The Rõuge renewable energy park: En route to zero-CO_2 community in rural Estonia

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Abstract
The aim of the Rõuge rural municipality in southern Estonia is to develop a zero-CO_2 community, except transportation, in nearest five years. 100 % renewable heating in public buildings is already reached as biomass for heating is the most important renewable energy source in the district. The municipality institutions use exclusively the green label electricity. In total, 580 300 EUR were invested to implement the energy programme in 2001 – 2006, corresponding to reductions of greenhouse gas emissions by 3 807 tons per year. The renewable energy park, coinciding with the municipal territory, is enhanced as the innovation, engineering, prototype centre and mix-up engineering solutions such as bio-energy installations, small hydro, ground source heat pumps, solar batteries and wind generator in the core area of park in Rõuge. Engineering and deployment of renewable energy sources embodies multiplying effect in the tourism sector. The park including the energy trail in the picturesque hilly landscape attracts 40 000 visitors annually, provides professional tours and promotes the renewable energy schemes to the public and students. Innovation and installations on renewable energy lead to the districts' development through provision of new business opportunities, linking forestry, agriculture and engineering. Local government investigates the synergies between energy and land use planning for the sound use of biomass resources.

Introduction

One of the main goals of local authorities is to make their communities environmentally and socially sustainable. In order to implement the European Union and national energy policies, the municipalities play the key role in increasing energy efficiency on the local level (EC 2004). The municipalities promote efficient energy consumption in public buildings, initiate and carry out energy saving projects, improve heating systems, use renewable energy and motivate the local households to save energy.

Estonia has one of the highest greenhouse gas emissions per capita in EU, 15.8 t per capita, which is also illuminated by greenhouse gas (GHG) intensity in relation to the GDP. The Estonian CO_2 emissions were 21.3 Mt in 2004 (EEA 2006a). The large share of energy in total GHG emissions is due to a high share of oil shale fired power production (90 %). The present technology of the oil shale boilers will not be in conformity with the future environmental requirements. Despite all circumstances Estonia will be below the Kyoto target, as current GHG emissions for 2010 are more than 50 % lower than in the base-year 1990 (EEA 2006b).

The Rõuge rural municipality, 2 365 inhabitants, is located in southern Estonia, in the middle of the Haanja natural park. The development plan of municipality declares to promote sustainable community in Rõuge, exploiting renewable energy sources and increasing energy savings, also to initiate and support energy-related projects in the tourism sector, environment and training. The development plan provides an overall view of Rõuge's environmental action. The national development and environmental goals correspond to the goals of the municipality, though the local agenda is more practical (Development

plan 2002; Valtin et al 1999).The ethos of sustainable energy is held historically in high agenda in the Rõuge neighbourhood. Over the last centuries there have been 22 watermills in the area. Water power has been used to grind flour, start engines, machinery, generate electricity.

The environmental objective of the Rõuge municipality is to be zero-CO_2 community, except transportation in nearest five years. The fossil fuel free programme includes a wide spectrum of actions and measures. The municipality can influence the amount and types of energy used, e.g. biomass, water and solar instead of oil or other imported fossil fuels. In order to facilitate sustainable energy objectives, the Rõuge renewable energy park was founded in 2001. The municipality aims to develop the renewable energy park as the innovation, engineering, prototype centre and mix-up engineering solutions for increasing the usage of renewable energy sources and novel energy solutions. First, the energy park deploys the set of renewable energy devices such as geothermal heat pumps, watermills and water rams, solar batteries, and wind generators. Second, it employs energy saving solutions, such as modern street lighting, energy efficient windows and insulation in public buildings. Here, the emphasis is on introducing sustainable energy consumption model for improving efficiency in rural countryside. Third, the energy park serves as a demonstration, education and campaigning area aiming to inspire, inform, and enable people on sustainable energy. The Rõuge community is pioneering in the energy demonstration tools and units, promotion campaigns and dissemination in Estonia and the Baltic's. The energy action influences positively others municipal activities and restructuring in general. The demonstration of innovative, energy-saving solutions supports economic development and establishes attractive tourism facilities in the pre-dominantly agricultural district. Natural landscapes, cultural heritage and new technologies all combined are introduced to professional visitors as well to domestic and international tourists. The energy park presents technological shift from conventional solutions to renewables and supports changing consumption behaviour in the rural communities.

