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The role of solar energy for carbon neutrality in Helsinki Metropolitan area

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Abstract: Helsinki Metropolitan area possesses significant solar potential, which can be utilized by installing solar panels and collectors in the cities' public and private premises to fulfill the emission reduction targets. However, current development of solar energy production in the region is in its infancy. This paper outlines how current state of solar energy utilization can be improved in public and private buildings and utility companies in the Helsinki Metropolitan area in terms of costs and financial mechanisms. We applied document analysis and semi-structured interview methods to study the role of solar energy for carbon neutrality in this area. The analyses showed that the Metropolitan cities do not have clear electricity production targets from solar energy yet. Furthermore, their subsidy schemes and financial measures for solar energy productions are not attractive for the promotion of solar energy. Thus, we propose the Metropolitan cities to adopt a policy outlining that a certain percentage (e.g. 20%) of energy should be produced from solar energy to achieve the 20% renewable energy target by 2020. Financial incentives and subsidy schemes for solar power installations should be more tempting and accessible to private and public building owners.

ABOUT THE AUTHOR

Karna Dahal is a PhD candidate in the Department of Environmental Sciences at the University of Helsinki. His research work within the Urban Ecology Research Group (UERG) focuses on exploring new solution-oriented methods and policies for the development of carbon-neutral cities. His areas of expertise are energy technologies, climate policies, and green chemistry. UERG focuses on research and teaching in urban setting and sustainable urban development. This research paper helps to enhance the small-scale solar energy production in the building premises. It is also helpful for promoting solar energy in the dark climatic region and achieve the carbon neutral goal of the cities around the world.

PUBLIC INTEREST STATEMENT

Cities in many countries are identifying the means of cleaner production and sustainable consumption of local energy resources to tackle the climate change and to ensure energy security of their regions. Renewable energy promotion is one way of fighting with the climate change and ensuring energy security of the cities because renewable energy sources are clean and available locally. Thus, cities need to produce renewable energy from various available sources in their local area. This perspective article describes the situation of small-scale solar energy production in the cities of Helsinki Metropolitan area and various economic measures to promote solar energy productions in the buildings in this region. Based on the various document analyses and interviews, it was discovered that implementation of subsidies and attractive financial schemes and attitude changing activities are essential for cities to promote small-scale solar energy in their buildings in the Helsinki Metropolitan area.

Subjects: Environment & Economics; Environment & the City; Environmental Policy; Environmental Politics; Environmental Change & Pollution; Renewable Energy; Building Regulations; Building Techniques; Energy policy and economics; Solar energy

Keywords: carbon neutrality; public and private buildings; subsidy schemes; financial measures

1. Introduction

Cities are currently responsible for generating 60–70% of the global greenhouse gas (GHG) emissions (Kammen & Sunter, 2016). Due to national and international political agreements, cities around the world are obligated to reduce GHG emissions (Bridge, Bouzarovski, Bradshaw, & Eyre, 2013; Fuller, Portis, & Kammen, 2009). In research, focus has been placed on urban climate policies, energy transitions, urban infrastructure regimes, and socio-technical niches to understand how to reduce GHG emissions and establish low carbon or carbon neutral cities (Bulkeley, Castán Broto, & Maassen, 2014; Fuller et al., 2009; Rohracher & Späth, 2014).

The economic and environmental need to transition to a low-carbon economy is one major concern around the world (Fuller et al., 2009). In general, major electricity consumption occurs at buildings in cities and a critical transformation in buildings is needed to fulfill the GHG reduction targets. Approximately 75% of the total global heating demand, which is 40–50% of total energy demand, occurs within the building sector (Wang, Yang, Qiu, Zhang, & Zhao, 2015). Energy transition to low carbon or carbon neutrality requires a shift of energy production from fossil fuels to the cleaner energy sources (Kammen & Sunter, 2016). In addition, decentralization of energy generation can be a core strategy to the promulgation of the low carbon or carbon neutral logic (Bulkeley et al., 2014). Thus, energy production from solar technology becomes important for the cities to reduce significant GHG emissions and fulfill their emissions reduction targets. This also promotes energy security of a region.

Energy transition to renewable energy is an important factor for carbon neutrality. Energy transition is dependent on the geographic situations that cause the niche to evolve, be incorporated into the regimes, and landscape variations (Bridge et al., 2013). Solar energy production is becoming most popular among the renewable energy sources due to the falling prices of photovoltaics (PVs) and technological advancements (Campbell, 2017). Energy production from solar PVs and collectors is also worthwhile in the high-latitude Finnish residencies despite dark winter conditions (Zalpyte, Work Efficiency Institute (TTS), BEF-Latvia, & Hovi, 2013). Currently, Finland has targeted to produce 38% renewable energy mix by 2020 while the City of Helsinki has targeted to produce 20% of its energy from renewable sources by 2020 (Dahal & Niemelä, 2016; International Energy Agency, 2013).

Although several cities have legislated carbon neutral targets to address the climate change, much of the efforts have been focused on technology and policy solutions, with little attention given to how such aspiring goals can be realized through productive financial measures. To attract the city dwellers and energy utilities to install solar panels and thermal collectors at their residential houses and utility facilities, central government, city councils, and the energy authorities should establish several measures which include attractive economic and policy plans. Effectiveness of such measures depends on the roles of the government, city organizations, and utility companies in bringing the solar technology in realization. Thus, economic feasibility of the solar plants is the most important in the implementation process.

Very few studies have been conducted related to the feasibility of solar energy production in building premises in the Helsinki Metropolitan area. In addition, financial measures are missing in the available research and policy papers. This article focuses on two major research questions:

(1) How the current state of solar energy production can be improved in the public and private buildings in the Helsinki Metropolitan area in terms of costs and financial mechanisms?

