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The role of local renewable energy sources in regional energy production: The case of South-East Finland

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Abstract
The focus of the paper was on discussing the challenges and possibilities of promoting and utilising various renewable energy sources at the regional level. National obligations and the rising prices of fossil fuels have put pressure on energy producers and end users to start utilising renewable energy sources. South-East Finland has one of Europe's highest forest industry concentrations, and renewable energy sources such as wood fuels are utilised widely. The study utilises earlier regional studies and statistics as well as new results from this study. These results are combined into regional potentials which are presented by regional energy balance. The analyses provide important background information for decision making. The various regions of Finland have different operational environments and local participants need motivation and activation regarding these local possibilities.

Keywords: Renewable energy; Wood fuel; Biomass; Wind power: Regional.

1. Introduction

The renewable energy sources have important role in EU and Finnish energy policies. The EU target for renewable energy as a percentage of energy used is 20% by 2020. In Finland, renewable energy sources must account for a 38% of total energy consumption by 2020. Total energy consumption in Finland was 1,467 PJ in 2010 [1] and the current figure for renewable energy sources is 35% [2].

The most significant role in increment of renewable energy sources will be by forest biomass. Forest biomass is utilised mainly in communities' CHP plants and the forest industry, where the most-cost effective renewable energies are already widely utilised. Meeting the percentage of 38% by 2020 requires that the production volume of the Finnish forest industry must be maintained at the current level. Increments in the utilisation of solid biomass will be concentrated on heating plants (thermal output of 0.5–5 MW), and further on replacing fossil fuels in smaller farm-scale heating systems (< 0.5 MW). Wind power and heat pumps should also have an important role in Finnish energy supply. Use of agro biomass has been decreasing in recent years and it seems that they will have no role in Finnish energy supply in 2020. National targets for various renewable energy sources by 2020 and the current end use of each are presented in Table 1.

The aim of the study described here is to introduce how the use of renewable energy sources could be developed at the regional level and what kind of actions must be taken under consideration when promoting the use of local renewable energy sources. Additionally, challenges and effects of increasing the use of renewable energy sources will be introduced. The region of South-East Finland will be used as a case example. The study combines the status of regional energy supply with availability of local

resources and provides information for energy end-users, bioenergy producers, and local decision makers, as well as for research organisations and regional authorities. It also provides regional data supply security analyses of different fuels.

Table 1. Use of different renewable energy sources in Finland and targets for 2020 [1, 3-8]

		Use in 2010, PJ	National target for 2020, PJ
1	Forest biomass	49.7	90
2	Wind power	1.1	21.6
3	Hydro power	46	50
4	Small-scale use of wood	43	43
5	Heat pumps	9.7	28.8
6	Transport biofuels	12.2	25
7	Biogas	0.5	2.5
8	Agricultural & natural biomass	will be studied	will be studied
9	Pellets	2.9	7.2
10	Recycled fuels (biofuels)	5.8	7.2
Total		170.9 PJ	275.3 PJ

2. Material and methods

This study concentrates on the regional significance and possibilities of various renewable energy sources through status of regional energy supply, availability of local resources, and analysis about potential renewable energy end-users. Over the past decade, utilisation of renewable energy sources has been a topical issue which has created a need to promote its possibilities for local target groups. These are, for example, energy companies, consumers, fuel producers, authorities, investors and decision makers. The various regions of Finland have different operational environments and local participants need motivation and activation regarding these local possibilities. Relevant, objective, and updated information must be available for them to back up decisions.

Life cycles of energy investments are usually up to 20-30 years, and in many regions the decision-making process can be quite time-consuming, while previous experiences with new energy sources and technologies could cause confusion. The previous functionality of technology for renewable energy sources could have been questionable in some cases, which could have caused these negative attitudes. All decision making needs sufficient supporting information and data about regional possibilities and challenges to ensure rational decisions. This supporting data could be the availability of regional fuels, current status of regional energy supply, and information about local experiences and competence.

Traditionally, wood fuels, such as black liquor, bark and forest biomass, hydro power and natural gas have been the most important fuels in South-East Finland because of the large-scale forest industry. The volume of wind and solar power has also been increasing regionally in recent years [9]. Regional possibilities for biogas production have been studied but only a few of the projects have been realised. Agro biomass has been tested in energy production but it seems that utilisation of it will not have an important role in regional energy supply.

