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USING RENEWABLE ENERGY AS AN INNOVATION SOURCE: CASE STUDY OF PÖRTOM COMMUNITY

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ABSTRACT:

The use of renewable energy as an alternative energy source cannot be overlooked at this present time of unstable price of fossil fuels combined with the recent economic crises. Renewable energy sources are available all over the world, but their availability greatly depends on their location. There are several technologies for exploiting renewable energy sources. These range from windmills to gigantic CHP power plants. Many communities are surrounded with renewable energy sources but lack the essential technologies for tapping them, and due to the price of the available ones, they are still avoided by every man. Consequently, the diffusion of renewable technology is exploited at low rate.

In this research the use of renewable energy as an innovation source was tackled by looking at the meaning of innovation and how the two issues – renewable energy and innovation – integrate. New knowledge can come in different ways: it could be an improvement on the present technology or a completely novel innovative idea. However, what is new to some people might not be new to others. The use of renewable energy technologies varies and their use depends on the way the lead user uses these technologies.

This study discovered how lead users' experience is used to analyze their energy needs by simulating the available data in proposing the capacity of the CHP power plant and location of the power plant to the lead users.

KEYWORDS: Renewable energy, Innovation

1. INTRODUCTION

1.1. Background of the study

Energy is one of the essential needs of a functioning society. The scale of its use is closely associated with its capabilities and the quality of life that members of the society experience. Worldwide, great disparities are evident among nations in the levels of energy use, prosperity, health, political power, and demands upon the world's resources (Tester, Drake, Driscoll, Golay & Peter, 2005:2). However, threats of global warming, acidification and nuclear accidents have put the need to transform the existing global energy into focus, especially with the growing demand for energy.

In order to sustain economic growth, our economy strongly depends on large amounts of fossil fuels such as oil, natural gas, and coal. The use of these fossil fuels has several negative impacts on the environment, among which are local air pollution and climate change. Therefore, for several decades, (inter)national governments have made plans to reduce the economy's dependency on fossil fuels by the substitution of alternative energy sources such as renewable energy sources. Renewable energy sources are defined as any energy resource, naturally regenerated over a short time scale and derived either directly from the sun (such as thermal, photochemical, and photoelectric), indirectly from the sun (such as wind, hydropower, and photosynthetic energy stored in biomass), or from other natural movements and mechanisms of the environment (such as geothermal and tidal energy). Renewable energy does not include energy resources derived from fossil fuels, waste products from fossil sources, or waste products from inorganic sources (IEA, 2006).

Oil is a very special product. It is not only the world's most used energy source, it is also used as an important basic material in the pharmaceutical chemical industries (Segtrop, 2006). During the last five years, the price of crude oil has more than quadrupled, from merely $15 per barrel to $75, moreover, its demand has never been stable (Segtrop, 2006).

Renewable energy sources contribute to the diversification of energy carriers for the production of heat, fuels, and electricity. They improve access to clean energy sources, they reduce pollution and emissions from conventional energy systems and, furthermore, they reduce the dependency on fossil fuels. Examples of such sources are biomass energy, wind energy, direct use of solar energy, hydropower, marine energy, and geothermal energy. In 2000, the share of renewable energy sources in the total global energy demand was about 13.3% of the total energy supply. However, for western economies this share was much lower: 6.2% of the total energy supply in OECD countries compared to 22.4% in non-OECD countries (IEA, 2002).

During the last decade we have observed an explosive attention, both in the popular press and among academics on innovation as a means to create and maintain sustainable competitive advantages. Innovation is considered a fundamental component of entrepreneurship and a key element of business success. This is becoming even more evident as we move into a post-capitalist, knowledge-based society (Johannessen, Olsen and Lumpkin, 2001). There are business opportunities for industry in terms of innovating into new technologies and products to develop as well as exploiting the markets, provided the new product will be sustainable.

1.2. Motivation

I choose to write on using renewable energy as source of innovation so as to show my readers such as students, researchers, decision makers, and investors, that it is possible that the renewable energy system perspective can be integrated into the innovation system perspective. I had the opportunity to be member of a team of students from different universities and countries on Nordic countries exchange 2009 (NORDEX 2009) project with diverse knowledge and background. Our goal is to look for alternative source of energy which must be renewable, for heating and electricity problems facing greenhouses, companies and municipality building of a community called Pörtom which belongs to Nårpes municipality near Vaasa here in Finland. I see this problem-solving as an opportunity to write my thesis on the above topic and become an expert in renewable energy sources and technologies. It will enable me to have in-depth knowledge about various sources of renewable energy and available renewable energy technology. It will expose me to the trends in research and development in terms of renewable energy source and the technology available. This study will also contribute to the field of knowledge, especially for interesting readers such as students, researchers, academics and other stakeholders' in renewable energy business.

1.3. Theoretical framework: energy and innovation

The theoretical framework of this thesis will be focusing on issues relating to energy transformation into an innovation system perspective. In looking at this, innovation will be the focal point and how it is diffused with renewable energy by looking at how lead user of an innovative product can be identified, and how lead user perceptions and preferences can be incorporated into innovation sources and emerging needs for new products, process and services. According to Johannessen, Olsen, and Lumpkin (2001), innovation implies newness. In order to measure innovation, it must be understood from three dimensions: what is new, how new and new to whom?

Bergek (2002) explains that the process by which a new technology emerges, improved and diffused in society can be studied from a number of perspectives. The neo-classical economics perspective focuses on how changes in relative prices influence technology choice (Bergek, 2002). Therefore, the rise in the price of fossil fuels is making user of this fuel to search for an alternative fuel. In this regard, lead users' experience will be used here to explore the source for innovation via renewable energy.

According to von Hippel (1986), accurate understanding of user needs has been shown to be essential to the development of commercially successful new products. Also lead users are users whose present strong needs will be dominant in the market-place for months or years in the future; hence their role is crucial for future development of new products.

1.4. Purpose of research

The *purpose* of this research is to find solutions to the energy problem encountered by greenhouse farmers and the building owned by Pörtom municipality, by looking at different types of technology available with regard to renewable energy and selecting the best for Pörtom and also suggesting the optimal location for the power plant. This objective will be achieved by answering the following questions, each of which will contribute to the purpose:

(a) What is the future of renewable energy in the dynamics of innovation?

(b) How has innovation influenced technology diffusion within the field of renewable energy technology?

(c) What is the energy problem encountered by greenhouse farmers and the municipality buildings of Pörtom?

(d) How can these greenhouse farmers and inhabitants of the municipality buildings solve this problem?

1.5. Research methods

There are different types of research methods applicable to research data collection and analysis. The adopted method mostly depends on the problem and researchers are always searching for the best outcome.

Akkanen (2007) explained four types of research methods based on the research approach by Kasanen et al (1991). According to Akkanen (2007) these methods as describe in the Figure 1 below are: Concept Analytical, Nomotetic, Decision-making methodology and constructive approach.

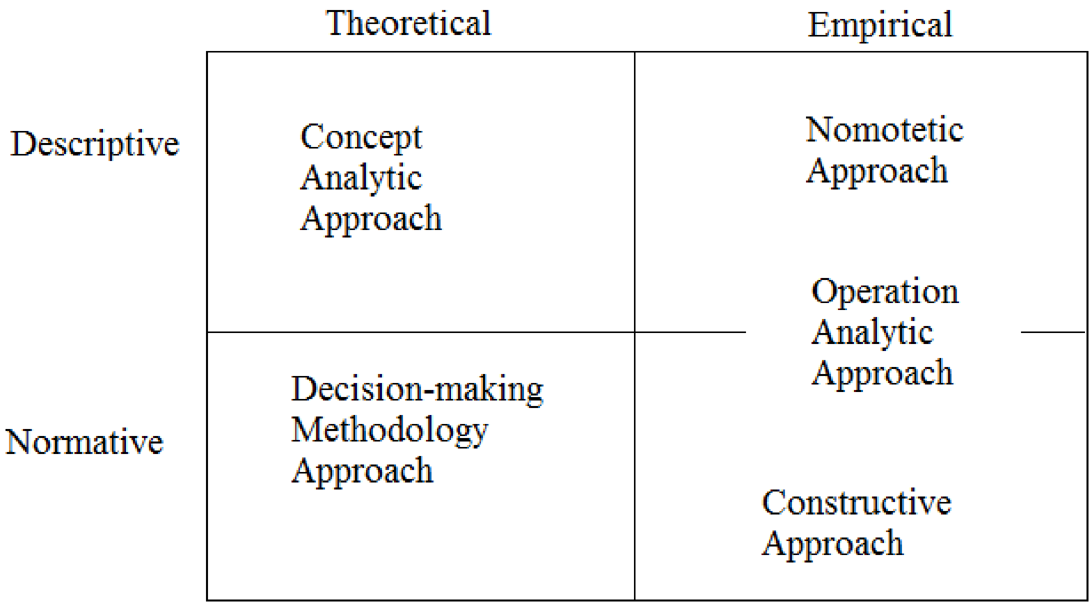


Figure 1. The relative position of business economics research approaches (Akkanen, 2007: 11).

Concept analytical approach is a research method used to improve concept systems. Concept systems are needed to describe, clarify, arrange and indentify new issues. As new terminology is emerging, also new concept system and old terminology are becoming new (Akkanen, 2007: 10-12).

Nomotetic approach is both empirical and descriptive research approach. This method is used to find casual connections between features and correlation in material observed. This material is collected from large population, which is processed by statistical methods.

Decision-making methodological approach concerns with development of a mathematical model, which are used by an organization when making decisions. Materials used to form information dependency of this model are generated through the data base of an organization. These dependencies combine with logic to form models and then describe the subject, which is the target of the research.

Operation analytical approach is an approach used for problem-solving, decision-making process, development and remodelling processes. Material used for this approach is empirical data or information.

Constructive approach is normative problem solving research method. It is goal oriented, creating innovations, working on an empiric level and making sure that the solution works also in practice.

The research approach to this thesis will be based on the information received from greenhouse farmers, which is an empirical type of information. The operation analytical approach will be used to solve the energy problems of the greenhouse farmers, to help energy decision-making processes and to develop a model that will be useful for future power plant planners. The research framework is summarized in figure 2.