(2) How solar energy production in the buildings can help cities in the Helsinki Metropolitan area to reach their 20% renewable energy production target by 2020 and carbon neutrality target by 2050.

The paper discusses various financial measures to install solar plants at buildings. To do so, we analyze documents from various sources and conducted interviews by solar energy experts, producers, and users in Helsinki Metropolitan area. Our findings show that Helsinki Metropolitan area possesses significant solar energy potential which can be utilized through various economic measures and motivating programs.

2. Background

Solar energy production in residential and commercial building sector is growing rapidly because of technological and economic advances (Fuller et al., 2009; Wirth, 2017). Real estate are becoming core of cities' energy policies to reduce GHG emissions (Fuller et al., 2009; International Energy Agency, 2014; Wirth, 2017). For instance, several cities in California (United States of America) have set targets for "net zero energy" for new buildings (Fuller et al., 2009). Installing solar plants in buildings also provides benefits such as new source of employment, reduced strain on the electric power system, and development of more comfortable and well-maintained buildings (Fuller et al., 2009). This will also help to establish zero emissions buildings and to create carbon neutral cities or regions.

A small-scale solar energy system has the ability to offer low to zero carbon emissions, offset capital-intensive investments for network upgrades, improve local energy independence and network security, and motivate social capital and cohesion (Kammen & Sunter, 2016). Both the small-scale and utility scale-solar energy productions have been growing slowly in Helsinki Metropolitan area in the recent 2–3 years, although the utility-scale solar energy production has more attractive supports from the Finnish Government than the supports for distributed solar energy production (MTV, 2016). One reason behind this can be recent changes in regulations for energy consumption in buildings, which are considered stricter than they were previously (Hakkarainen, Tsupari, Hakkarainen, & Ikäheimo, 2015).

The Helsinki Metropolitan area situated on the southern coast of Finland (at 60˚ N) receives about 870 kWh/m^2 insolation annually (European Commission, 2012). With this insolation, solar panels and thermal collectors effectively generate heat and electricity as most solar technologies function well in this solar irradiation level (Laleman, Albrecht, & Dewulf, 2011; Zalpyte et al., 2013). In Finland, long period of daylight in the summer compensates the winter darkness (Motiva, 2016a). Thus, energy production from solar PVs and collectors is also possible at Finnish residencies (Zalpyte et al., 2013). Despite this, only a limited number of private households and public buildings have installed solar panels and thermal collectors in the Helsinki metropolitan area.

Recent modeling Lidar data for solar insolation over roof parts at Helsinki Metropolitan area confirms that significant potential of solar energy exists in the area. It is estimated that a total of 1.93 TWh/year solar potential is available from 17.3569 km^2 area of suitable roofs in the Helsinki Metropolitan area (Kesäniemi & Räsänen, 2017). The City of Helsinki alone has 7.450 km^2 suitable roofs at 37 171 buildings which can yield 809.2 GWh/year of electricity, if all the roofs are covered by solar panels (Kesäniemi & Räsänen, 2017). The solar potential in building roofs in Helsinki area can fulfill 5.4% of total energy demand in the city and about 5–7% total energy demand in the Helsinki Metropolitan area. If the solar energy is produced from building walls, this amount will be largely increased.

A total of 1 984 MWh solar electricity was connected to grid in Helsinki Metropolitan area in 2015, which is a significant increase from 385 MWh in 2012. Two larger solar plants in Suvilahti (275 MWh annual production), and Kivikko (800 MWh annual production) alone produced total of 1 075 MWh electricity enough for 537 one-bedroom apartments (Galkin-Aalto, 2015; Uusitalo, 2015). In addition, energy extraction from buildings to cooling network is as considered solar energy and almost 32 GWh of district heat was produced during the summer 2012 from cooling network in Helsinki and about half of that was estimated to be solar energy (Hakkarainen et al., 2015).

3. Materials and methods

Document analysis and semi-structured interviews methods were used to study the role of solar energy for carbon neutrality in the Helsinki Metropolitan area. Semi-structured interviews consist of several key questions that help to define the areas to be explored, but also allows the interviewer or interviewee to diverge to pursue an idea or response in more detail (Gill, Stewart, Treasure, & Chadwick, 2008). In comparison to structured interviews, this method also allows flexibility on the expansion of information to participants that may not have been previously thought of by the interview team (Gill et al., 2008). A total of eight respondents in the Helsinki Metropolitan area were interviewed individually; one respondent from the energy industry (Helsinki energy company, Helen Limited), two respondents from Helsinki Region Environmental Services Authority (HSY), one respondent from the University of Helsinki, two respondents from the City of Helsinki, one respondent from solar technology providing company (Solnet Green Energy company), and one respondent was local citizen. All these organizations and companies have installed solar panels in their buildings. The local citizen is also a renewable energy expert and he has installed solar panels and thermal plants in his building. Due to the infancy state of solar energy development in the Helsinki Metropolitan area, a relatively small number of respondents were involved. However, the information obtained from these interviewees were beneficial to analyze the documents related to solar energy development scenarios in this region. The names of interviewees and some personal and institutional information related to data were kept confidential.

The main purpose of conducting interviews was to explore the views, experiences, expectations, and motivations of solar plant owners, energy experts, and solar energy and technology providers. The interview data were collected according to several themes used in the interview questions (see Appendix A). The categorized themes were:

- Solar plants owners' motivations and satisfaction with energy production
- Subsidy systems and financial measures
- Procurement processes of solar equipment
- Solar economy and technology situations
- Current problems and improvement measure for solar energy production

These categorized themes used in the interview transcripts were applied to the contents of documents.