2.1 Calculation

In South-East Finland in total 162 PJ of primary energy was used in 2010, which covers about 11% of primary energy consumption in Finland. Of the total use of wood fuels, South-East Finland consumed about 25% because of the energy-intensive forest industry [1]. The status of energy supply in South-East Finland in 2010 is illustrated in Figure 1 [10].

The regional energy balance includes detailed data about primary energy sources used in heat and power plants, industry, and the domestic sector. The energy balance also indicates the end-use of energy and local possibilities for increasing the use of renewable energy sources. This study introduces regional potentials for the following renewable energy sources:

- forest biomass and other wood fuels [11]
- wind power [9, 12]
- solar energy
- biogas [13, 14]
- agro biomass

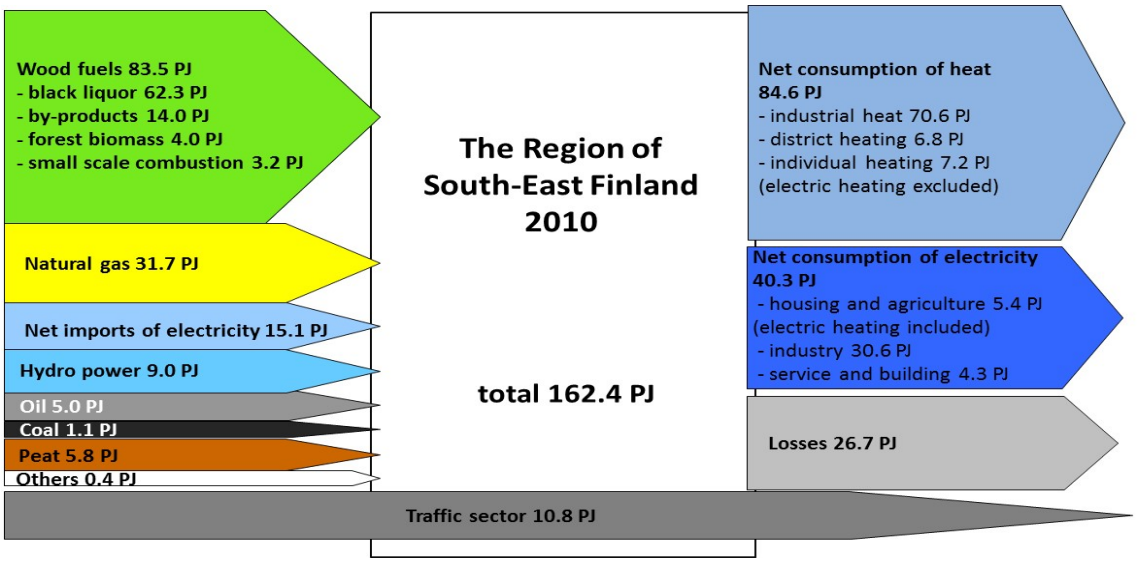

Figure 1. The energy balance of South-East Finland [10]

The study consisted of individual subtasks concerning the resource potentials and use potentials of various renewable energy sources. All regionally possible renewable energy sources were studied and potentials were analysed. Initial data utilised for evaluating the potential of forest biomass, wind power, and biogas are based on earlier studies. Regional solar energy and agro biomass potentials were estimated in this study. However, all results were updated to match the presumable status better in 2020. One main result of this study is an estimation of the regional energy balance in 2020.

Regional potentials for availability and end-use of biomass have been studied previously [10, 11], and regional statistics regarding the use of wood fuels exist [15]. It was assumed that solid biomass will be the main fraction of wood fuel, of which utilisation will increase regionally by 2020. In particular, the use of forest biomass will increase. Forest industry by-products, such as black liquor, bark, chips, and sawdust volumes were evaluated to maintain the current level. The small-scale use and development of use of wood fuels and particularly forest biomass were evaluated by regional statistics provided by the Information Centre of the Ministry of Agriculture and Forestry [16] and Finnish Forest Research Institute [15]. An individual heating plant consumes about 100 solid-m³ of forest biomass annually and it was expected that current small-scale use of it could double by 2020 [11, 17]. Current small-scale use of forest biomass was combined with the existing number of farms for evaluating the increment potential of small-scale use.