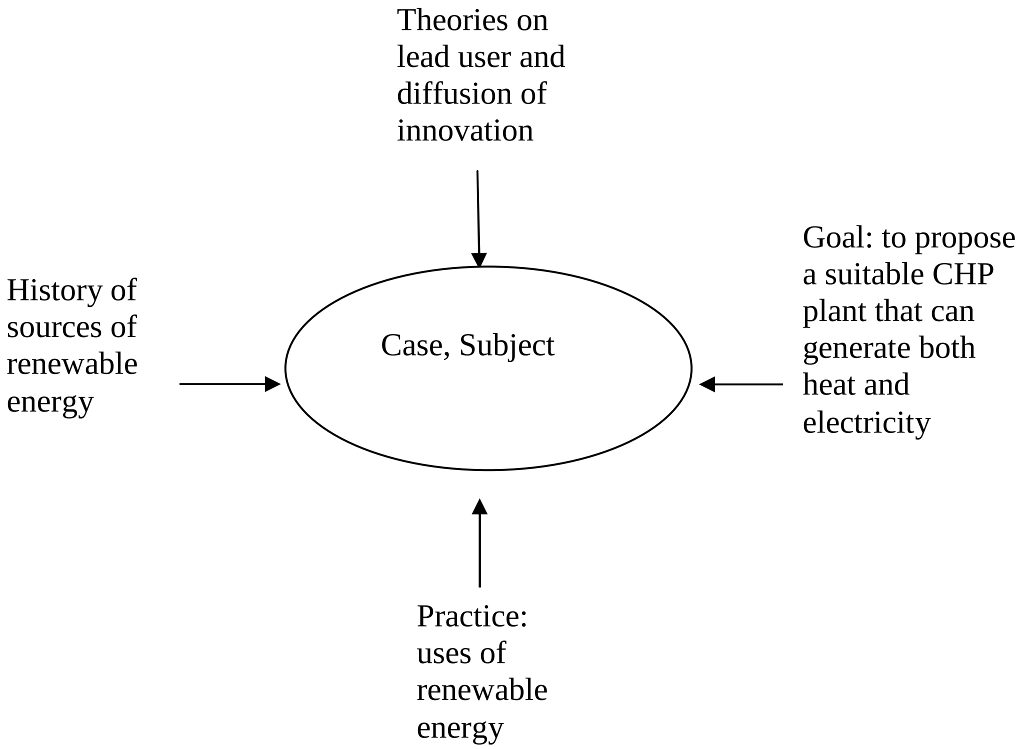


Figure 2. Research framework (built on Akkanen's (2007: 12) basic concepts: history, theory, goal and practice) (CHP means Combined Heat and Power).

Based on figure 2 above, give below are explanations with regards to history, theory, practice and goal.

History in this context will be looking at the history of innovation, energy, renewable energy sources and renewable energy technologies available.

For theories, von Hippel’s theory of lead users shall be used to analyse how renewable energy can be used as an innovation source. Moreover, diffusion of innovation theory will as well be used to see how old technologies are diffusing and how new technologies are emerging.

The use of renewable energy technologies varies and it depends on the availability of energy sources within the location where the energy is needed.

The goal here means achievements at the end of the project. This depends on the information received from the lead users and analyses of this information’s in order to achieve the goal. The lead users in this case are the greenhouse farmers and the occupants in municipality buildings of Pörtom. The lead user’s analysis will be used for this case scenario.

The practices will be comparing the old paradigm and new paradigm of renewable energy paradigms in terms of renewable energy uses. There is need for change since the current energy has not contributed positively to the global environment, the practice will touch on how the new energy in term of cost has made some changes.

Data collection methods will be in form of interviews with the greenhouse farmers, records on usage of oil, and types of renewable technology used by these greenhouse farmers.

2. LITERATURE REVIEW

The purpose of this chapter is to contain theoretical frame work which will be focusing on the study of renewable energy resources and technologies based on global renewable resources as shown in table 1 below. This chapter will also be structure in such a way that answers to research questions (a) and (b) will form part of the literature review.

2.1. Renewable energy

Global renewable energy markets have grown tremendously in the past decade. Few people realize that some forms of renewable energy have become big business. Annual investment in renewable energy was an estimated $80 billion worldwide in 2002, up from $6 billion in 1995 (Martinot, 2004). This growth has been driven first and foremost by national and local polices, many of which effectively overcome the barriers that continue to put renewable energy at a competitive disadvantage to fossil fuels. According to market research.com (2009), in 2007, percentage growth of global renewable energy was 11.6% with a value of $246 billion, it is forecasted that by the year 2012, the global renewable energy market will have a value of $398.7 billion, an increase of 62% since 2007. The global renewable energy market grew by 3.6% in 2007 to reach a volume of 2,739.9 billion KWh. In 2012, the global renewable energy market is forecasted to have a volume of 3,216.8 (Market research, 2009).

According to Johansson, McCormick, Neij and Turkenburg (2004) renewable energy sources are highly responsive to environmental, social and economic goals. Presently, renewable energy provides about 14 percent of global primary energy consumption, mostly traditional biomass, and about 20 percent of electricity, mostly large-scale hydropower. However, ‘new’ renewable energy contributes only 2 percent of the world’s primary energy use. Such renewable energy sources that use indigenous resources have the potential to provide energy services with zero or almost zero emissions of both air pollutants and greenhouse gases.

Johansson et al (2009) argued that, natural flows of renewable resources are immense in comparison with global energy use. This holds both from a theoretical and technical perspective, however the level of their future use will depend primarily on the economic performance of technologies utilising these flows. Johansson et al (2009) argued that rapid expansion of energy systems based on renewable energy sources will require actions to reduce the relative cost of new renewables in their early stages of development and stimulate the market in this direction. Johansson et al (2009) further explained that, this expansion can be achieved by finding ways to drive commercialisation, while still taking advantage of the economic efficiencies of the marketplace.

Table 1. Global renewable resource base (Exajoules a Year). **(**The current use of secondary energy carriers (electricity, heat and fuels) is converted to primary energy using conversion factors involved). (Johansson et al., 2004: 3)

Resource	**Current use**	**Technical Potential**	**Theoretical potential**
Hydropower	10.0	50	150
Biomass energy	50.0	>250	2,900
Solar energy	0.2	>1,600	3,900,000
Wind energy	0.2	600	6,000
Geothermal energy	2.0	5,000	140,000,000
Total	**62.4**	**>7,500**	**143,909,050**

According to Johansson et al (2004), renewable energy sources supply about 14 percent of the world’s primary energy use predominantly traditional biomass, used for cooking and heating, especially in rural areas of developing countries. Large-scale hydropower supplies about 20 percent of global electricity and its scope for expansion is limited in the industrialised world, where it has nearly reached its economic capacity (Johansson et al, 2004). In the developing world, considerable potential still exists, but large hydropower projects often face financial, environmental, and social constraints and it is estimated that together ‘new’ renewable (modern biomass energy, geothermal heat and electricity, small-scale hydropower, low-temperature solar heat, wind electricity, solar photovoltaic and thermal electricity, and marine energy) contributed about 9 EJ in 2001, or about 2 percent of the world’s energy use (Johansson et al., 2004).

2.1.1. Hydropower

Hydroelectricity is obtained by mechanical conversion of the potential energy of water in high elevations. As it can be seen on table 1, the total theoretical potential of hydro energy is estimated at 150 Exajoules a year while the technical potential of hydroelectricity is estimated at 50 Exajoules a year (Johansson et al, 2004). The energy values and technical values are due to variance in rainfall and hydro energy is not evenly accessible. Rainfall may also vary in time, resulting in variable annual power output. Hydroelectricity generation is regarded as a mature technology, unlikely to advance further but there is room for small-scale hydropower advancement.

Johansson et al., 2004, elaborate on the criticism of large dams, modern construction d and ecological impacts. Johansson et al, 2004 then agued that, the most important impacts of large dams are the displacement of local communities, particularly indigenous people, changes in fish population and biodiversity, sedimentation, biodiversity perturbation, water quality standards, human health deterioration, and downstream impacts. The World Commission on Dams has done substantial work on this issue and elaborates a comprehensive set of recommendation for the reconciliation of conflicting demands surrounding large dams. Some of the these recommendations includes: Gaining public acceptance, comprehensive option assessment, addressing existing dams, sustaining rivers and dams, sustaining rivers and livelihoods, recognising entitlements and sharing benefits, ensuring compliance, sharing rives for peace, development and security.

2.1.2. Biomass power

Biomass is classified as plant, animal manure, and or municipality solid waste. Also belonging to this classification is natural forestry waste. Biomass resources are abundant in most parts of the world, and various commercially available conversion technologies could transform current traditional and low-tech uses of biomass to innovate modern energy. Substantial contribution of biomass to global energy mix depend on the available energy crops and advance technology to do the conversion to the required form of energy needed. According to Johansson et al (2004), a number of studies show that potential contribution of biomass in the long run can take a variety of estimate as shown in table 2 below.

Table 2. Examples of plant biomass (Johansson et al., 2004: 5).

Woody Biomass	**Non-woody biomass**	**Processed Waste**	**Processed fuels**
Trees Shrubs and scrub Bushes such as Coffee and tea Waste from forest floor Bamboo Palms trees and leafs	Energy crops such as sugarcane Cereal straw Cotton, cassava, tobacco stems and roots Grass Bananas, plantains and the like Soft stems such as pulses and potatoes Swamp and water plants	Cereal husk and cobs Pineapple waste and other fruits Nut shells, flesh and the like Plants oil cake Sawmill waste Industrial wood bark and logging wastes Black liquor from mills Municipal waste	Wood charcoal and residues Briquette and densified biomass Methanol and ethanol Plant oils from palms, rape, sunflowers and the like Producer gas Biogas

Biomass is used in traditional ways as fuel for households and small industries but not in a sustainable manner, and modern industrial-scale biomass applications have increasingly become commercially available. However, the biomass challenge is not so much an issue of availability but sustainable management, conversion, and delivery to the market in the form of modern and affordable energy services. Table 3 shows the global estimate for biomass potential and different types of biomass in residue forms together with their simulation for year to come.

Table 3. Global estimate for biomass potential (Johansson et al., 2004: 6) (FR = forest residues, CR = crop residues, AR = animal residues, MSW = municipal solid waste).