Document analysis is a form of qualitative research in which documents are interpreted by the researcher to provide robust understanding around an assessment topic (Glenn, 2009). It also incorporates coding content into themes similar to how interview transcripts are analyzed (Glenn, 2009). Document analysis helped to supplement data from the semi-structured interviews. It provided (1) background and context of solar energy development, (2) information about the factors affecting the promotion of solar energy, (3) additional questions to be asked while conducting interviews, (4) supplementary data for the entire context of the research, and (5) verification of findings from interview data sources. We analyzed various types of documents, such as several solar energy data, periodic or final reports related to solar energy technologies, climate and carbon reduction strategies of the cities, and solar energy production data and assessment documents gained through the interviews. Most of these documents were obtained from the websites of the associated companies and organizations. Documents were also employed to verify and situation analyses of the interviews data.

Both the document analysis and interview methods proved complementary to each other for the collection and analysis of the data related to solar energy and carbon neutrality in the Helsinki Metropolitan area. There are very few policy and research documents related to solar energy in Helsinki Metropolitan area.

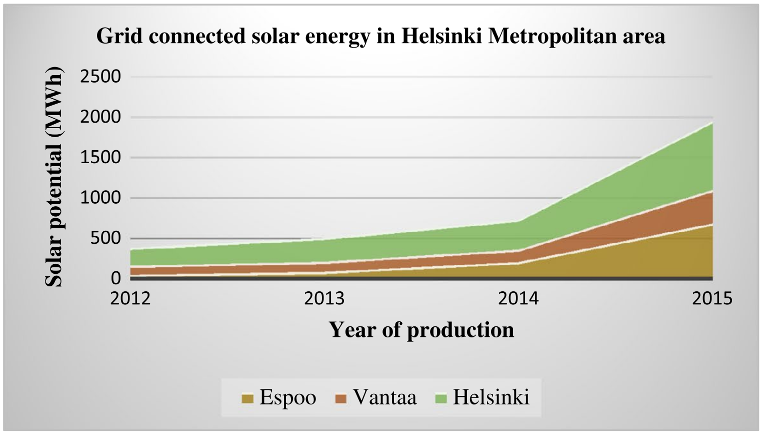
4. Results

4.1. Current state of solar energy in Helsinki Metropolitan area

Despite having such a big solar potential in this region, only very small amount (about 2 GWh/year) energy has been extracted from solar plants (Figure 1). Several utilities, companies, and organizations have started installing solar panels recently in their roofs and the grid connected solar energy production has started to increase (Figure 1) but private buildings and housing companies are still behind the progress (Hakkarainen et al., 2015). A comparable proportion of development to solar energy production happened in 4 years in three Metropolitan cities (Helsinki, Espoo, and Vantaa) but the City of Kauniainen does not have any solar energy production yet (Figure 1). The City of Helsinki is leading the progress as it produced 851 MWh in 2015 while the cities of Espoo and Vantaa produced 686 and 417 MWh, respectively, in 2015 (Figure 1). Yet, this amount is negligible in comparison to the available solar potential in the Helsinki Metropolitan area (theoretically over 800 GWh/year). The respondents commented that many people still have the misconception that solar energy production is not feasible in the dark winter climate of Helsinki. However, recent development shows that attitudes towards solar energy production in Helsinki Metropolitan area are changing. People are becoming more climate friendly and take interest in clean technologies (Jung, Moula, Fang, Hamdy, & Lahdelma, 2016). In the same time, the purchasing price for equipment used in solar plant has been lowered (International Renewable Energy Agency, 2016). However, the central government and Metropolitan cities do not have clear electricity production targets from solar energy which is not encouraging for the promotion of solar energy in this region and realization of the carbon neutrality target by 2050.

Figure 1. Grid connected solar energy in Helsinki Metropolitan area.

Sources: Helen Ltd., Caruna Oy, Vantaan Energia; HSY.



4.2. Solar energy prices and subsidies scenarios

Financial feasibility of solar energy production can be mapped through the investment cost, component prices, technological development, subsidies, taxes and distribution fees. General equation for the production cost, return on investment cost, and energy payback time of solar energy can be expressed as (Auvinen, 2016a):

$$\text{Production cost}\,(€/\text{MWh}) = \frac{\text{Life cycle cost}\left(\frac{€}{\text{MWh}}\right)/\text{m}^2,\text{pv or collector/year}}{\text{Total system output}\left(\frac{\text{MWh}}{\text{m}^2,\text{pv or collector/year}} \times \text{performance time (year)}\right)} \quad (1)$$

Life cycle cost includes system investment (€/m²) and operating and maintenance cost (€/m² collector or PV surface) (Auvinen, 2016a). Performance time for the solar energy system is usually 30 years (Auvinen, 2016a). The estimated production cost for a solar power plant of 3.5 MW capacity in general condition is about 16.3 c/kWh in Finland at this time.

$$\text{Annual return on investment}\,(\%) = \frac{\text{Net yearly energy saving cost}\,(€)}{\text{Cost of investment}\,(€)} \times 100\% \quad (2)$$

Net yearly energy saving cost can be obtained from adding the cost of solar energy production and cost of surplus energy sold in a year and subtracting all taxes and maintenance costs. Energy payback time can be calculated with Equation (3) (Bhandari, Collier, Ellingson, & Apul, 2015).

$$\text{Energy payback time (years)} = \frac{\text{Total investment cost}\,(€)}{\text{Yearly return on investment cost}\,(€/\text{years})} \quad (3)$$

Currently, investment costs rebate on PVs with 25% subsidy is approximately 6.6% annual return for 13 years as per the average prices of the energy in municipalities in Finland (Auvinen, 2016b). This is still quite a long payback time with a small rebate margin of the investment to solar energy because most investors expect to achieve payback within few years of the investment. In addition, payback period for energy production from fossil fuels and some renewable sources are usually short. However, this payback time is not applied to private and public building owners.