Currently, in South-East Finland there are 17 operational wind mills with total electrical power of 43 MW. Their annual electricity production is about 80 GWh [9, 12]. Ten of these wind mills are located by the shore and the rest are inland wind mills. National feed-in tariff has encouraged investment in wind power production and there are various on-going projects concerning the regional production of wind power. However, almost all projects are currently frozen in the region [18]. In this study, regional wind power potential has been evaluated by earlier studies and the latest information about wind power. Hydro power in South-East Finland's rivers is basically constructed and it is evaluated that no more will be constructed.

Regional solar energy potentials are hardly studied earlier in Finland and for South-East Finland such potential does not exist. In Finland and South-East Finland as well, the annual radiation is about 1,000 kWh/m² [19]. Annual electrical production by solar power panels is generally 150 kWh/m² (η=15%), and, when generating heat, annual production is about 350 kWh/m² (η=35%). Traditionally, solar energy in Finland has been used in small-scale residences and summer cottages outside the power grid. Over the past decade the production volumes have increased constantly and interest in solar energy has increased. This is because of a positive environment, increased knowledge, and the decreasing price of technology. It is presumable that utilisation of solar energy will further increase when approaching 2020. Individual residents could utilise solar energy apart from oil, electricity, or other energy sources.

In the past decade, biogas has been studied widely in Finland, but the share of biogas from Finnish primary energy consumption is only 0.1% [1]. The future potential of regional biogas production was

evaluated by regional statistics regarding current biogas production [8] and the local structure of energy supply [10]. Currently, in South-East Finland there are five operational biogas plants: three landfills, one industrial sewage treatment plant, and one community sewage treatment plant.
Agro biomass is considered important fuel in Europe, but in Finland it has been bypassed by forest biomass and other wood fuels. This is because of more challenging combustion and handling of agro biomass and because of good availability of wood fuels. In Finland, potential agro biomasses are grain straw and reed canary grass. A few years ago, plans and demonstrations about the utilisation of reed canary grass existed, but the cultivation of it has decreased significantly since. It seems that agro biomass will not have a significant role in Finnish energy supply by 2020 [2, 4]. For this study, the potential of grain straw was analysed from actual regional cultivation areas and regional yields [20, 21].
The use of different energy sources will be presented by regional energy balance for 2010 and 2020. 2020 illustrates the potential for renewable energy source utilisation in South-East Finland when regional resources and limitations are taken under consideration. In the future, the importance of local fuels will increase when dependency on imported fossil fuels decreases and different local target groups must be informed about these regional possibilities.
The innovation of this study is to combine regional energy resources to current and potential use of fuels. In addition, this study highlights actions and needs that must be taken under consideration when increasing the use of local renewable energy sources. Combining the availability of fuels with use potential of fuels has been given little attention in national research. These results must be introduced more effectively to all target groups.

3. Results

The results of this study indicate the background information needed for the decision-making process in municipalities and local energy companies. The required background information includes, for example, data about the potential of available renewable fuels and general technical data about suitable production technologies. The study provides information for evaluating the feasibility and possibilities of different alternatives in South-East Finland's energy supply. Because of long traditions in the utilisation of wood fuels, they will have a key role in the energy supply of regions in the future as well. In particular, the utilisation of forest biomass could further increase and it could replace natural gas in municipalities' heating plants and oil in larger residences and buildings. Also, a portion of peat can be still replaced by wood fuels in large CHP plants, as almost every CHP plant in South-East Finland is already using domestic wood fuels [11].
The results of this study provide information for local decision makers and give back-up data for decisions. In many cases regional energy resources and potentials are not studied or properly informed. A lack of information could slow the decision-making process. The following chapters will introduce potentials for different renewable energy sources in South-East Finland and point out some of the challenges in utilisation of renewable energy sources.