Source	**Types of residue**	**Biomass residue potentially available (EJ/y)**			
		Year			
		1990	**2020-2030**	**2050**	**2100**
1	FR, CR, AR		31		
2	FR, CR, AR, MSW		30	38	46
3	FR, MSW		90		
4					272
5	FR, CR, AR, MSW			217 - 245	
6		88			
7	FR, CR, AR, MSW		62		
8	FR, CR, AR		87		
9	Energy crops			660	1118
10	Energy crops			310	396
11	Energy crops			449	703
12	Energy crops			324	485

Bioenergy technology includes all technologies, which produce energy from biomass. The thesis will be considering those technologies for the supply of heat or electricity, such as pellet burners, steam boiler and gasification technology. This technology varies in size from small pellet burner of 10kw to boiler of 150MW etc.

Bioenergy is the most widely used renewable source of energy in the world. According to Johansson et al (2004) and IEA, (2005) bioenergy provided almost all global energy two centuries ago, and still it provides 11% of the world primary energy supplies. A wide range of environmentally sound and cost-competitive bioenergy systems are already available to provide a substantial contribution to future energy needs. Solid biomass is widely used as biomass-fired heating system, especially in colder climates. In developing countries the development and introduction of improved stoves for cooking and heating has a big impact on biomass use. Combustion of biomass to produce electricity is applied commercially in many regions. The globally installed capacity to produce electricity from biomass is estimated at 40 GW(e).

Large variety of raw materials and treatment procedures make the use of biomass a complex system that offers a lot of options. Biomass energy conversion technologies can produce heat, electricity and fuels using solid such as pellet burners, liquid such as steam boiler and gas such as gasification technology. Furthermore, anaerobic digestion of biomass has been demonstrated and applied commercially with success in many situations and for variety of feedstock's including organic domestic waste, organic industrial waste, manure, and sludge. Large advanced systems have been developed for wet industrial waste (Johansson et al., 2004).

Omer (2006), agued that biogas not only provides fuel, but is also important for comprehensive utilisations of biomass forestry, animal husbandry, fishery, agricultural economy, protecting the environment, realising agricultural recycling, as well as improving the sanitary conditions, in rural areas.

Gasification is based on the formation of a fuel gas, mostly CO and H_2 by partially oxidising raw solid fuel at high temperature in the presence of steam or air. The technology can use wood chips, groundnut shells, sugar cane bagasse, and other similar fuels to generate capacities from 3 to 100 KW. According to Omer, (2006), three types of gasifier designs have been developed to make use of the diversity of fuel inputs and to meet the requirements of the products gas output such as degree of cleanliness, composition, heating value etc.

2.1.3. Solar power

Omer (2006) explains the difficulty in availability of data on solar radiation. Even in developing countries, very few weather stations have been recording detailed solar data for a period of time long enough to have statistical significance. Two of the most essential natural resources for all life on the earth and for man's survival are sunlight and water. Omer, (2006) agued further that, sunlight is the driving force behind many of the renewable energy. The worldwide potential for utilising this resource, both directly by means of the solar technologies and indirectly by means of biofuels, wind and hydro technologies is vast.

Solar energy has immense theoretical potential but the amount of solar radiation intercepted by the Earth is much higher than annual global energy use (Nakicenovic, Grubler and McDonald, 1998). Large-scale availability of solar energy depends on a region's geographic position, typical weather conditions, and land availability.

According to Nakicenovic, et al (1998) with regard to primary assessment on solar energy as shown on table 4 below, the energy before the conversion to secondary or final energy was estimated. Nakicenovic, et al (1998) explains further that, the amount of final energy used greatly depends on the efficiency of the conversion device used (such as the photovoltaic cell)

Table 4. Solar energy potential (Goldemberg, 2004:30 original source: Nakicenovic et al., 1998).

Region	**Minimum Exajoules**	**Maximum Exajoules**
North America	181	7,410
Latin America and Caribbean	112	3,385
Western Europe	25	914
Central and Eastern Europe	4	154
Former Soviet Union	199	8,655
Middle East and North Africa	412	11,060
Sub-Saharan Africa	371	9,528
Pacific Asia	41	994
South Asia	38	1,339
Centrally planned Asia	115	4,135
Pacific OECD	72	2,263
TOTAL	**1,575**	**49,837**

Solar energy is versatile and can be used to generate electricity, heat, cold, steam, light ventilation, or hydrogen. There are several factors that determine the extent to which solar energy is utilized, and these include the availability of efficient and low cost technologies, effective energy storage technologies, and high-efficiency end-use technologies.

Photovoltaic's system is one technique used to produce electricity by direct conversion of solar light to electricity. Current operating capacity of solar photovoltaic (PV) is estimated at 1.1 GW (electricity) with efficiency of 12 to 15 which is likely to increase to 12 to 20 percent in the year 2020 and up to 30 percent or more in the longer term (Johansson et al, 2004; IEA, 2007).

Solar thermal system is also another mode of electricity generating system which utilised high temperature from the sun. Examples of solar thermal electricity technologies are parabolic trough systems, parabolic dish systems, and solar powers towers surrounded by a large array of two-axis tracking mirrors reflecting direct solar radiation onto a receiver on top of the tower. The total installed capacity is currently about 0.4 GW (electricity) (Johansson et al, 2004).

According to Johansson et al (2004), *solar thermal heat* application can be used to generate electricity by using the world’s low and medium temperature estimated at about 100 EJ a year. Solar technologies do not cause emissions during operation, but they do cause emission during manufacturing and possibly on decommissioning, unless produced entirely by solar breeders. The most controversial issue for photovoltaic (PV) systems is weather the amount of energy required to manufacture a complete system is smaller or larger than the energy produced over it lifetime, although the energy payback time for PV system is 3 to 9 years and this is expected to reduced 1 to 2 years in the longer term.

2.1.4. Wind power

Wind turbines transform the kinetic energy of the wind to electricity via the blades and a generator. The size of the design depends on the type of generator and the control method adopted (Bergek, 2002). The utilisation of energy from renewable sources, such as wind, is becoming increasingly attractive and is being widely used for the substitution of oil-producing energy and eventually to minimise atmospheric degradation. Wind energy is non-depleting, non-polluting and a potential source of the alternative energy option. Wind power supplied approximately 40Thw electricity in the world in 2000 and wind and power could supply 12% of global electricity demand by 2020 (Bergek, 2002; Omer, 2006.)

A region’s mean wind speed and its frequency distribution have to be taken into consideration in order to calculate the amount of electricity a wind turbine is capable of producing (Johansson et al, 2004). Table 5 below shows annual average of wind power density exceeding 250 to 300 watts per square metre at 50 metre high.

Table 5. Estimated annual wind energy resources. (Johansson et al, 2004:10 adapted from Goldemberg, 2002) (Note: The energy equivalent is calculated based on the electricity generation potential of the referenced sources by dividing the electricity generation potential by a factor of 0.3, this value is the efficiency of wing turbines, including transmission losses, resulting in a primary estimate).

Region	**Land surface with Sufficient Wind condition**		**Wind energy resources without land restriction**	
	Present	**Thousands of km^3**	**TWh**	**Exajoules**
North America	41	7,876	126,000	1,512
Latin America and Caribbean	18	3,310	53,000	636
Western Europe	42	1,968	31,000	372
Eastern Europe And former Soviet union	29	6,783	109,000	1,308
Middle East and North Africa	32	2,566	41,000	492
Sub-Saharan Africa	30	2,209	35,000	420
Pacific Asia	20	4,188	67,000	804
China	11	1,056	17,000	204
Central and South Asia	6	243	4,000	48
Total	**229**	**30,199**	**483,000**	**5,796**

There are modern electronic components, which make innovators to control output and produce excellent power quality and this development makes wind turbines more suitable for integration with electricity infrastructure and ultimately for higher penetration. According to Johansson et al., 2004, there has been gradual growth in the size of wind turbine commercial machine, from 3 kilowatts of generating capacity in the 1970s with a diameter of 10 metres to 5 megawatts with 110 to 120 metres and designers are still researching for better innovation in this direction. The current market demand have driven the trend towards larger wind turbines through economies of scale, less visual impacts on the landscape per unit of installed power, and expectation on offshore development are shown in table 6 below.

Table 6. European offshore wind resources (Johansson et al, 2004:11; adapted from EWEA and Greenpeace, 2002) (Note: Figures show electricity production in TWh per year.)

Water depth	Up to 10km offshore	Up to 20km offshore	Up to 30km offshore
10m	551	587	596
20m	1,121	1,402	1,423
30m	1,597	2,192	2,463
40m	1,852	2,615	3,028

The most negative environment impacts of wind technologies are acoustic noise emission, landscape, bird behaviours', moving shadows which are caused by the wind mill rotor and electromagnetic interference with radio, television, and radar signals.

2.1.5. Geothermal power

Geothermal energy consists of thermal energy stored in the earth's crust. Mostly geothermal resources depend in part on the specific application or energy service that is provided and the sources, transportation mechanism of geothermal heat is unique to geothermal energy (Tester, et al., 2005). Geothermal energy has large theoretical potential but only small quantity can be classified as resource and reserves as shown in table 1. Geothermal energy is available as other renewable energy but it is widely scattered (Johansson et al., 2004). Global potential of geothermal can be survey according on regional bases as shown in table 7.

Table 7. Annual Geothermal Potential by Region (Johansson et al., 2004)

Region	**Million Exajoules**	**Percentage**
North America	26	18,9
Latin America and Caribbean	26	18,9
Western Europe	7	5,0
Eastern Europe and former Soviet Union	23	16,7
Middle East and North Africa	6	4,5
Sub-Saharan Africa	17	11,9
Pacific Asia	11	8,1
China	11	7,8
Centrally planned Asia	13	9,4
TOTAL	**140**	**101.2**

Geothermal technology use is in two fold: electricity production and direct application. Johansson, et al 2004, estimate conversion efficiency of geothermal power plants at about 5 to 20 percent while global installed capacity is 8 GW(e) generating about 53 TWh of electricity per year (Johansson et al., 2004). Direct application of geothermal can be use in a various way such as space heating and cooling, industry, greenhouses, fish farming, and health spas. Geothermal utilized existing technology and is also straightforward. It is used in United State of America, Italy, Turkey, Germany, Mexico, Indonesia, Japan, and New Zealand. Direct use of geothermal has a capacity of about 16 GW deliveries 55 TWh of heat per year (Johansson et al., 2004). Geothermal fluids contain a variety quality of gas, largely nitrogen and carbon dioxide with some hydrogen sulphide and smaller proportions of mercury, ammonia, boron, and radon, most of these chemicals are not harmful (Johansson et al., 2004:13).