Table 1 presents the solar and traditional sources of electricity in Helsinki Metropolitan area. The data excludes online purchase transfer fees, energy taxes, and 24% value added tax (VAT). Solar electricity purchase price with the 25% subsidies is still a bit higher in comparison to the purchase prices for traditional sources of energy.

As the household does not get investment subsidies for solar energy production, solar electricity price becomes much higher than the traditional sources of energy. Currently, small-scale solar electricity production price is about 11 c/kWh with payback time 20 years. The price for solar heat production is also higher in comparison to heat production from fossil fuels. This shows that without subsidies solar heat and power production at residential and public buildings is expensive.

However, one respondent commented that even without the subsidies, current investment on solar energy can be aligned with the average purchase price, levelized cost of energy (LCOE). But, it seems to be correct only if the subsidies are provided to produce solar energy. LCOE is the

Table 1. Heat and electricity purchasing prices in Helsinki Metropolitan area

	Solar electricity price (c/kWh)	Traditional electricity (c/kWh)	Solar heat price (c/kWh) [4–100 m² collectors]	Fossil fuel price (c/kWh)	DH heat price (c/kWh)
Purchasing prices (excludes online purchase transfer fees, energy taxes, and value-added tax (24%))	6.67	4.5–5.8	3.7–9.2	Light fuel oil—6.9 Natural gas—4.6 Hard coal—3.9	5.81

Data sources: Helen Ltd. and Statics of Finland (Auvinen, 2016c; Helen, 2017; Tilastokeskus, 2017).

measurement for the cost of electricity produced by a solar plant in its lifetime which can be compared to the costs for different methods of electricity generations (Lai & McCulloch, 2016). It can be expressed as (Lai & McCulloch, 2016):

$$\text{LCOE} = \frac{\text{Lifecycle cost}(€)}{\text{Lifetime energyproduction}(\text{kWh})} \tag{4}$$

The average purchase price LCOE for utilities in Helsinki area is about 7.3–11.6 c/kWh and for small houses and condominium apartments are about 12–18 c/kWh (Auvinen, 2016c). According to the respondents, new solar enterprises have been established and solar promotions activities have been happening time to time. The City of Helsinki and HSY sometimes gather these enterprises to discuss about the solar energy investments.

In terms of investment cost per area for solar plant construction, larger solar plants require smaller investment costs in comparison to smaller plants (Equation 4). For instance, it costs approximately 300 €/m^2 for smaller and 200 €/m^2 for larger solar thermal plants constructions (Pasonen, Mäki, Alanen, & Sipilä, 2012). Similarly, system acquisition cost for residential solar plants reaches up to 7.3–11.6 c/kWh but it costs only 3.3–5.3 c/kWh for businesses and municipalities (Motiva, 2016b). The unit price covers the prices for panels, inverter, control, brackets, and wires and installation cost. Usually solar plants' major cost increases due to the secondary or system balance costs. For instance; about 53% of total cost increases due to the installation and additional costs such as cabling, permitting, financing, taxes, marketing, inspection, and interconnection costs (Pasonen et al., 2012). Maintenance cost usually arises between 5 and 10% of total investment cost. It depends on the size of the system, the smaller the system the higher the maintenance cost. For solar thermal plant, control unit, expansion vessel, and heat transfer fluids need to be replaced at least once in the lifetime of the system. The pump usually lasts for the full lifetime of a solar thermal plant (Motiva, 2016b).

The average price for district heat in Finland is about 5.5 c/kWh and it never reaches higher than 8 c/kWh (Pöyry, 2013) which is much lower than the cost for small-scale solar heat production in buildings. Therefore, solar heat production in the buildings is not seen as viable replacement of electricity and light fuel oil in the present pricing situation. Similarly, heat production from solar heating would be viable in the case of fuel crisis, tax exemption on solar energy, high subsidies for investment and installation cost, oil price increases, and price increases on CO_2 allowances (Auvinen, 2016c). However, heat production from larger solar collector systems connected to the district heat network would be beneficial because heat consumption from district heating network is enormous and spontaneous in comparison to typical solar heating network. This provides better return on solar investment but variable costs for replaced heat production also determines the return percentage (Pöyry, 2013). For example, Denmark has exploited its district heating network to integrate profitable heat production from solar (Hakkarainen et al., 2015). In fact, such integrations in the energy system are essential if the cities would like to generate significant energy from renewable sources to become carbon neutral. This will help to reduce further emissions from DH and helpful to fulfill the 20% renewable energy production target by 2020 and carbon neutral by 2050. At present, heat production from solar integrated combined heat and power (CHP) plant is also not feasible in dark climatic regions Finland.

Solar thermal is also profitable with other hybrid heating systems such as solar thermal collectors with electric heating, geothermal, air-water heat pump, radiant fireplace, and bioenergy (pellet boilers) (Hakkarainen et al., 2015). Hybrid solar energy production in Finland as well as Helsinki area is rare but promotions of such energy systems is essential to fulfill 20% renewable energy production target by 2020 and carbon neutral by 2050. It is also profitable for single family houses, especially when it replaces the DH because DH prices for single family houses in summer time becomes € 10/MWh higher in comparison to housing companies (Auvinen, 2016c). In addition, solar heating production businesses for corporate or municipal heating systems can be competitive with the other forms of heat production because such businesses can get investment subsidies and value added tax (VAT) is not liable for purchasing of heat production from solar heating systems (Auvinen & Liuksiala, 2016; Varonen & Myllymäki, 2014). Currently 20% subsidies are given to install solar heat collector plants which can rebate 5–10% on total investment cost during its lifetime production (Auvinen, 2016c). However, 20% subsidy is not available for small-scale solar heat production in building premises at present.