3.1 Wood fuels

In 2010, forest biomass was utilised in South-East Finland's heat and power plants at about 3,960 TJ (550,000 solid-m³). [6] It is estimated that forest biomass could be utilised in existing heating and power plants up to 5,400 TJ (750,000 solid-m³) annually by replacing peat and natural gas. If investing in new boiler capacity, forest biomass could be used up to 7,200 TJ (1 million solid-m³) [11]. These new investments basically replace natural gas and oil in smaller heating plants. It is realistic to estimate that a maximum of 5,400 TJ of forest biomass could be used in South-East Finland by 2020 [11]. Most of the increment will be covered by large CHP plants replacing peat and natural gas with forest biomass. Decision making in large CHP plants is mainly guided by economic (e.g. price of fuels and taxation) and environmental aspects. The extra use of forest biomass will create new business opportunities for rural areas. Temporary lack of machinery and labour could exist, and in some cases infrastructure (e.g. forest roads and terminals) needs improvement [17].
Forest biomass utilisation in heating plants has been increasing the entire 21st century. In South-East Finland natural gas and oil has been replaced by domestic biofuels in the past decade in local municipal heating plants. However, there are still about 5–10 potential heating plants that could start utilising domestic renewable fuels [11]. The decision-making process in municipalities regarding the new heating plants could be time-consuming and it needs sufficient background information, including data about local energy resources, operational models, suitable technologies, and possible reference plants [17].

It is evaluated that small-scale use of forest biomass in farms and other individual heating systems could double by 2020. Current small-scale use of forest biomass is 320 TJ (44,000 solid-m³) and it could increase up to 630 TJ. There were 3,200 farms in South-East Finland in total in 2010 and if a single farm consumes on average 120 solid-m³ of biomass there are about 370 farms in South-East Finland using forest biomass [16, 17]. However, this figure includes also small-scale industry and other larger buildings utilising forest biomass. In light of these results, there could be 730 small-scale users of forest biomass in South-East Finland by 2020. The price of competitive fuels, local availability of forest fuel, and suitable production machinery has an effect on the volumes of forest biomass utilised on a small-scale. Extensive guidance is one of the most important factors when promoting the use of forest fuels on a small scale.
Refining of biomass has been a topic around Finland and Europe for several years. In South-East Finland there is one liquid biodiesel production plant (100,000 tonnes per annum) under construction in Lappeenranta. The raw material of the plant is crude tall oil [22]. A large-scale biomass gasification unit (200 MW) utilising bark has been integrated to the pulp mill in Joutseno [23]. Another gasifier in Kotka will be converting lignin to gas and will replace natural gas in lime kiln [24]. These large projects are carried out by the forest industry.

3.2 Wind power and hydro power

Currently, in South-East Finland there are 17 wind mills in total with total electrical power of 43 MW. 10 of these wind mills are located by the shore and 7 are inland wind mills in the Lappeenranta region. Annual production of these wind mills is some 80 GWh, depending on the annual full load hours [9, 12].
During the past decade there were various on-going projects regarding wind power in South-East Finland [9]. It seems that part of these projects will not be realised because of radar interference, natural values, and challenges in location requirements. For this study the most feasible projects were selected and the potential of wind power in 2020 was estimated [9]. In 2020 the total number of wind mills in South-East Finland could be about 70 and the regional potential is 210 MW, which equals 380 GWh of electricity. This new capacity will increase the self-sufficiency of electricity production and increase the share of renewable energy in South-East Finland.
Hydro power is basically already constructed in South-East Finland. It is evaluated that the volume of hydro power will remain at the current level by 2020 [10]. However, by renovation of hydro power plants, the maximum production capacity could be slightly increased.

3.3 Solar power

Previously in South-East Finland, solar power was mainly used at summer cottages and other sites outside the electricity grid. The annual total amount of solar power in Finland was only 5 GWh of electricity and 39.6 PJ (11 GWh) of heat [19]. There are no regional statistics available at the moment. However, solar power is becoming more and more interesting for households and larger buildings. It could produce part of the energy needed locally.
For evaluating solar energy potential in South-East Finland, the number of oil heating systems in the region was defined, as well as the number of suitable larger buildings that could utilise solar power. There were about 22,500 households using light fuel oil for heating in South-East Finland [10]. It was evaluated that 5% of them could utilise heat and electricity from solar by 2020. According to current use of solar energy in Finnish households, one-third of the total energy is electricity and two-thirds is heat. For larger buildings such as offices and supermarkets solar energy would be utilised as electricity. It was evaluated that a total of five hectares (1 ha = 100m * 100m = 0.01km²) of solar power would be installed for public and office buildings by 2020. This five hectares of solar power equals 7.5 GWh of electricity per annum. If 5% of single households currently using oil would install solar panels and start using solar power (30%) and heat (70%), then it means that 1.5 GWh of electricity and 29.5 PJ (8.2 GWh) of heat would be produced by solar energy in 2020. In total, 17.2 GWh of energy from solar would be produced in 2020 in South-East Finland.
Today, it is possible to sell surplus electricity to local electrical power network operators. However, in Finland there is no feed-in tariff for solar electricity, which lowers its economy. Technology and applications for solar energy are becoming more affordable for individual consumers, and equipment and services are easily available, which has increased interest in it. Environmental aspects and rising prices of fossil fuels and electricity have also made solar energy more tempting. However, payback periods for solar energy investments could be still rather high, but they are becoming more feasible year by year.

