largest conventional power stations in Scotland. The CO_2 savings are significant, accounting for 396,988 and 152,038 tonnes annually for electricity and gas displacement respectively in scenario 1 and 1,065,000 and 407,872 tonnes for scenario 2.

The total cost for a wide implementation of these scenarios is £1,385,676,000 and £3,741,514,500, respectively. These figures came out with only taking into account the price of an individual SWH. A more complex economic study is needed to have a better image of real costs.

The limitations of the DECC methodology were discussed above and the main conclusion is that calculations similar to the ones done here are really complicated and cannot rely on rules of thumb. The most appropriate method that is currently available using aerial photogrammetry technology should be used if a detailed and accurate estimate is to be arrived at. Accurate 3D photographs of high resolution can capture the geographical characteristics of wide scale terrains using special laser sensors. High terrain resolution of even 5cm on the target plane is feasible according to up-to-date technology. The photographs are saved in a GIS mapping system in which the user can extract data like 3D objects, shadings, even material properties. Hence, roof area suitability can be calculated with great accuracy if the right properties are set on the map. When the available roof areas are identified by the software then these are being cross checked with solar potential maps (like that of Ref.[9]) and a total PV electrical or SWH thermal capacity and annual energy generation are yielded. This was the method applied in the Bristol showcase. The more accurate the LidAR data the closer to the realistic values the solar potential capacity in a city can get.

It is obvious that an enormous solar potential exists in Scotland. The multiple benefits of using solar energy in Scotland are becoming more widely accepted, not only by individuals but also by decision makers, industry, investors, academics and green-thinkers. With proper policy action taken and detailed studies developed to underpin investment, government at all levels can develop building integrated solar programs that can only bring growth, prosperity and higher living standards to the people of Scotland.

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APPENDIX 1. The Solar Cities movement

Organized green communities worldwide, energy independent with decentralized generation, distribution and storage, careful environmental treatment of the urban zones and healthy society are just some values of the future that the founders of the International Solar Cities Initiative (ISCI) have dreamt for humanity when they gathered in Daegu, South Korea, in 2004 and decided to work together 'for a better world'.

Their word, known as "The Daegu Declaration", represent these values clearly[g]:

> "*In order to ensure our common future, we have come together today to commit ourselves to achieving sustainable development and climate protection through the application of renewable energy and the efficient usage of energy. As part of any solution to the global climate problem, the importance and role of cities is paramount. Through active collaboration among International Solar Cities, energy efficiency policies and renewable energy technology and industries can be introduced and promoted actively by each city*".

Two of the founding city members of the ISCI have promoted renewable technology substantially since the Daegu Declaration. The ISCI 2004 Congress hosting city, Daegu, already numbers installed PV systems in 1,178 sites, 7.5 MW of SWH in 299 sites, a 462kW of PV and solar thermal generation facility in the EXCO campus, a 200kW solar thermal tower, a 200kW Daegu World Cup Stadium underpass, a solar campus at Kyungpook National University and many other significant renewable energy projects, such as the 11.2MW fuel cell power plant, the hydrogen production and charging station and the energy storage demonstration for 100 households[h,i].

On the other side of the East China Sea, Dezhou has started to transform into a solar city. The famous "Solar Valley" (fig. 2) is the city's characteristic example of a

[g] International Solar Cities Initiative, The Daegu Declaration, [Online], Available: http://iscicities.org/dgd.htm

[h] International Solar Cities Initiative, Member Cities, DAEGU (Korea) Showcase, [Online], Available: http://iscicities.org/members_dgs.htm

[i] WEC 2013 Organizing Committee and the Daegu Metropolitan Government, Green Energy Tour Program.

rapid boost in the solar industry development. Today Dezhou solar energy enterprises generate an annual turnover of $3.46 billion[j]. 99% of the central district houses use SWH on their roofs and 800,000 people are employed in the solar industry[k]. As an ISCI city member, Dezhou really believed in the Daegu Declaration values and is one of the leading cities globally which promote solar energy development so widely.

There is no point of listing all the case studies worldwide to prove that the Solar Cities Movement is happening. The examples above are just showcases of right renewable energy policies in a community level to help societies gain their energy freedom, achieve high growth rates and live in better and greener urban environments.

(a) (b)

Figure 2 Dezhou's Solar Valley (a) 3D graphical design and (b) project implementation.

[j] Wei Yong, Green Economic Development with Renewable Energy Industries, International Renewable Energy Agency Publications.

[k] Alex Pasternack (2009), Almost Everyone Has a Solar Water Heater in Dezhou, China, Treehugger [Online], Available:http://www.treehugger.com/renewable-energy/almost-everyone-has-a-solar-water-heater-in-dezhou-china-video.html