Subsidy systems play an important role in boosting the solar energy production. Several types of subsidy systems can be implemented, such as feed-in-tariff systems, renewable energy subsidies, tax exemption for solar energy production, investment cost subsidies, and subsidies in maintenance costs or inverter replacement costs. Feed-in-tariff system for renewable energy production is quite common in European Union (EU) member countries. Finland has investment support for solar energy productions, but the support is available only for the public sector and companies. High enough feed-in-tariff is required to promote solar energy production. If higher feed-in-tariff is applied, lower payback time is achieved and higher rate of PV installations will be possible. Feed-in-tariff for energy production from renewable energy sources (wind, biogas, and wood fuel) in Finland is 83.5 €/MWh but solar energy is excluded in the Finnish feed-in-tariff system at present (Energy Authority, n.d.).

Yet, some benefits are available to compensate the lack of investment subsidy and feed-in-tariff for small-scale solar energy production in Finland. For instance; energy taxes are not obligated to small-scale solar energy production. Electricity produced for own use (<100 kW or 800 MWh/year) are exempted from tax (Vero, 2016). The household production of PVs smaller than 50 kVA does not need to pay income tax if the maintenance and loss of system value are higher than the value of the electricity sales (Varonen & Myllymäki, 2014). Similarly, the PV power plant installed in the existing utilities and building roofs are not liable to property tax in Finland (Vero, 2016). In addition, small households can also get up to 50% domestic help tax subsidy for the home renovation and installations work which is helpful for solar plant installations (Vero, 2017). However, this domestic help subsidy is limited to € 2,400/per person per year for maximum two persons in a family house with 100 € deduction in it (Vero, 2017). Respondents say that this is, however, a good financial offset for home energy-efficiency improvements and small-scale solar energy production in the private buildings. If the surplus electricity needs to be sold, the producer earns about 2–6 c/kWh from surplus energy sells but it costs about 0.07 c/kWh for transfer fees at present (Auvinen, 2017). Even though such transfer fees are not much applicable in the small-scale solar energy production, it reduces income from the sold surplus electricity. This means the government has an option to revise policies to avoid such electricity transfer fees from small-scale renewable energy production.

Some regulations are different in different municipalities which also impacts on the cost of solar energy production. For example, operational licenses are not required to install the solar plants in Vantaa which reduces the costs and administrative work (MEAE, 2017; PKSRVA. n.d.). However, other municipalities have not eased such building regulations to enhance the production of solar energy.

4.3. Effects of current financial mechanisms and subsidies

Solar energy investment movements dependent on subsidies, energy taxations, and price development for other energy sources (Auvinen, 2016b; Pöyry, 2013). Higher subsidies and lower energy taxes can provide short payback time with higher investment rebate rate. Similarly, cheap system component prices can also reduce the investment cost and lower energy production price. Households, housing associations, and co-operatives are currently excluded from the scope of the Ministry of Employment and Economy's investment aids and feed-in-tariff systems (Pöyry, 2013). This means that all building premises owned by the housing cooperatives and private individuals in the Helsinki Metropolitan area are automatically limited from such energy subsidies. Respondents feel that these immature financial incentive systems discourage the production of household solar energy. If sufficient subsidies are available for them, small-scale solar energy productions would be cost-competitive. But instead, investment subsidy amount has been reduced from 30 to 25% for PV power plants (MEAE, 2017) which – according to the respondents – has discouraged solar energy development.

4.3.1. 25-year analysis for a small-scale PV system

For example, total investment cost for a small PV plant (3.5 kW) with 14 solar panels occupying 20 m^2 installed in a resident's building costs about 6,500 € which produces 2,500 kWh solar energy annually. All produced electricity is consumed in that building. As this small-scale solar energy production does not get investment subsidy but gets domestic help tax subsidy about 5%, current consumer electricity price including taxes is 15 c/kWh. Minimum bank interest rate in the loan is 2%. Assuming price of electricity increase by 1% every year, annual maintenance cost 0.1% and inverter replacing cost 10% for 25 years, payback time would be 17 years. The average production price of solar electricity [LCOE] for 25 years would be 23 c/kWh. Similarly, the solar electricity production price at 25th year becomes 10 c/kWh. Due to the maintenance costs and inverter needs to be replaced in 15th year, the system will bear loss of 1 310 € until 25th year. However, if the current 25% investment subsidy is provided, payback time would be 12 years. The average purchase price of electricity for 25 years would be 18 c/kWh. Similarly, the solar electricity price at 25th year becomes 8 c/kWh. The average profit during 25 years will be about € 1 323. This shows investment subsidies and possible subsidies for maintenance costs and inverter replacement plays important role to make the solar energy profitable. If the bank loan is not taken, the solar electricity cost would become more profitable.

Though income tax leverage is not large, this may influence negatively on installation of larger solar plants. If the domestic electricity is sold, income tax is liable over the value of the electricity sold after deduction of expenses on solar power plants but such expenses are higher than the sold electricity price in Finland at this moment (Vero, 2017). However, household production and consumption of heat and electricity do not need to pay energy taxes in the current legislation. This is a good scheme for enhancing small-scale and household solar energy production.

According to several respondents, a few domestic solar energy producers feel that maintenance cost became too expensive for them. For instance, the solar collector plant installed in 1998–2002 in the EcoViikki area in the City of Helsinki costed a lot for maintenance. The household solar energy production can cost up to 10% of total cost to replace inverters (Hakkarainen et al., 2015). Other annual maintenance cost can be about 1% annually. This increases significantly the life cycle cost of the solar power plant. If subsidies are available for maintenance cost or at least replace the inverter during 15-year period, this would reduce the LCOE as well as cost of the electricity and heat price. If the current 20% investment subsidy is also available for small-scale production, it will encourage building owners and housing associations to install solar thermal plants in their buildings. Providing investment or any other subsidies which are not available for hybrid solar systems currently would also ease the solar energy investments.