2.1.6. Summary: renewable energy forms

Global renewable energy markets have grown tremendously in the past decade. This growth has been driven first and foremost by national and local policies, many of which effectively overcome the barriers that continue to put renewable energy at a competitive disadvantage to fossil fuels.

Natural flows of renewable resources are immense compared to global energy use. Renewable sources supply 14 percent of the world primary energy use such as biomass.

Large-scale of renewables, such as hydropower, supply about 20 percent of global electricity. There are also modern biomass energy, geothermal, solar heat, wind, solar photovoltaic and marine energy sources. All of these stated renewable energy forms, contributed about 9EJ and about 2 percent of the world' energy use in 2007 and their supplies can be innovatively improved in order to have a competitive advantage over fossils fuels.

2.2. Innovation

In order to understand the meaning of innovation, it is worth-while to look at it from different perspectives while also keeping attention on different opinions of some notable scholars in the field of innovation. There are various definitions of "innovation" that appear in the literatures. This section of the thesis will be comparing some major definitions. According to Organisation for Economic Co-operation Development (OECD) (1997), Joseph Schumpter, an economist, defined innovation from five different views:

1. introduction of new product or a qualitative change in an existing product;
2. process innovation new to an industry;
3. the opening of new market;
4. development of new sources of supply for new material or other inputs;
5. changes in industrial organisation.

With regards to Schumpter definition, technological product innovation involves either a new or improved product whose characteristics differ significantly from previous product. The characteristics of the product may differ due to use of new technologies, knowledge or materials. Also technological process innovation is the adoption of novel or significantly improved production methods, methods of product delivery. The word "new" or "improved" applies to a firm: even though the new method adopted is being used by others this still represent innovation for firm that adopted the new method. Therefore, innovation involves both creation of new knowledge, as well as the diffusion of the existing knowledge; precisely innovation is not easy to define. However, it is believed that innovation can be used to maintain sustainable competitive advantages

(Young, 1994; Darzin and Schoonhoven, 1996; and Kanter, 1985) and innovation goes down to the concept of newness as mentioned above. It is important to note that innovation is not the same as change – rather it is a concept of newness and it depends on which perspective one is looking at its meaning.

Focusing on innovation from firm-level, innovation can be defined as the application of new ideas to the products, processes or any other aspect of a firm’s activities (Roggers, 1998). Roggers claims that his definition looks simple, and to be precise about innovation definition, it involves some consideration of number of issues. Roggers outlines those issues by comparing the definitions of innovation by OECD.

Innovation can be defined as any new, improved goods or service, which has been commercialised, or any new or substantially improved process used for the commercial production of goods and services.

In his own contribution, Philips (1997) distinguishes between technological innovation and non-technological innovation which includes novel marketing strategies and changes to management techniques or organisational structure. In Philips’ explanation a firm is defined as technologically innovative firm, if at least one product is introduced or substantially improved or process in a three year period. While a non-technologically innovative firm was defined as a firm having introduced one of the changes mentioned above.

Covin and Miles, as sited by Johannessen et al., (2001), considered innovation as a fundamental component of entrepreneurship. Also in their own contribution, Nonaka and Takeuchi (1995) saw innovation as an important element of business success.

Jacobson (1992) contributed to innovation definition by looking at it from knowledge perspective; Jacobson defined innovation as continuous change of state of knowledge which produces new knowledge equilibrium and, which also produce new profit opportunities. Jacobson argued further that the rate of change is increasing due to exponential advancements in technology, frequent shifts in the nature of customer demand, and increased global competition.

D’Aveni (1994) supported the opinion of Jacobson (1992) as sited by Johannessen et al (2001) and characterized innovation as situation such “as hyper-competition and as we move into a more knowledge-based society, an increasing number of industries and firms are likely to face such hyper-competitive conditions. Hence, the unending and increasing stream of knowledge that keeps marketplaces in perpetual motion will require companies to focus even harder on being innovative in order to create and sustain competitive advantages” (Johannessen et al 2001:20).

Gibbons, Limoges, Nowotny, Schwartzman, and Trow (1994) defined innovation based on individual organizational level as the application of ideas that are new to the organization, whether the new ideas are incorporated in products, processes, services, or in work organisation, management or marketing systems. However, for better understanding of innovation, it was discovered that nearly all definitions given above focus on the concept of newness. Slappendel (1996) argue that the perception of newness is essential to the concept of innovation as it serves to differentiate innovation form change. According to Johannessen’s et al (2001) suggestion on isolation of useful definition and measurement of innovation, three newness related questions needs more explanations: “what is new, how new, and new to whom?” Johannessen et al (2001) explain also that for better understanding of the type of innovation concepts, the following innovative activities need more studies: (1) new products, (2) new services, (3) new methods of production, (4) opening new markets, (5) new sources of supply and (6) new ways of organising.

2.2.1. Innovation as newness

Almost all the innovation mentions above focus on novelty and newness, however, Johannessen et al., (2001) argued that most of the widely-used definitions of innovation focus on novelty and newness. According to European Commission’s (1995: 9) Green Paper on Innovation defines innovation as “the successful production, assimilation and exploitation of novelty in the economic and social spheres”. Nohria and Gulati (1996) also defined innovation as a new strategy adopted by organization manager toward innovating a product or services. Damapour (1991: 556) defined innovation as “the generation, development, and adoption of novel idea on the part of the firms while Zalman, Duncan, and Holbeck (1973: 10) defined innovation as “any idea, practice, or material artefact perceived to be new by the relevant unit of adoption”. According to Johannessen et al., (2001), all of the above definitions never agreed on the basic questions about the nature of newness: what is new, how new, and new to whom? For better understanding of these basic questions, it required some performance measurement of innovation.

2.2.2. What is new?

In other to understand the true meaning of innovation from newness perspective, Johannessen et al, (2001) argued that newness of innovation can be found from analysis of innovation from previous studies. Performance of any economic depends how frequent new ideas are introduced in products and processes improvement. This measurement performance of newness is weak and contains some deficiency between definition and measurement, hence, the operationalizations and measurement of innovation in prior research provide little guidance to the question “what is new?” However, Kirzner (1976; 1985) in Johannessen et al, (2001), concluded that to “operationalize what is new in a better way, it require innovative activities across broadly-defined relevant units of adoption

2.2.3. How new?

Different approaches have been used to address the issue of how new, that is, the degree of newness that constitutes an innovation (Johannessen, et al, 2001). Gersick, (1991) focuses on the degree of newness by considering the issues of revolutionary innovations. Linton (2007: 18) describes revolutionary innovation as innovation “build on the past and sustain the existing set of production and technological skills in use in firm”. The invention of the combustion engine and IBM’s introduction of the DOS operating system are examples of revolutionary innovations. There are patterns of changes in historical time scale on innovation as claimed by Johannessen et al (2001).

However, Drazin and Schoonhoven (1996) noted that the emergence of a new design lead to additional innovation, bringing new approaches and technologies in its wake. Johannessen et al (2001) explain that the pace in IT-sector has been very high within existing technological regimes. It is also noted that, the issue of differences in incremental and radical innovation are also recognised in studies of innovativeness (Johannessen, et al, 2001). According to Linton (2007) innovation is often described as either being radical or incremental. Hage (1980) agued that innovations vary along a continuum from incremental to radical. Dosi (1982) and Dewar and Dutton (1986) claim that radical has been linked to revolutionary innovations, whereas incremental is linked to innovation with a paradigm.

Linton (2007) explain that incremental innovation is very easy for an organisation to implement and become part of the organisational routine, and because it required little modification to the current routines, processes and actions, while radical innovation, involves total changes to the innovation or organisational routines, processes and actions. Damanpour (1996) supported Linton opinion by referencing to radical innovation as innovation that completely changes the activities of an organisation and moves apart from the existing practices, while incremental innovation depicts innovations with lesser degree of movement from existing practices. Linton (2007:19), argued that “understanding the determinant of how radical or incremental an innovation is can be of great assistance for making better decisions about adoption and implementation of innovation with one’s firm”. Linton explained further that every organization is different and that the degree of innovation “radicalness” can be unique for every organization within the same industry.

2.2.4. New to whom?

Johannessen et al (2001) suggested that the extents of newness of an innovation are related to the domain in which the innovation is adopted and also there is need for relevant units of adoption. Copper (1993) and Kotabe and Swan (1995) argue that examination of innovation can be done in terms of both newness to organisation which is referred to as organisation-based framework and newness to the market also referred to as newness to market framework. Furthermore, Kotabe and Swan (1995) claim that innovation measurement captures the ability of a firm to service and continue to update the innovative technologies which are key consumer concerns. As expressed by Johannessen et al (2007) even though when the innovation is new to an organisation there are still some external factors which affect the adopted innovation. Johannessen et al (2007) then suggested that, "newness to the industry, rather than newness to the market, represent a more broadly-construed and inclusive framework.

2.3. Innovation source

There are many sources of innovation in the chain of innovation; the most recognised is the manufacture. Another source of innovation is the end user; this type of innovation source according to Hippel (1988) is referred to as lead user. Lead user could be individual or company who developed an innovation for their own use because existing products do not meet their needs. As already mentioned, innovation could be by business, inform of research and development either through on-the-job modification of practice, exchange and combination of professional idea and many other ways. Mostly radical and revolutionary innovations tend to emerge from research and development, while more incremental innovations emerge from practice.

2.3.1. Lead users as a source

As already mentioned above, innovation "might be something which has never previously existed, it could be something new to our own personal situation or capable of having a fresh use at the time that we become aware of it" (Spence, 1994:26). For better understanding of innovation source, it is good to know who is an innovator. As defined by Spence (1994), innovators are first people who adopt a product. In this sense lead users are known to be inventor. Lead users could be developer of innovation process. According to von Hippel (1988) this type of innovation source are rare, as developer of innovation process can only develop 50% of the sample innovation. Another type of users is that which is referred to as manufacturer, this user have the capability to develop all processes involve in innovation. The duty of users developed all, is to develop new idea or improvement of existing innovation.