Resources and measures

To achieve the goal of zero-CO_2-municipality, the set of engineering and 'soft' measures, energy devices, advisory services, tourism activities, training facilities have been concerted to create prototype infrastructure. Measures focus on more efficient use of energy, the benefits reducing the need for energy, changing fuel composition in generation, which entails replacing some fossil fuels with bio fuels, and an increase in the percentage of connections to district heating. The novel deliverables of the renewable energy park are the combined or autonomous solutions for renewable energy production. In addition, components of tourism infrastructure are selected to supplement energy installation and increase the demonstration value of the sites. The activities renewing old energy installations and deploying novel ones aim to improve the area with landscaping and sensible building design. A guiding principle of the energy park is technical excellence working in harmony with nature. Though greater knowledge of various measures' cost efficiency can improve the decision-making basis for the local administration, companies, and citizens, this is an area in which surveying, feasibility studies and R&D work should be carried out more to specifying the socio-economic benefits of a range of measures more precisely.

Calculating the reduction of CO_2 emissions, the use of Intergovernmental Panel on Climate Change (IPCC) default emission factors universally would not be appropriate for many fuels and that it is generally preferable to establish default values for fuel-specific emission factors at the state level (Herold 2003). For calculating the greenhouse gas emissions reduction, it is assumed that oil shale is the fuel displaced at the margin for electricity generation in Estonia. As a basis for energy assessments, calculations of carbon dioxide emissions from electricity are based on total emissions in Estonia (National Report 2004). Figures are based on the emissions caused by the oil shale fuel from a life cycle perspective, i.e., everything including emissions from generation, transport and use as assessed in the OSELCA project (Eesti Energia 2006). In heating systems, other baselines of replaced fuels such as for example oil are also considered case by case.

THE RESOURCES OF RENEWABLE ENERGY

The increase in renewable energy use has great potential for the reduction of CO_2 emissions from the energy use in the municipality. The following section provides a summary of the overall RES actions in the Rõuge municipal territory. A major renewable energy source is biomass as 58 % of the territory of the municipality is covered by forest, which makes wood an important raw material for both forest industry and energy sector. The amount of wood used for energy, including both firewood and by-products of forest industry, in the Võru county is 74 300 m^3/y with the energy content of 0.15 TWh. The current share of biomass in municipality premises heating energy is already 100 %. Wood chips, briquettes and pellets are produced in the municipality, though the majority of produced biomass fuels is delivered to the cities or exported. Assessing present land use and extrapolating data, the energy crops such as willow could be grown on 1 000 hectares, corresponding energy supply of 40 GWh annually, causing reduction GHG emissions by 36 000 t of CO_2 eqv. if base case is oil fuel. However, energy input is needed to cultivate the short rotation crop and to process it into bio fuel, so the net energy gain and CO_2 saving could be significantly reduced. Local government investigates further the synergies between energy and land use planning for the sound use of local resources.

Another major energy source is Põdrasoo peat deposit with the reserve of 540 000 tons with the energy content of 1.6 TWh, while the peat production has quotas, both a national one and on county level.

The potential hydropower resource of the Rõuge rural municipality is estimated up to 180 kW. During the first half of the 20th century there were hydro turbines and mill wheels in use of this capacity – altogether in 22 installations, the biggest station was Vastse-Nursi with 40 kW. Starting engines of in total capacity, it would be feasible to produce 900 MWh which would cover up to 15 % of the municipality's electricity needs. The renewable hydro energy ranges potentially GHG emissions reduction by 1 010 t of CO_2 eqv. compared to the base case of oil fuel.

In addition, the region has a moderate solar, wind as well as geothermal energy potential. The resource capacity of solar

energy in the southern Estonia is 950 kWh/m^2. The potential annual yield of thermal energy with solar panels is 350 kWh/m^2 and the production of electrical power with PV-systems 100 kWh/m^2/y. Wind energy resources are comparatively small in southern Estonia. The average wind velocity at a height of 10 m is only 2–2.5 m/s and energy density at the height of 30 m only up to 100 W/m^2. On the western coast of Estonia, the energy density value is up to ten times higher.

HEATING SUPPLY

The present thermal energy of Rõuge rural municipality is covered entirely by renewable energy sources, mostly firewood. The firewood is used in farms and country houses as well in several public buildings. Two district heating systems use woodchips as a fuel. Rõuge district heating system, using of 2 400 m^3 chips, supplied 1 380 MWh of heating energy (2006). This causes the reduction of CO_2 eqv. emissions by 1 242 tons in base case of oil. Reconstruction of the Rõuge boiler-house and district heating network completed in 2006 increased energy efficiency of boilers from 73 % to 78 %. It also marked a shift towards district heating, expanding the number of costumers. The district heating systems based on bio fuels provide good opportunities for reducing greenhouse gas emissions since they are more efficient than individual boilers systems. There is also social impact of switching to bio-fuels increasing employment, since biomass schemes are labour-intensive than imported fossil fuel-fired systems. Several residential houses have been insulated during past few years to reduce heat consumption. Still, there is the certain potential (20 %) of thermal energy savings.

Municipality's primary school switched its heating system from wood to a ground source heat pump (GSHP) system in 2001–2004 having 4 heat pumps in operation with the total capacity of 275 kW. Total annual heating energy production was 620 MWh in 2006.Operational cost of heat pumps is 40 % less costly compared to previous firewood heating scheme.