One respondent considered that if investment subsidies are provided to home solar installations, people do not want to obtain domestic help tax subsidy due to both subsidies falling under same subsidy mechanism. He also thought that instead of increasing subsidies amount, subsidies should be slowly discontinued as the LCOE price is getting aligned with the other types of energy systems.

There are several possible financial mechanisms to purchase solar power plants such as investment from own capital, loan or cash debt, hire-purchase, financial leasing, and operations lease financing (Auvinen, 2015). Own capital investment is more profitable in comparison to others while loan or cash debt easies on the investment on the installation of solar plants. Own capital evades the costs from interest on the loans. Respondents also thought that loans provided by banks and other finance companies for investment to solar energy can be helpful but they become expensive, especially for private individuals due to the higher end user prices. However, municipalities can be loan guarantees for solar energy investment at the household level. Hire purchases and leasing agreements have the advantages that a municipality or a company can make investments without the need for collaterals. Majority of buildings in the Helsinki Metropolitan area are commercial companies' spaces and municipal offices which can be the advantages for cities and companies in this regard.

Even though the government's energy policy measures for solar energy productions at households and utilities is not looking attractive at present, residents and utility companies are quite satisfied with their solar energy productions. This is not due to solar plant holders obtaining incentives for solar plant installation and the profits they may earn, but they are quite aware of the green energy systems. This is a good sign for the development of renewable energy production and realization of carbon neutral target.

4.4. Measures to boost solar energy in Helsinki Metropolitan area

With the current energy policies, subsidy system, and the development of investment costs and production rates, PV energy production in Helsinki area cannot reach the renewable energy production targets (Pasonen et al., 2012). Even though the solar energy production is growing, it is still in its infancy in the Helsinki Metropolitan area. This pace of solar energy production cannot contribute to fulfill renewable energy production targets by 2020 and to establish carbon neutrality in Helsinki Metropolitan area by 2050. However, several measures in terms of energy policies, awareness programs, and attractive financial schemes can be implemented to boost solar energy. Such measures are, e.g. inclusion of solar energy in the real estate planning, profitable solar energy investment planning, municipalities' solar energy investment towards public interest favoring, cooperative participation of the municipalities in the acquisition of solar energy, and including zero energy building concept in energy policies (Auvinen, 2015). As many buildings and majority of the land are municipal properties in the Helsinki Metropolitan area, municipalities can provide their lands and roofs for solar energy production free of charge for a certain time.

Most respondents in this study were content with the current subsidies scheme but they also think that the government should increase the subsidies to boost solar energy production in Finland and Helsinki Metropolitan area. They think home renovation subsidies and investment subsidies both are essential to make solar energy profitable. Respondents also agree that subsidies are vital for the development of hybrid solar energy production and energy storage batteries both in the residential houses and utility premises. Few respondents think that cash payment for the investment finance is difficult for all the consumers but some energy producers invested in cash. Cash payment reduces the production cost of the solar energy and lowers the purchase price. They also consider easy loan access from banks or other finance companies can help to develop the solar energy productions at private and public buildings. Respondents reiterated that if the cities are obligated to significantly reduce emissions by certain deadlines or carbon neutrality by 2050, small-scale energy production in the public and private buildings is vital. They also agree that several packages of inspiring financial and policy measure are also essential to advance the small-scale solar energy productions in buildings in the cities in the Helsinki Metropolitan area.

Some current energy policies can be revised to boost solar energy production in buildings. For instance, if the energy transmission fee is avoided, it encourages the building owners to produce surplus solar energy. The cities in Helsinki Metropolitan area can adopt an energy policy outlining that a certain percentage of energy should be produced from solar energy to achieve the 20% renewable energy targets by 2020. Several other policy measures can support solar energy development in the Helsinki area. For instance, adopting a serious carbon pricing policy can promote the solar energy production. Another way of promoting solar energy production is to regulate quota obligations for electricity distributors and industries so that they should obtain a certain amount of electricity from solar energy and other renewable energy sources. This helps to promote solar energy production in buildings.

Similarly, a respondent says that several solar businesses have been established offering solar panel installations as well as handling of administrative processes for the construction of solar plants in their customers' properties. This includes obtaining permissions, applications for subsidies, and training of solar plant owners for operation of the solar plants. Currently, installation costs vary from one company to another. If the cities direct all the solar businesses and energy companies through common guideline instructions to take minimum amount of installation costs acceptable for both the companies and users, this can be financially rewarding for both the parties. Likewise, municipalities, environmental administrations, and other concerned parties are sometimes organizing seminars and workshops for informing people about the advantages of the solar energy production (Finsolar, 2017; Smart Energy Transition, 2017) but such activities can be performed more frequently. Although the solar energy production is in its infancy, the respondents consider it is one of the positive things happening in the Helsinki Metropolitan area.

5. Discussion

The results show that solar energy production at household level in the Helsinki Metropolitan area can be improved through various incentives and financial measures. The solar energy production is growing progressively along with changes in perception of the residents towards solar energy. Although the current development is in its infancy, lower purchasing price of solar equipment has made solar energy more accessible to individuals and companies. Several utility companies and residents have shown positive attitude towards the production of solar energy in their buildings in recent years.

One reason for the increasing popularity of solar power is that individuals and companies are looking for more climate friendly sources of energy. For instance, several utilities and residents' houses in Helsinki Metropolitan area have started installing both PVs and solar thermal collectors. Solar PVs and thermal plants in present days are more advanced, efficient, and economical which lowers the production and maintenance costs of the solar energy during the entire life time of the solar plants.