3.4 Biogas

Biogas is one alternative for local energy production in municipalities and rural areas. Cleaned and upgraded biogas can also be used as a transport fuel locally or through the natural gas pipeline. In this study, biogas potential was evaluated regionally for South-East Finland [13, 14].

The current use of biogas in energy production in South-East Finland is about 72 TJ in 2011. The largest biogas utiliser was a sewage treatment plant in Kouvola which produced 50 TJ biogas and utilised it as electricity, heat, and transport fuel distributed through the natural grid [8]. In this study, biogas potential is expected to double to 145 TJ by 2020. The growth will consist of increased production in existing sewage treatment facilities (7 TJ), one new large biogas facility located in Kotka (50 TJ), and five new farm-scale facilities (total 4 TJ) [25]. This evaluation is based on the existing structure of energy supply and urban areas, as well as local knowledge about on-going projects concerning biogas.

Biogas has enormous potential for decentralised energy production both nationally and regionally. Possible feed stocks for new plants could be biowaste, sludge, animal manure, and in some cases energy crops. Potential sites for these plants would be existing communities' sewage treatment facilities and some larger farms. High investment cost, the small unit size of Finnish farms, and challenging operation conditions during winter have reduced interest in biogas production. Typically, biogas plants need raw material with gate fees for profitable business. In the future, the price of energy and environmental aspects could increase biogas production.

3.5 Agro biomass

The agro biomasses in South-East Finland with the most potential are straw and reed canary grass. Straw could be harvested from cultivated areas and reed canary grass could be cultivated, for example, in fallow land. Fallow land in South-East Finland comprises about 24,000 hectares and average dry matter yield of reed canary grass in Finland is about 4.5 tonnes per hectare.

Straw potential was evaluated for each Finnish grain (wheat, rye, barley, and oats). By annual cultivation areas and harvesting losses noted, the annual regional potential for grain straw is about 1,800 TJ in South-East Finland. The heating value of reed canary grass is 16.6 GJ per dry matter tonne [26, 27]. Annual potential for reed canary grass is about 1,900 TJ in South-East Finland. The maximum amount of agro biomass that could be harvested in South-East Finland is about 3,700 TJ, consisting of straw (~50%) and reed canary grass (~50%).

Due to the strong status of wood fuels and lack of suitable handling and combustion capacity, agro biomasses are an unutilised energy resource in South-East Finland. In this study, it is assumed that agro biomasses will have only a minor role in regional energy supply. In the future, production of liquid renewable biofuels could increase the utilisation of agro biomasses significantly.

3.6 Regional possibilities for renewable energy sources

Because of the forest industry, utilisation of wood fuels has a long tradition in South-East Finland. On the other hand, natural gas has also been used widely since the 1970s.

Renewable energy sources will basically replace fossil fuels in South-East Finland. The growth in forest biomass utilisation (1,980 TJ) is significant because in South-East Finland a part of bark is already gasified for lime kiln in Joutseno, which decreases the amount of bark used in conventional energy production (1.440 TJ). This bark must be replaced by forest biomass (75%) and peat (25%). The rest of the increase in forest biomass utilisation (900 TJ) will replace peat (180 TJ) and natural gas (1,620 TJ) in heating and power plants. In addition, investments in new biomass boiler capacity are planned [10, 11, 28]. This increase will strengthen the regional biomass markets and create new entrepreneurship.