ELECTRICITY SUPPLY

Energy consumption in the municipality has been increasing annually due to the additional installations. The electric energy for the municipality is supplied by the state-owned company "Eesti Energia". The municipality uses exclusively the green label electricity. Eco-labelled electricity will reduce the environmental impact. The use of green electricity is not considered to create emissions of carbon dioxide. Calculations are based on a oil shale-based electricity of 1.122 kg of carbon dioxide per kWh, which means that every MWh of green electricity the municipality buys will reduce emissions by 1 122 kg of carbon dioxide per year. Municipality total electricity use is metered 640 MWh in 2006. If we assume that this consumption is made up of green electricity, it would yield a reduction of 718 tons of CO_2 eqv. per year.

Major consumers of electricity, farms and country houses are quite dispersed in the rural countryside; the transmission expenses are relatively high. The power lines have been renewed last five years to improve their technical condition. Low-tension lines are mostly too long and there are problems with the quality of tension.

SMALL HYDRO ENERGY

There are five small hydro stations in operation with total capacity 57 kW in the municipality. The capacity of the biggest station Saarlase is 37 kW. The Ala-Rõuge guesthouse is located in the operational mill and consumes majority of generated energy, an average of 3–5 kW, used for floor heating, lighting and home appliances. In total, renewable energy delivered by 5 small hydro plants is estimated 99 800 kWh annually in case of energy efficiency 20 %. Gross annual GHS emission reduction is 112.0 t. As unique power installation hydraulic ram pumps are deployed for pumping water in several farms.

SOLAR ENERGY

The thermal solar potential is mainly unexploited and it could compete on the demand for hot domestic water. In 2004, two thermal solar collectors 3 kW (5 m^2) installed on a schoolhouse for heating 550 litres tank of household water. The collectors are used for pre-heating water as it is connected to the ground heating system. Total annual heating energy production of collectors was 18.6 MWh in 2006 which gives net GHG reduction 20.9 t CO_2 eqv. The system is fully PC controlled. Solar panels could be deployed for thermal power much more in housing. The thermal solar systems could constitute economically and environmentally attractive solutions for the isolated villages if these systems are smartly incorporated in the building envelope. The estimated area that could be used for PV-systems is 1 000 m^2 producing 1 000 MWh of energy in a year. It is possible to use solar panels up to 800 households to meet the demand for hot water and produce 1.7 GWh/y with given installations.

WIND ENERGY

Wind generation has seen rapid growth in Estonia, with generation increasing almost tenfold in just two years. In southern Estonia and Rõuge the resources of wind energy are quite modest. However, a 3 kW windmill with a vertical axes was installed on top of the 25-metres-high Ööbikuorg viewing tower (August 2006). The power curve for a Ropatec wind turbine has been applied for assessment. Twenty-five metre lattice towers are typical for these relatively small machines. 10 % capacity factor with 100 % absorption 3 kW rated capacity yields an average output of 0.3 kW. Renewable energy collected is 878 kWh which gives net GHG reduction 985 kg CO_2 eqv. The generated electricity is transferred to the network of Ööbikuorg centre. The automatic wind rotor is primarily used in cases when the public energy network does not cover the necessary energy output. The advantage of the wind generator with horizontal rotation is reliability and automatic switching at 2 m/s. The wind rotor can also be used for a water pump, mill or for production of thermal energy. The wind energy unit is least energy-efficient and cost-efficient among renewable energy units.

STREET LIGHTING

In 1985, a street lighting system with 146 DRL lights of 300 W was launched in Rõuge small town. In 2005–2006, the lights were replaced with Philips lights (75, 100 W), plus 12 parkland lights (50 W). The electricity consumption of street lighting system is 57 000 kWh/y. Total annual energy saving is about 6 500 kWh and a corresponding reduction in GHG emissions 7.3 tons. In addition to saving energy, the quality of life for peo-

Table 1. List of implemented measures

Measure	Category	Implemented	Investment thous EUR	Reduction t CO_2 eqv.emissions yr
Technological measures, total			324.8	2228.1
Ground heat pumps for school building (220 kW)	Investment on RES&EE	2001–2004	111.9	620.0
Biomass district heating system (800 kW)	Investment on RES&EE	2006 (renov.)	112.5	1242.0
Expanded district heating (+286 MWh/y)	Investment on RES&EE	2006	Incl above	225.0
Small hydro stations (57 kW)	Investment on RES	1994–2002	n/a	112.0
Solar collectors (3 kW)	Investment on RES	2004	4.7	20.9
Wind turbine (3 kW)	Investment on RES	2006	12.6	0.9
Street lighting system	Investment on EE	2005–2006	83.1	7.3
'Soft' measures, total			285.0	1579.0
Green-labelled electricity	Procurement	2002	-	718.0
Energy advice on RES and energy efficiency	Business consultancy	2003–2006	30.0[1]	300.0[1]
Environmentally and energy aware teaching, outdoors visits	Training	2002–2006	255.5[1]	561.0[1]
GROSS TOTAL			580.3	3807.1

RES – renewable energy sources; EE – energy efficiency; [1] Estimates

ple living in the area improved due to sound lighting regimes and higher safety.