It has been observed that solar energy production at private and public buildings can be economically beneficial with subsidies. In addition, as it is clean energy, it significantly reduces emissions which help to achieve renewable energy production goals and fulfill carbon neutrality targets of the cities. In the case of larger scale production, solar energy can also be integrated with other sources of renewable energy systems such as geothermal, bio-energy or heat pump systems. It can also be integrated with the DH system. Such integrated systems are economically viable, techno friendly, and complementary to mainstream energy system (Hakkarainen et al., 2015). It will be helpful in fulfilling the carbon neutral target of the cities. Furthermore, retrofit efforts, such as improving energy efficiency and adding solar PVs and solar thermal systems, need to be expanded in buildings.

Nowadays some solar PVs and collectors as well as auxiliary equipment for installations are manufactured also in Finland (Auvinen, 2016a). Moreover, utilizing local production of community-based digital services which would work without changes in wiring can reduce the total investment cost for solar energy production. Currently, a few institutions and associations have started to promote solar energy production in Finland including Helsinki Metropolitan area (Hakkarainen et al., 2015). A few solar technology providers in Helsinki Metropolitan area are in the process for acquiring the permission from local energy network and municipal permissions for solar plant installations. All these activities are vital to the development of solar energy productions. Yet, solar energy promotion activities are happening at slow pace.

Subsidies are vital for the promotion of solar energy. With the current subsidies and current state of investment costs and production rates, small-scale PV energy production in residential houses and building corporations is not economically competitive as compared to energy production from fossil fuels. However, larger production of solar energy with current 25% investment subsidies have made it inexpensive as compared to small-scale production and comparable with the other sources of energy production. The government can bring attractive subsidy mechanisms such as feed-in-tariff-system as in Germany (12.31 c/kWh for larger production and 6.26 c/kWh for smaller production for 20 years) (Wirth, 2017) to boost small-scale solar energy production in Finland. If the currently distributed 25% investment subsidy is also available for small-scale solar energy production in building premises, it will definitely attract more citizens to install solar plants in their buildings as it becomes profitable energy production. However, solar energy is excluded from the Finnish feed-in-tariff system at present which discourages solar energy investors and citizens to utilize solar energy. Subsidies can also be provided to rental housing which are more often occupied by low-income families (Fuller et al., 2009). This will encourage all income levels of people to produce and consume solar energy from the buildings where they reside. These subsidies are not required for longer period, just to boost the current solar installations pace.

Even though the property tax is exempted for solar plants installations at existing buildings and utilities, it can also be exempted for solar plants installations at the permitted lands to increase the solar energy production. At the moment, household solar electricity is not sold much due to the smaller production but selling of large quantity of household energy require to pay income tax as per the legislation. Taxable income from sold household solar energy is calculated after the deduction of expenses on solar power plants (Varonen & Myllymäki, 2014). This can be a barrier for installation of large solar plants in buildings of housing companies and associations. In addition, subsidies can be available also for maintenance costs because such costs are more than 10% of total investment costs. Private houses can get domestic help tax subsidy for repairing and installations of equipment at buildings. If the investment subsidies are provided to solar plant installations in the private buildings, the fear of losing domestic aid arises among citizens. Home renovation subsidies and investment subsidies both are important to make the solar energy profitable. Thus, the government can provide both investment subsidies as well as domestic aid for renovations and installations to make solar plant installations at private buildings attractive and affordable to residents.

In fact, promoting solar energy productions in housing buildings can also increase the real estate business profits. If the government desires to promote solar energy productions at housing companies and residential property, it can upgrade current energy subsidies systems. It can also revise the energy tax amount so that solar energy along with other renewable energy productions will be increased. As in Germany (Wirth, 2017), government and cities can regulate quota obligations for electricity distributors and other industries to boost the solar energy production in private and public buildings. Due to possessing a substantial solar potential and falling prices of PVs in recent years, solar energy promotion in the Helsinki area becomes a strong alternative.

There are also other financial measures that can be adopted by various entities within the cities and by national government. One such measure can be financial providers such as banks can offer easy loan schemes for solar energy producers. They can bring special financial measures as in Germany and many cities in California and Colorado (USA). Germany provides soft loans up to 2000 €/kW in addition to capital grant up to 25% for the eligible solar PV panels (PV Magazine, 2016). The City of Boulder in Colorado has issued up to $40 million in special assessment bonds at lower costs to finance clean energy improvements (Fuller et al., 2009). The central government or city administrations can also provide capital grants and personal loans at lower costs. Such mechanisms can include paying for the improvements up front, refinancing their mortgages or securing home equity lines of credit, and acquiring personal loans (Fuller et al., 2009). Additional financial measures such as on-bill financing, specialized unsecured bank loans for solar installations and energy-efficiency retrofits, mortgages designed to reward investments in energy efficiency, and other funds such as second mortgages and unsecured personal loans (Fuller et al., 2009). These financial measures are also applicable in the cities in Helsinki Metropolitan area.

If the cities are to significantly reduce emissions by set deadlines and aim at carbon neutrality, small-scale energy productions are vital and cities should adopt innovative financial mechanisms for small-scale clean energy development. For instance, City of Berkeley's program "Berkeley FIRST (Financing Initiative for Renewable and Solar Technology)" has facilitated the residents to generate small-scale solar energy production through various cost-effective financial measures (Fuller et al., 2009). Similarly, City of London has prioritized developing off-grid energy systems which include small-scale solar energy production (Bulkeley et al., 2014). City's cooperation to approve loans to citizens can drive the residential solar energy productions in the right direction. Choosing partners and formulating an appropriate marketing strategy when launching a new solar energy development program are extremely important. Such partnerships between an academic or other analysis group, city councils, and central government officials can facilitate the team needed to overcome the diverse issues that can arise (Fuller et al., 2009).