Renewable energy sources in transport are evaluated to equal the national targets in Finland: 5.75% in 2010 and 20% in 2020 [2, 4]. However, the amount is doubled because of double counting of non-food based liquid biofuels.

In Table 2 the use of renewable energy sources in South-East Finland are summed up in 2010 and possible use in 2020. The table indicates the numerical change of different renewable energy sources.

In Figure 2 the use of primary energy sources in South-East Finland in 2020 is combined together with the use of primary energy sources in 2010. This indicates the total significance of different energy sources and volume of change.

As seen in Figure 2, the use of renewable energy sources should increase from 2010 to 2020. The share of renewable energy sources could rise from 57% to 63% by 2020. In particular, forest biomass, wind power, and renewables in transport fuels will increase.

Table 2. Current use of renewable energy sources in South-East Finland and possible use in 2020

		Current use in 2010, TJ	Possible use in 2020, TJ
1	Forest biomass	4,280	6,050
2	Wind power	290	1,370
3	Hydro power	9,000	10,800
4	Small-scale use of wood	3,240	3,240
5	Heat pumps	will be studied	will be studied
6	Transport biofuels	620	2,160
7	Biogas	72	144
8	Agro biomass	not significant	not significant
9	Solar power	< 1	62
Total		17.5 PJ	23.8 PJ

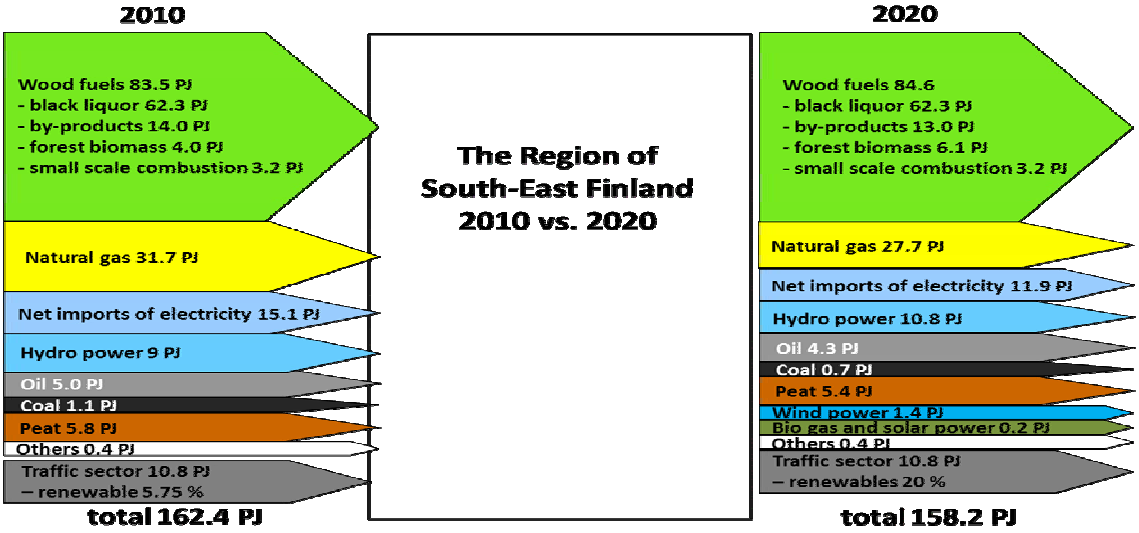

Figure 2. Use of primary energy sources in South-East Finland in 2010 and 2020

Wood fuels already have the most operational markets which enable their potential increment. The Finnish feed-in tariff for wind power has created feasible operational conditions for new wind farms, but for solar energy there are currently no subsidies. Increased solar energy will be based on the activity of individual consumers and companies. New biogas plants still need investment grants. Local decision makers and actors need objective regional information and research regarding possibilities for local renewable energies.

4. Conclusion

Objective research of local possibilities and limitations is needed to back up regional decision making. Awareness of regional possibilities is important when increasing and developing the use of renewable energy sources. For the region of South-East Finland, possibilities, challenges, and significance of different renewable energies for energy supply were studied. The most important renewable energy sources for South-East Finland are wood fuels, while wind power and solar energy have relatively the highest growth potentials. By improving the general operational conditions and competiveness of renewable energy sources, local employment and supply security for energy production can be guaranteed.

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