Based on the theory above, innovation source are the users of the various technologies available in the field of renewable energy. Hippel (1998) argued that “several innovations were sometime attributed to a single innovating user or manufacturer”. When a product idea is initiated by user we term the user as the inventor. Although it is possible that manufacture is also developing the idea separately in such a situation they are also known to be inventor of the product but in parallel with the lead users who has experience of the product.

2.3.2. Innovativeness ranges

As it was mention above, not all what is new are always accepted. According to Spence (1994) no matter “the nature of innovation not all people will accept it and, of those who do, not all will adopt it at the same time”. Innovation acceptance depends on individual behaviour. Innovators are the very set of people that adopt a particular technology. These people are not inventor, because they are just the first people to take advantage of innovative technology into use.

2.3.3. Classification of adopters

The figure 3 below illustrates aggregate acceptance of innovation of an individual over time plotted against cumulative time scale, which represents a normal distribution curve.

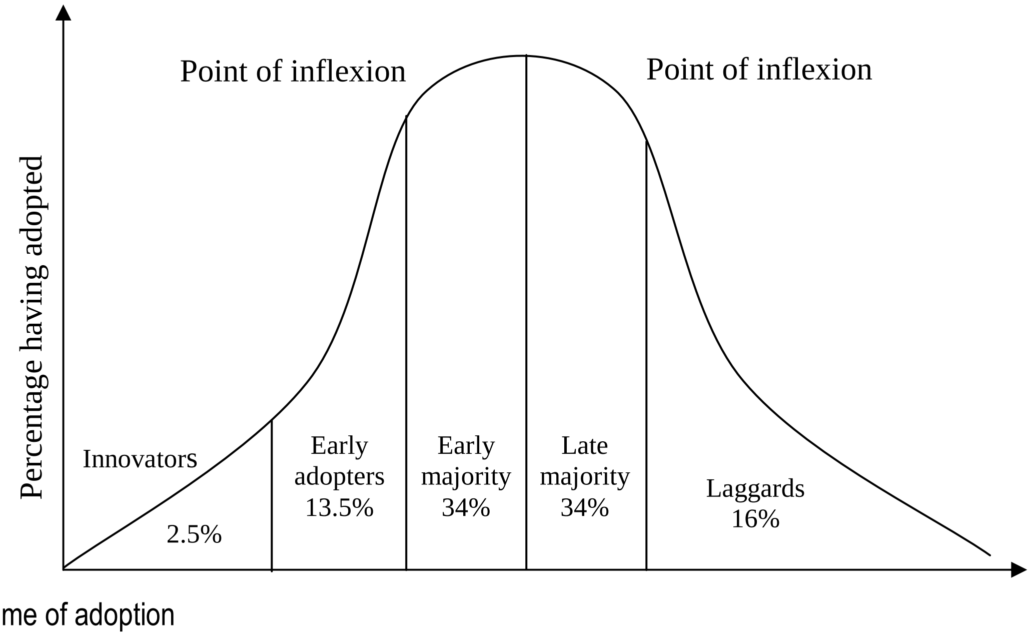


Figure 3. Adopter categories (Spence, 1994:43).

Spence (1994) in his book classified adopter behaviour characteristics into five categories namely:

1. Innovators
2. Early adopters
3. Early majority
4. Late majority
5. Laggards

Innovators are the first set of people that adopt what they perceive to be a new idea buy new technology or put into practice a fresh or revised technique (Spence, 1994). According to Rogers (2003) innovators are willing to take risks, youngest in age, have the highest social class, have great financial lucidity, very social and have closest contact to scientific sources and interaction with other innovators.

Spence (1994) classified the second category as the *early adopters*, who are just little more cautious than the innovators. “Early adopter is the type that is believes to have the highest degree of opinion leadership among other adopter categories. Early adopters are

typically younger in age, have a higher social status, have more financial lucidity, advanced education, and are more socially forward than innovators (Rogers, 2003).
People within the category of *early majority* adopt an innovation at a slower rate. (Rogers 2003) claim that early adopter have average social status, contact with early adopters, and show some opinion leadership as well.

Late adopters of an innovation seek more of public opinion before making move to join their counterpart. *Late majority* are typically sceptical about an innovation, have below average social status, very little financial lucidity, in contact with others in late majority and early majority, very little opinion leadership (Rogers, 2003).

Spence (1994) called the *laggards'* category of adopters "the slowest, and the last people to adopt anything". Laggards are always used to their old ways of doing things. They are very poor set of people with little or no education at all. They never believe because of their isolation from social organizations. Laggards have lowest social status, lowest financial fluidity, oldest of all other adopters, in contact with only family and close friends, very little knowledge about opinion leaderships (Spence, 1994).

2.3.4. Innovation diffusion

As already defined that innovation could be some new idea or improvement on the old process. According to Brown (1980) "innovations do not immediately appear over the entire earth's surface once they are perfected" but innovation is a distribution characteristics which is dynamic in nature, " the process by which such changes occurs, that is by which innovations spread from one locale or one social group to another, is called diffusion. The process of spreading of innovation from the innovators to other people is known as diffusion of innovation. "As more and more of the potential users within an industry, community adopt an innovation as part of product or process development we have diffusion in the demand for this innovation" (Karlsson, 1988:15).

The above theory of innovation explains life cycles of technology from innovative stage to the obsolescence stage. In the early stage of technology innovation, growth is always slow as the technology is trying to establish itself. At some point people begin to demand and the technology continue to grow. The growth shown on the curve occurs as a result of incremental innovation or as an improvement to the technology. At a point on the curve, the technology approaches end of it life cycle, then growth slow and eventually decline. As soon as the current technology is approaching decline stage, innovative organizations strive researching into new technology to replace the old ones. Figure 4 shows how current technology diminish and how new one emerges.

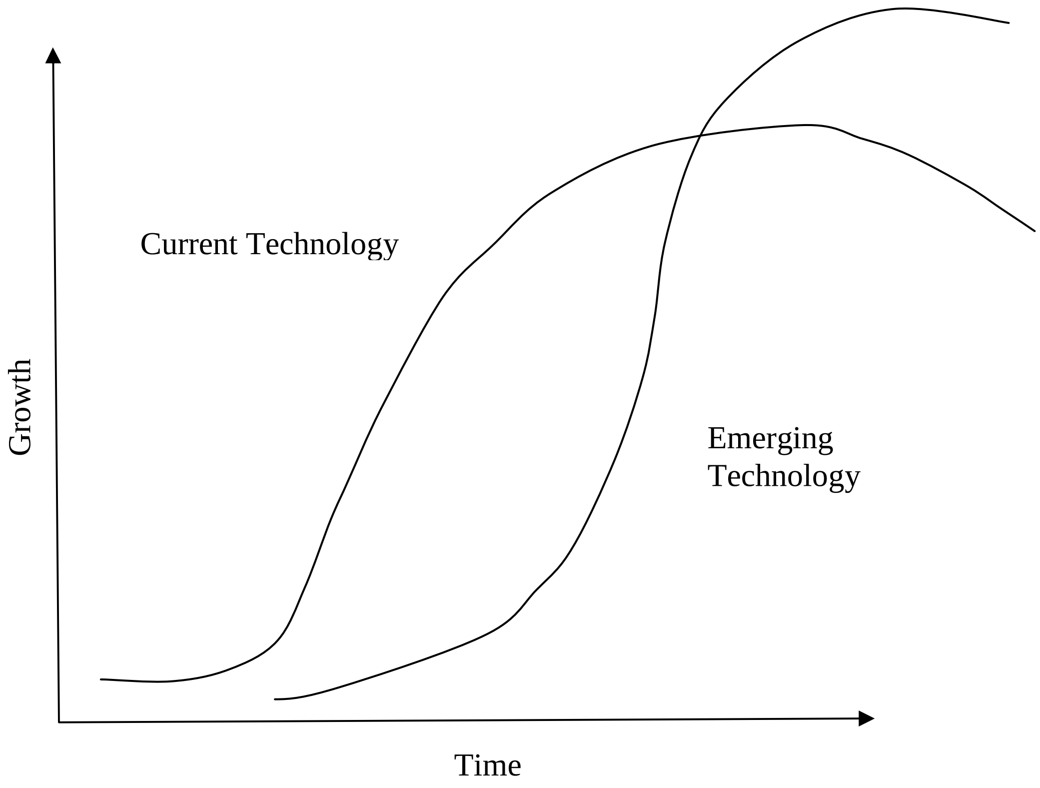


Figure 4. Typical diffusion curves. Adopted from (Spence, 1994:78).

2.4. Integrating renewable energy and innovation

2.4.1. Innovation technology diffusion within the field of renewable energy

Energy sector is subject to set of parallel and interesting force of change. The most fundamental is awareness of the environmental consequence of the existing energy system. Fossil fuels and their roles in acidification and global climate change figure prominently in the contemporary environmental and energy debate. As a response to the new awareness, a demand for “green” energy is emerging. (Jacobsson and Johnson, 2000: 625).

The use of renewable energy was considered an important technology as a result of oil crises of the mid 1970s, which affected almost every countries of the world. However, the diffusion of the new technology was back-up with an action plan set up by different national. In studying how this new technology may transform the energy sectors, an application of innovation system perspective is need when analysing the process of innovation and diffusion (Jacobsson and Johnson, 2000). There are many ways of analysing the development and diffusion process of renewable energy sources. This study shall concentrate on the perspectives of renewable energy as an innovation sources. The relative advantage of renewable energy sources is difficult to turn into an economic advantage. Therefore, the diffusion of renewable energy sources strongly depends on government polices. According to Dinca (2009), the Spanish government in 1980 enact an Energy Conservative Law in order to stimulate the adoption of biomass power generation. “By 2007, there were 525 MW of power plants using biomass resources, generating just 1.1% of the total electricity production. Only 15% of the readily available biomass resources are used for electricity generation” (Dinca, 2009).

There are different types of innovation systems, where each type focuses on a specific aspect depending on one’s unit of analysis. In National Innovation systems, country is used as unit of analysis (Porter, 1990; Nelson, 1992; Lundvall, 1992; Edquist, 1997). Also used is the Regional Innovation System in which the cultural variables such as where social networks is put into consideration (Saxenian, 1994 in Jacobsson and Johnson, 2000).