In addition to subsidies, financial and policy measures, issues related to attitudes are challenging. Although there is increasing interest towards solar energy production, implementation of attitude changing programs can help to enhance solar energy production in the Helsinki area. For instance, city administrations and environmental institutions can repeatedly organize workshops, seminars, webinars, and solar energy demonstrating programs. They can also organize visit packages for citizens to familiarize themselves with existing solar plants. Similarly, such organizations can organize participatory programs for citizens to establish community solar plant installations. The metropolitan cities can also collaborate with other neighboring towns to establish new community solar plants. They can share their knowledge, technology, and other resources with towns.

Proper solar energy production targets have not been set in the cities in the Helsinki area which is vital to achieving the low carbon or carbon neutral goals. For instance, development of solar energy production in London has been one of the key strategies to the emerging low-carbon regime (Bulkeley et al., 2014). The four Metropolitan cities in Finland can adopt a joint climate strategy outlining that a certain percentage (e.g. 20% of total renewable energy production) of energy should be produced from solar energy to achieve the 20% renewable energy targets by 2020 and carbon neutrality by 2050. If the strict climate strategies to promote renewable energy productions are applied, the electricity price will be increased and feasibility of solar PVs will also be improved. PVs will also be feasible option outside the electricity grid as its consumption demand will fits to the small-scale electricity production from PVs.

6. Conclusions

This study shows that solar energy development in the Helsinki Metropolitan area is progressing steadily but current development is in its infancy in comparison to its production capacity. Thus, there is potential for solar energy production to be expanded in the future, which will have positive impact to achieving 20% renewable energy production by 2020 and carbon neutrality goal of the cities in the Helsinki Metropolitan area. This expansion is already taking place despite lack of attractive energy subsidies. Residents and utility companies who have installed solar plants in their buildings are positive towards their investments on solar energy production. Yet, the current financial measures and subsidy mechanisms are not strategic enough and supportive for the development of solar energy production and carbon neutrality target in the Helsinki Metropolitan area. The current subsidy policies restrict the financial incentives to small-scale energy production in the public and private buildings. Investment and production cost for household solar energy is quite high and it is not competitive at this time. In addition, exclusion of investment subsidy and feed-in-tariff for solar energy production has discouraged energy producers and investors to invest into the solar energy development. Without such motivating financial incentives, real estate owners have a significant financial burden to install solar PVs and thermal plants. Current income taxes, lower surplus electricity price and fees for transmission are barrier for the production of larger solar plants in the public and private buildings. For that reason, policies for energy subsidies, taxation system, and electricity purchasing regulations should be revised to promote small-scale solar energy productions in the buildings in the Helsinki Metropolitan area.

Financial assistance for solar power installations should be more appealing and accessible to private and public building owners. The system balances and maintenance costs become larger for small-scale solar energy plants. Thus, financial aids can be available also for both the system balances and maintenance costs. The government can provide both investment subsidies, as well as domestic tax subsidies simultaneously for renovations and installations of solar plants at private buildings, which promote small-scale solar energy productions. The attractive financial schemes such as easy loans, cities' guarantee for loans approval, and establishment of funds for financing to solar plants are very essential. Cities can also adopt a solar energy production target through strategy outlining a certain proportion of energy (e.g. 20%) should be produced from solar energy to achieve renewable energy and carbon neutral targets of the cities. City authorities and the government can provide awareness through workshops, seminars, webinars, and street climate demonstrations to enhance the solar energy production and change the attitudes of people towards solar energy.

Author Contributions
Karna Dahal collected the data, performed the analyses, and drafted the manuscript, Jari Niemelä provided supervision of all stages, edited, and commented on the manuscript, and Sirkku Juhola edited and commented on the manuscript.

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Appendix A

Questions for all respondents (residents, energy experts, and energy utility companies)

- How do you compare solar power with the energy produced from other sources?
- What is your opinion about the current subsidies and financial measures?
- How is the effect of winter time for solar energy production? i.e. effect due to snow and darkness?
- What is your understanding about technological measures for solar energy distribution and storage?
- What is your opinion about the current policies for energy and property taxes?
- How do you see the future of solar energy production in Helsinki area?
- How are the comparisons of solar energy price with the other types of energy (oil heating, natural gas, etc.)?

Questions for individual solar plant owners

- Why solar energy was purchased? What is the intended use of solar energy?
- How was the progression of purchasing process? (licensing, permitting, delivery, installation or any other process)
- Did you experience any difficulties during the purchase, installation, and maintenance?
- How affordable was the price for the solar panel?
- How were the incentives for solar energy production? How do you feel about it? i.e. is it good enough or needs to be improved?
- Have you used any technological measures to control snow problem?
- Have you used any advance techniques such as smart metering and energy storage batteries in your solar plant?
- Is the produced energy enough to meet the required energy consumption at home? if any surplus energy is sold? If yes, how is the price and tax for it?
- What differences did you find between the winter and summer production of solar energy?
- What are the good and bad aspects of the learning from your solar plant installation project?

Questions for solar energy producing utility companies

- What sorts of solar energy programs do you have at the moment?
- How big is your solar energy production and how is the demand of solar energy (PVs and thermal power) currently?
- Any other solar power plant is planned to build in the future?
- How are the interests of your customers towards solar energy?
- Do you get any subsidies to generate solar energy? If it is so, how is it helping you to lower the energy price and to compare it with other sources of energy?
- How were the incentives for solar energy production? How do you feel about it? i.e. is it good enough or needs to be improved?
- What is your opinion about the current subsidies and financial measures?
- How do you fix the solar energy purchase price from the customers who sell their surplus solar energy to your company? Any effect of taxes to these prices?