Impact of measures

With the zero-CO_2 energy plan in the municipality, 580 300 EUR has been invested in energy measures in 2001–2006 and a corresponding total reduction in CO_2 emissions equivalent to 3 807 tons per year. The major reduction was achieved by the conversion to RES and the substitution of new biomass and ground heating technologies. Heating systems were switched to modern installations causing higher energy efficiency and savings. It seems to appear that the 'soft' measures and the impact of a small RES demonstration devices make a quite marginal share in implementing energy policies. In fact, the non-direct impact of soft measures is 40 % of total energy savings and CO_2 reduction.

CAMPAIGNING, TRAINING AND PROMOTING OF RES

Reduction targets could be achieved by improving energy consciousness. The Rõuge municipality is very active in the field of promotion of renewable energy and joins energy saving campaigns. Public access to the energy park with visitors enables using the energy centre facilities for tours and studies attracting 40 000 visitors annually. In the Ööbikoru valley, the 2 km-long energy trail with 6 renewable energy sites provides theme entertainment for tourists. There are many specialised groups to learn renewable energy in the energy trail and at the energy park. Environmentally and energy aware teaching provides introduction, guiding and instruction to 200 classes annually at the renewable energy park, aiming to educate around 10 000 children and students on the theme of renewable energy and energy impacts. The approximation of carbon dioxide reduction of education projects is based on the total effect of pupils switching off electrical equipment in schools at the end of the day and taking that knowledge home with them. The estimated energy savings for the energy awareness activities is about 500 MWh per year, and a corresponding reduction in CO_2 emissions equivalent to 561 t per year which is allocated throughout of Estonia.

In the local school, the energy class is equipped, including green power education toolkit, incl. Rutland 503 Windcharger (25 W) and 30 W Solar Photovoltaic Panel, plus power monitors. Six classroom tests have been elaborated such as Window for heating efficiency, Light for lighting efficiency, Power thief for energy classes of home appliances, Stand-by, Renewable energy sources and Dripping faucet. Energy day of the school has been set every autumn. A workbook, background information on tests and models as well as explanations and calculation tables supports students in carrying out experiments. In addition, students compete in energy-related computer games and quizzes at the energy day. Engineers and energy auditors present best practices on energy savings in buildings. Students have opportunity to handle energy audit instruments such as CO_2-meter, and thermo visor.

Engineering training courses held at the park to stimulate the 'greening' of businesses, industry and consumers. Energy advice programme is a free tool for raising awareness on energy use, environmental impact and related costs. Another segment is the initiatives for SME by providing examples and calculations on energy efficiency, energy consumption for heating and electricity. The promotion of innovations and best practices is targeted at SME, which could benefit the local economy, the environment, and job opportunities. This measure will have in a way limited, but long-term impact. In order to obtain an estimate of the potential, the impact for 2010 is based on an investment for a local biomass fuel market established for owners of single-family homes.

Conclusions

The Rõuge municipality is currently going through an important process of transformation and modernization in terms of energy use, all designed to make Rõuge into a more sustainable, beautiful and habitable rural district. Rõuge presents pioneering experiences in the energy production and use in particular for

the rural remote countryside. Municipality launched all major renewable devices as demonstration units assisting to achieve European Commission targets for RES-e and bio fuels market penetration. The consumption of fossil fuels by individual heating systems is reduced by at least 20 % through connection to district heating systems or replacing with RES. The efficiency of heating systems is expected to arise. The municipality uses eco-labelled electricity.

The Rõuge renewable energy park has an essential role in raising awareness of renewable energy technologies and the solutions these can bring in the wider context of sustainable development. The taken measures enjoyed strong support by various players, stakeholders and are expected to yield further reductions in GHG emissions. Innovation and installations on renewable energy lead to the districts' development through provision of new business opportunities, linking forestry, agriculture and engineering. The further steps towards zero-CO_2 community consist of long-term implementation of biomass and hydro energy and increasing in energy efficiency in housing and private sector. Initiatives are channelled in the single-family houses on cost-effective measures for reduced and more efficient use of energy. Measures are primarily directed at heating systems, but are also related to lifestyle. Activities of the park enhance the environmental awareness of the society and upgrade capabilities in searching for economically and environmentally attractive solutions while applying RES, especially in tourist and ecologically sensitive communities.

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