Based on the action plan for renewable energy in Finland, twenty years goals was set in 1990, and “realisation of the goals of the Action Plan, and the related measures, would bring an increase of 3 Mtoe (50%) in the total annual use of renewable energy sources by 2010” (Ministry of Trade and Industry, 2000: 28). Table 7 below shows the breakdown of the increase as it is estimated with “90% from bioenergy, 3% from wind power, 3% from hydropower, 4% from ambient energy via heat pumps, and under 0.5% from solar energy" (Ministry of Trade and Industry, 2000: 28).

Table 8. The target specified in the Action Plan, by energy source, 2010 (Ministry of Trade and Industry, 2000: 28).

	Realised			**Primary energy target for increasing renewable 1995 - > 2010**		**Electricity generation, target for Renewables 1995 - > 2010**	
	1990	**1995**	**1997**				
	Mtoe	Mtoe	Mtoe	Mtoe	%	MW (Peak)	TWh
Bioenergy*	**4.0**	**5.0**	**5.7**	**2.8**		**1,050**	**6.2**
Industry	2.87	3.72	4.31	1.5	40	500	3.5
District heating	0.08	0.19	0.28	0.8	4 times	550	2.7
Small-scale use	1.07	1.07	1.12	0.5	45	-	-
Hydropower*	**0.92**	**1.10**	**1.03**	**0.09**	8	**420**	**1.0**
Wind power*	**0**	**0.0009**	**0.0014**	**0.09**	100 times	**500**	**1.1**
Solar energy*							
Solar electricity	0	0.0001	0.0001	0.004	40 times	**40**	**.05**
Solar heat	0	0.0002	0.0002	0.004	20 times		
Heat pumps*	**0**	**0.01**	**0.03**	**0.1**	10 times		
Total *	**4.9**	**6.1**	**6.8**	**3.1**	**50**	**2,010**	**8.35**
Share of total energy consumption, %	18.1%	21.3%	22.1%				
Share of total Electricity consumption, %	30%	27%	27%				31%

*Total in each column is made of figures in bold and the answers show an approximation

Note: Bioenergy does not include peat, two-thirds of the industry's bioenergy is obtain from wood-processing industry' black liquors, average hydropower in the 1990s = 1.08 Mtoe. The increase in the table is generated by plants of under 10 MW. Bigger plants cause an additional increase of 0.5 TWh. 31% calculated from the scenario of total energy consumption (Ministry of Trade and Industry, autumn, 1998 in Ministry of Trade and Industry, 2000).

2.4.2. Diffusion of renewable energy in Finland

Renewable energy technologies can be termed radical innovations and for radical innovations to be successful, they have to overcome considerable barriers among prevailing standards. Diffusion of renewable energy has been very slow globally. But in the case of Finland, diffusion of renewable energy has been quite good due to the support received from the government. Finnish government in spring 1997 formulated her first energy strategy policy; the objective of the energy policy is by "utilising economic means of steering and marking mechanisms, to create circumstances that support both economic and employment policies. These circumstances should ensure the availability of energy, should keep the price of energy competitive, and should enable Finland to meet her international commitments with respect to emissions into the environment" (Ministry of Trade and Industry, 2000:9 -10)

2.5. Diffusion of renewable energy market technologies

2.5.1. Renewable energy market

The environments where renewable energy carriers are available determine an understanding of the market potential and the demand for the renewable energy. According to Martinot (2004: 1) "renewable energy market have grown tremendously in the past decade, this growth has been driven first and foremost by supportive national and local policies, many of which have effectively overcome the barriers that continue to put renewable energy at a competitive disadvantage to fossil fuels". This thesis will be focusing on the available market for renewable energy in global perspective and much attention will be on Nordic countries market opportunities for renewable energy. Wind power and solar photovoltaic are the fastest growing renewable energy markets (Sawn, 2003 in Martinot, 2004). The two markets have been growing with an annual rate of 15-40% in the recent year (Martinot, 2004). Germany has been leading in the application of grid-connected wind power. Countries like Demark has reached the peak in the application of wind power energy and is not expected to grow any further. There are still opportunities for market expansion in other European countries. Most of the developed country has been using renewable energy as their sources of power generation such as power-grid-connected wind and biomass.

2.5.2. Potential of renewable energy market in Nordic countries

Biomass is locally available, and it is cheap, hence this thesis is focusing on the available energy sources within the local area of the case studies. It is important to compare the availability of energy sources within the Nordic countries due to their similarity and their geographical location.

The availability of biomass utilised for energy generation in a country reflect to what extents the potential market for renewable energy of the nation and “the aggregated figures of renewable energy potential and the current installation disprove considerable regional differences. Solar potential varies considerably, with average annual installation in tropical regions, 3 times that of temperate latitudes. Geothermal energy and micro-hydro are even more location specific, biomass are more widely available. Biomass resources are more widely available, land use and climate constrain result in significant differences in the scale of potential resources and the type of application” (Gross, Leach, and Bauen, 2003: 106). “Wind energy is also widely distributed but wind regimes differ significantly both within and between regions, and modest variations in wind speed can have a profound effects on energy output” (Gross, et al 2003: 106).

Most OECD countries have ambitious plans and targets, with particularly strong support in Europe recently reinforced by the EU Renewable Directive and in the policies of several states and in the US. Developing countries also have policies support for renewable energy development (Gross, et al 2003: 106).

The global contribution of renewable energy in the generation of electricity is about 17.9%, but most of this is from large hydroelectric scheme (Gross, et al, 2003:106; IEA, 2007:5)

2.5.3. Potential and use of biomass in Denmark

Biomass resources uses for energy generation includes electricity, heat and transportation. About 70% of renewable energy consumption comes from solid biomass such as straw, firewood, organic waste, chips, and wool pellets. Denmark energy generation is based on their national resources. Biodiesel produced in Denmark are exported to other country such as Germany, where about 2 billion litres of biodiesel is used for transportation purposes. Germany leads the world in the use of biodiesel (Martinot, 2004; Nordic Energy Research, 2008).

Table 9. Potential and current use of biomass in Denmark (Adapted from Nordic Energy Research, 2008:8).

PJ/ year	**Biomass potential for energy use**	**Current use of Biomass for energy**	**Difference**
Straw	55	18.5	36
Organic waste	30	28.7	1.3
Wood	40	34.4	5.6
Biogas	40	3.8	36.2
Total	**165**	**85.4**	**79.1**

Table 8 shows that Denmark has utilised organic waste and wood for energy generation but they still have potential for both straw and biogas.

2.5.4. Potential and use of biomass in Iceland

The use of bioenergy is very negligible in Iceland. This is due to large share of other renewable energy sources. Electricity and heat generation is via hydropower or geothermal power, and biogas. The sole potential use of bioenergy is in transportation while the energy source for municipality heating is from solid waste (N.E.R., 2008).

2.5.5. Potential and use of biomass in Norway

Bioenergy in Norway account for about 1.1% of the energy demand and waste is used for generating heat. Forestry and agricultural, pulp and paper residue, and organic waste are also used for energy generation.

Table 10. Biomass use in Norway (TWH/year) (N.E.R., 2008:14).1

Fuel /Biomass Resource	**Domestic Resources**	**Import**	**Current use of Bioenergy**
Raw wood	6.4	1.9	0.9
Processed wood	10.0	5.6	5.3
Wood waste from furniture & wood products	0.5	1.8	0.7
Municipality Waste	4.4	-	0.9
Wood waste from construction	0.9	-	0.3
Landfill gas	1.0	-	0.1
Other biogas	3.0	-	0.1
Wood fuel	7.2	-	7.2
Straw & Crop husk	4.5	-	0.1
Total	**37.9**	**9.3**	**15.6**

Table 11. Potential availability of biomass resources for energy purposes in Norway (N.E.R., 2008:15).

Fuel/Biomass Resources	**TW/year**	**PJ/year**
Timber	4.6	16.56
Processed wood	5.4	19.44
Wood waste from furniture & wood	1.2	4.32
Straw & Crop husks	4.5	16.2
Oil crops	0.2-0.25	0.75-0.9
Municipality waste	2.4	8.64
Wood waste	0.8	2.88
Landfill gas	1.1	3.96
Other biogas	3.1	11.16
Wood fuel	19.2-23.2	69.12-83.52
Total	**42.5-46.55**	**153-167.58**

Berg, Jørgensen, Heyerdahl, and Wilhelmsen (2003) claim in Nordic Energy Research (2008) that bioenergy derived from agriculture in Norway can be improved from current yearly 0.1 TWh (0.36PJ) to 5.5 TWh (19.8 PJ) in which straw and crops residues will contribute about 4.5 TWh (16.2 PJ) and 1.0 TWh from other energy crops such as Mischantus, reed canary grass, Alfalfa, Napier grass, etc.

2.5.6. Potential and use of biomass in Sweden

Energy usage has increased from 10% in 1980 to 19% in 2006, which corresponds to 416 PJ (116TWh) of biomass. Most of the Swedish bioenergy are source from forestry sector and this account for 90% of the bioenergy used in Sweden. The forestry energy sources are logging, sawmill by-product, pulp mill by-product, and black liquor from forestry industries, the latter has the largest share (Hillring, 2006; N.E.R, 2008).

Present contribution of agricultural residue such as straw, energy cereals and lignocelluloses' energy crops is about 1TWh (N.E.R, 2008). Sweden has the capacity of doubling bioenergy sources from 115 TWh to more than 220 TWh with agriculture contributing 30- 35 TWh (108 - 126 PJ) per year (N.E.R., 2008).

Table 12. Biomass potential in Sweden by 2020 (N.E.R., 2008:18).

Fuel	**TWh**	**PJ**
Forest and logging residues	75.0	270.0
Industrial by-products	13.3	47.9
Black liquor	39.4	141.8
Domestic firewood	12.0	43.2
Densified wood fuels	6.4	23.0
Recovered wood	2.5	9.0
Tall-oil	1.2	4.3
Peat	4.0	14.4
Agro biomass	1.1	4.0
Municipal solid waste	7.2	25.9
Total	**162.1**	**583.6**

2.5.7. Potential and use of biomass in Finland

The interest in bioenergy and other forms of renewable energy has risen in tandem the with the increase in the price of fossil fuel and climate protection has been raised on the policy agenda (Rikkonen and Tapio, 2009: 1).

Finland's use of bioenergy for energy generation is estimated to be 20% of gross inland energy consumption while "41% of total renewable energy use in Finland, with 312 PJ originating from biomass sources out of the total 372 PJ renewable energy" (N.E.R., 2008:8). According to Nordic Energy Research (N.E.R., 2008: 9), "20% of total consumption of primary energy is based on wood, which represent 42 million m^3 (306 PJ)". Wood pellet is another source of energy, its production started in 1998 and one fourth of 190,000 tons was used in energy generation in 2004 while the rest is exported to other countries (N.E.R., 2008).

Finland is covered with about 23.3 million hectares of forest and a growing biomass of stem wood. According to Finnish Forest Research Institute as cited by N.E.R. (2008) "annual sustainable stem wood from Finnish forest amount to 69 million m^3, commercial use of stem wood is 80% of the sustainable use of 56 million m^3 in 2004". The annual wood use for energy generation is expected to increase by 5 million m^3 by the year 2010 (N.E.R., 2008). According to VTT, and sited by N.E.R. (2008) Finland is capable of supplying 19 PJ of reed canary grass in district heating and for producing pellet by 2010, also potential for straw is estimated to 1.8 million tons in which 10-20% could be used for energy generation.

Table 13. Biomass growth in Finnish forests (N.E.R., 2008:10).

Type of Biomass Growth	**Yearly Growth (Million m^3)**
Growing stock of stem wood biomass	2.9
Growth of stem wood	87.0
Total drain of growing stock	**89.9**

Nordic Energy Research (2008) claims that, the present use of forest industrial by-product is estimated at 77 PJ in 2004 and there is tendency that the output will decrease due to tightening competition, therefore the potential use will decrease by 10% from 77 PJ to 70 PJ.

There is also some agriculture bioenergy potential. Production of food in Europe is estimated at 15% of total energy consumption, 5% out of this 15% is consumed by agriculture which includes production of mineral fertiliser. Rikkonen and Tapio (2008:1-2) argued that bioenergy, in its different forms, relates mostly to forests in relation to available national resources in Finland since the country is located in Boreal vegetation zone. However, as the prices of oil increases, biomass production from agriculture has also become a relevant and widely discussed issue in national policy, due to the economic structure emphasised by the pulp and paper industries, as well the steel and electronic industries, Finnish agriculture accounts for few percent of the total national economy energy consumption. Finnish agriculture energy sources are fuel oil (73%), wood energy (12%), electricity (10%), natural gas (2%), gasoline (1.5), peat (1%), and district heating (0.5%) (Rikkonen and Tapio, 2008).

Potential for biogas production is plentiful. Biogas is mainly used for heat and electricity generation. Finland recently has increased collection and use of landfill gas in order to promote the use of biogas. Potential for biogas from municipality solid waste, landfill gases, residues from the food processing industry, sewage disposal, and residues from agricultural sector such as straw, litter, and energy crops is estimated to be 7.9 – 10.0 PJ in 2015 (N.E.R., 2008).

2.6. Future for sustainable renewable energy

The future opportunity for renewable energy is driven by three desirable characteristics:

(1) Renewable energy is abundant and available everywhere.
(2) It inherently does not deplete the earth’s natural resources.
(3) It causes little, if any, environmental damage (Tester et al., 2005).

If deployed properly, renewable energy can contribute to better sustainable environment. However, there are some notable barriers that prevent developments of renewable energy that have been enumerated in the literature. These barriers include cost-effectiveness, technical barriers, and market barriers, such as unstable cost and pricing structures, legal and regulatory barriers, market performance, and social and environmental barriers (Painuly, 2001; Beck and Martinot, 2004 in Matinot, 2004). Painuly, (2001: 75) explained that, some barriers are common to technology while some are inclined to a specific country or region. For better future of renewable energy barriers to their development needs elimination. Elimination of these barriers required strategic policies to back the development.

Table 14. Common barriers to renewable energy (Martinot, 2004: 4)

Category	**Barriers**
Cost and pricing related	Conventional fuels receive large public subsidies while renewable energy may not. Renewable have high initial capital costs but lower operating cost, making them more dependent on financing and the cost of capital. It is difficult to quantify future fuel-price risks for fossil fuels and incorporate monetary values for those risks into economic decision-making. Transaction costs are often higher for small, decentralized renewable energy facilities than for large centralized facilities. The real economic costs of environmental damages from fossil fuels (human health, infrastructure, and ecosystems) are rarely prices into fuel costs.
Legal and Regulatory	Independent power producers (IPPs) may be unable to sell into common power grids in the absence of adequate legal framework. Transmission access and pricing rules may penalize smaller and/ or intermittent renewable energy sources. Permitting requirements and sitting restrictions may be excessive. Utilities may set burdensome interconnection requirements that are inappropriate or unnecessary foe smaller power producers. Requirement for liability insurance may be excessive.
Market performance	Consumers or investors may lack access to the credit required for capital intensive renewable energy investments. Financier, developers, and consumers may unfairly judge technology performance risks. Market participations may lack sufficient technical, geographical, and/ or commercial information to make otherwise sound economic decisions.

2.7. Renewable energy policies

Promotion of renewable energy requires the help of good policies to overcome those barriers directly or indirectly. Most notable policies are mention below (Geller, 2003; IEA, 2003; Reiche, 2002; Beck and Martinot, 2004; Sawin, 2003):

1. U.S. Public Utility Regulatory Policies Act (PURPA). This policies required utilities to purchase power from independent power producers via a long-term contracts at an approximating prices to the utilities.
2. Electricity feed-in laws. Germany was the first country to enact the law, also in other European countries similar laws are in place, this law set fixed price for utility purchase of renewable energy. In 1991 Germany renewable energy

producer have the capacity to sell 90% at retail price and the utility were obligated to purchase the power.

3. Cost reduction policies. There are numbers of policies design to provide incentives for voluntary investments in renewable energy by reducing the cost of the investments. There are five types of these policies (1) capital reduction up front - subsidies (2) capital reduction after purchase - tax relief; (3) offset cost - production tax (4) loan and financial assistance (5) capital reduction and installation cost - bulk procurement
4. Public benefit funds. Provision of such fund for subsidising the cost difference between renewable energy and traditional power plant, reducing the cost of loans for renewable facilities, providing energy efficiency services, supporting research and development.
5. Marking infrastructure policies. A range of market-facilitation policies are used to build and maintain renewable energy market infrastructure which include design standards, sitting and permitting requirement, equipment standards and licensing and education of contractor.
6. Emission trading policies. This policies aim at gas reduction at power plant emission, such as NOx, SOx and $CO_{2.}$ This type of policies creates some incentives for certain emission.
7. Renewable energy targets. Many countries have adopted different renewable energy targets, these targets have been set in form of scenarios with about ten year span or more.

2.8. Theoretical framework for empirical study

The empirical study starts with *lead user identification:* The lead user in this context means the potential customer who had fore knowledge about a technology in his/her capacity. For the purpose of this thesis, lead user identification will be based on report of NORDEX2009 project. There are about twenty greenhouse farmers in Pörtom, but nine out of the twenty corporate with NORDEX 2009 project.

Annual lead users' energy needs: This is the total amount of energy needs by farmers' couple with the municipality buildings.

Lead users' energy needs simulation: Lead users' energy simulation is typical model of the energy needs.

CHP Plant: This is a combination of heat and power generating plant.

As it was explained in section 2.3, lead users are sources of innovation, and in this thesis they are referred to as customers. Figure 11 shows the theoretical framework for the empirical studies. It illustrates the stages involved in finding solution to the energy problems encountered by the greenhouse farmers and community of Pörtom.

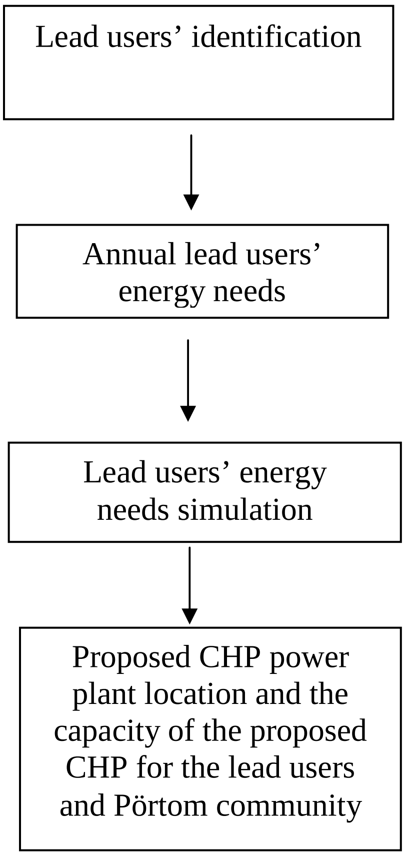


Figure 11. Framework for empirical study

3. RESEARCH METHOD

3.1. Introduction

This chapter presents the research method adopted in this study. It will further explain the method of data collection and the types of document used in thesis analysis.

Following the explanation on the types of document, this chapter will then step further to explain reasons for using qualitative research method and briefly explains the research methods used. The strategy will as well be explained, followed by the method of data collection and analysis. In justifying the methods used, there is some discussion on the benefits and disadvantages of each method employed in the study.

3.2. The method of data collection

In this study, the use of operational analytical approach will involve the use of interviews and documentary analysis. These methods provide significant insight for understanding the fact under study.

3.2.1. Document as source of data

This study started with the collection of various sets of data sourced for the purpose of this study. It was necessary to be selective in obtaining documents since huge quantities of information are collated and recorded by farmers and inhabitant of municipality building owners for their own purpose (Sapsford and Jupp, 1996). Although written documents exist in large volumes in organisation today (Silverman, 2004; Sarantakos, 1998; Hakim, 1987), base on this study, emphasis was placed on the documents that are generated by the greenhouse farmers. Some of these documents include records on monthly oil consumption, monthly electricity consumption, the size of the greenhouses and desk review of relevant of relevant literatures, texts, and other materials that contained information concerning this study.

3.3. Types of Documents

Documents are used in nearly all areas of research, as long as the relevant sources are available, and, in most cases, relevant documents are either found or generated in the course of study. Guba and Lincoln (1989) described the essence of document hunt with the following words:

> *"There is an assumption that if an event happened some record of it exist (especially in today's heavily documented society) To put it in another form, every human action leaves tracts"* (p.278).

The question here is, in what form does the document exist and for what purpose has it been collected? In the submission to give answer to the questions, researches frequently deal with documents as secondary material. Becker (1989); Sarantakos (1989) both argued that data are called 'secondary' because they were not primarily developed for the study in which they are now used. However, documents are generally described as being either textual or non-textual (visual), either category of which may demonstrate variation in form and quality. According to their construction, interpretation and representation, documentary sources can be tentatively sorted into four categories (Sarantakos, 1989; Sapsford and Jupp, 1996; Silverman, 2004):

A. *Personal documents:* such as diaries, memoranda, autobiographies.
B.*Archival records:* such as services and maintenance record books of the green- house farmers.
C.*Formal reports:* such as those related to the research topic, comprising books, manuals, printed files, journals, magazines, pamphlets, brochures, newspapers and many more.
D. *Administrative documents:* such as progress reports, minute of meetings, agendas, proposals and institutional memoranda.

For the purpose of this study, documents were classified into: primary documents, secondary documents. According to Becker (1989); Straus and Corbin (1997), primary documents were those compiled by eyewitnesses of the described event, secondary documents were those sourced from primary data, such as written diaries, accounts, and tables. Data used in this study were sourced from the secondary documents. These data were accounts showing the amount of heavy oil used in generating their energy needs on a monthly basis and also data was source from the farmers on monthly electricity consumption. As heat is the primary product and the amount of electricity produced is limited by the heat production, the most important data source was the amount of heavy oil used by the farmers and the size of the greenhouses metre square (m^2) (Bogsti et al., 2009:15).

3.3.1. The Process of documentary research

There are various methods applicable in processing documents used in research. Sarantakos, 1989; and Robson, 2002 identified four basic processes used in research as: identification and selection of documents; data collection; data analysis and interpretation. In this study, the choice of document used was dependent upon many factors such as its availability, accessibility, and relevance to the study. Available data collected from the farmers were processed and simulated to arrive at their energy needs, for the proposed CHP plant.

3.3.2. Interview

Interviews form a minor part of the data-collection for this study. The interview only helps to gain insight and determine meaning through an interactional relationship between the interviewer and interviewee (Fowler, 2002). The method helped when sourcing for the secondary data from the greenhouse farmers and also knowing meaning of some technical terms used by the farmers.

According to Fowler (2002), an interview is defined as a meeting for the purpose of discussion, a conversation between a researcher and a person whose views he wishes to publish, or an oral examination of an applicant.

There are about twenty greenhouse farmers spreading across community of Pörtom (Bogsti et al., 2009:15).

Out of these twenty farmers, only nine were interested in this research. Due to an agreement between farmers and NORDEX project coordinating team before the commencement of this research, farmers' names will not be revealed in this thesis. Rather their names shall be coded.

3.3.3. Types of interviews

Terminology is always the problem in qualitative research methods (King, 1994). According to Kvale (1996), qualitative research interview are aimed at gathering a description of the life-world of the interviewee with regard to interpretation of the meaning of the describe happening. Interview can take different forms. The form adopted in a particular research study is dependent on what the researcher intends to achieve. At the two extremes are the completely structured and unstructured interviews (Haralambos and Holborn, 2004). A completely structured interview is a questionnaire administered by an interviewer who is not allowed to deviate from the questions provided. In this case, the interviewer simply reads out the question to the interviewee. At the other end of the scale is the completely unstructured interview, which takes the form of a conversation where the interviewer has no predetermined questions. In this study, semi-structured interview method was adopted. Unlike the structured interview, semi-structured interview has predetermined questions but the order sometimes modified, which allows the interviewer to reset the question in the order of relevance and also investigate certain responses for the purpose of clarity. Moreover, using this method allowed changes to the wording of a particular question and sometimes omitting or including questions that seemed inappropriate or necessary. Semi-structured interview method falls between the two extremes mentioned above.

3.3.4. The interview process

The interview process commenced with visitation to the farmers' greenhouse in community of Pörtom with other NORDEX 2009 group members. As already mention above about twenty farmers were spread across the community. All of these farmers speak Swedish language. Nine out of the twenty farmers that had an agreement with

NORDEX 2009 project speak Swedish language. The first visitation to the farmer was not as easy because NORDEX 2009 project team members consist of ten students from three different continents: Africa, Asia, and Europe with just three students who can speak both Swedish and English language fluently. The interviews, most of which lasted between two to three hours were carefully conducted by the entire ten students.

3.3.5. Limitations

According to Silveman (1997); Sarantakos (1998); and Patton (1990), most common limitation of documentary study relate to inaccessibility of some documents. This was so in the case of greenhouse farmers in the community of Örtom, out of the nine farmers, farmer D was able to provide all the information requested in order to simulate their energy needs. During the interview there was an issue of language barrier between the interviewee and interviewer.

3.3.6. Benefits and disadvantages of interviews

Benefits: Interviews are flexible and adaptable way of finding information out (Robson, 2002). However, interview are never describe as the most suitable research method (Haralambos and Holborn, 2004), interview present one of the most useful ways to investigate real-life situation when compared to other methods of inquiry.

The use of face-to-face interview presented the chance to modify the line of investigation (Robson, 2002). Interview method presented the opportunity to adjust when certain interesting responses emerge from a previous question. Non-verbal clue also sometimes presented messages which aided in the understanding of verbal responses, at time changing and in the extreme cases reversing the meaning (Robson, 2002).

The concepts of the words used during interviews by the interviewer and interviewee were clarified during the interviews (Haralambos and Holborn, 2004). The responses were not limited to fixed choices, thereby giving the respondent the chance of presenting a vivid explanation of their understanding of the issues under investigation. Interview method of sourcing for information was very practical. It gives access to many different groups of people and different types of information. (Haralambos and Holborn, 2004). As Ackroyd and Huges (1992) put it,

> *"Using as data what the respondent says about himself or herself potentially offers the social researcher access to vast storehouses of information. The social researcher is not limited to what he or she can immediately perceive or experience, but is able to cover as many dimensions and as many people as resources permit" (p 481).*

Disadvantages: The use of the interview as a data-gathering technique in a study has several benefits as well as, drawbacks. Interviews are time consuming (Robson, 2002): Most of the interview sessions during this projects lasted over an hour, which is not appropriate because of the busy nature of greenhouse farmers.

Interview are sometime very expensive and require careful preparation, such as making arrangements and securing necessary funding for visits, especially in this case, where is necessary to travel from Vaasa to Pörtom. Note taking during interviews require special skills.

Another problem that Haralambos and Holborn (1995) note is that there is chance that interviewer may direct interviewee towards responding in a particular way. Consciously or unconsciously, the interviewee may be responding in a way they believe meets expectations of interviewer rather than saying what truly believe. This problem is known as interviewer bias. Haralambos and Holborn (1995) argued that this cannot be completely eliminated from interviews because they are interactive situations. During the interview, however, this problem were minimised through the approach taken, listening rather than speaking; presenting questions in straightforward; eliminating cues which might lead interviewee to respond in a particular way.

Despite the problems associated with interviews, they offer a rich source of data which provided access to how greenhouses are been operated and their current source of energy.

3.4. Qualitative data analysis

As noted above, qualitative research presents an inductive view of theory and research. It emphasises a preference for treating the former as something that results from collection and analysis of data (Bryman, 1997). In this study, effort was placed on understanding why greenhouse farmers want to change from their present source of energy. Data were source from the nine farmers that cooperate with NORDEX 2009 project. Only farmer coded with D was able to show a complete data which was then used for simulation of other farmer’s energy needs.

3.5. Concluding remarks

This study employed two major data collection techniques: semi-structured interviews and analysis of relevant documents from the farmers. All the interviews were done with all members of NORDEX project 2009 team.

4. ANALYSIS

4.1. Energy problem analysis

This chapter will be focusing on a simple way of generating energy through the use of technology using biomass and the distribution of the energy to the point of need. This chapter will also look into location of CHP power plant.

4.2. Energy production

4.2.1. Combined heat and power plant technology (CHP)

Combined heat and power (CHP) has been in used for long. It is a process of combining electricity generation with thermal loads in buildings and factories. Many people have been yearning for the use of CHP over the years due to changes in the marketplace and government polices, and the future of global climate changes as a result of the use of renewable fuels along with the operation of CHP power plant coupled with energy price increases resulting from 1973 and 1979. At the turn of the century, the uses of CHP systems were the most common means of generating electricity (Elliott and Spurr, 1999).

In the 80s there was steady growth in the installation of CHP most especially in the United States with capacity ranging from 10 gigawatts electric (GWe) in 1980 to 44 GWe by 1993. Also in Europe, Demark, Finland, and Netherlands are the front liner in the use of CHP for generating both heat and electricity (Elliott and Spurr, 1999).

4.2.2. Electric energy production from biomass

Energy production from biomass requires heat from combustion, which creates kinetic energy and the transformation of this kinetic energy produce electricity. Typical CHP plant consist of combustion stage where chemical energy in biomass is released as heat in combustion, the heat is then transform to thermal energy, the transformation continue to kinetic energy which is the generation stage, and finally to electric energy (Bogsti, Sundsfjord, Gyibah, Röösgren, Rusk, Gabienu, Bada, Flink, Huang, and Unger, 2009).

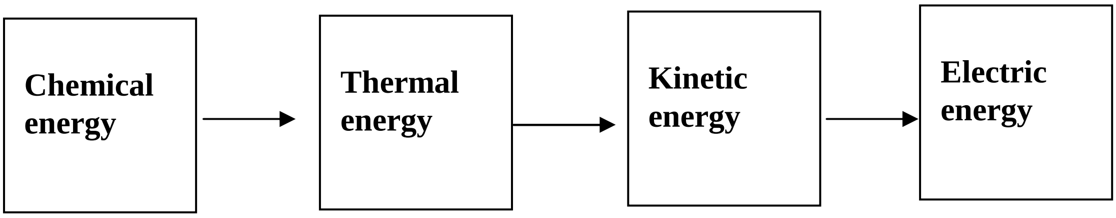


Figure 5. Electricity production from biomass (Bosgti, et al., 2009:58)

4.2.3. CHP steam cycle

In a steam cycle technology, heat is generated in the boiler via combustion process, the heat generate steam which operate a steam turbine which turns generate electricity (Bogsti, et al., 2009:58).

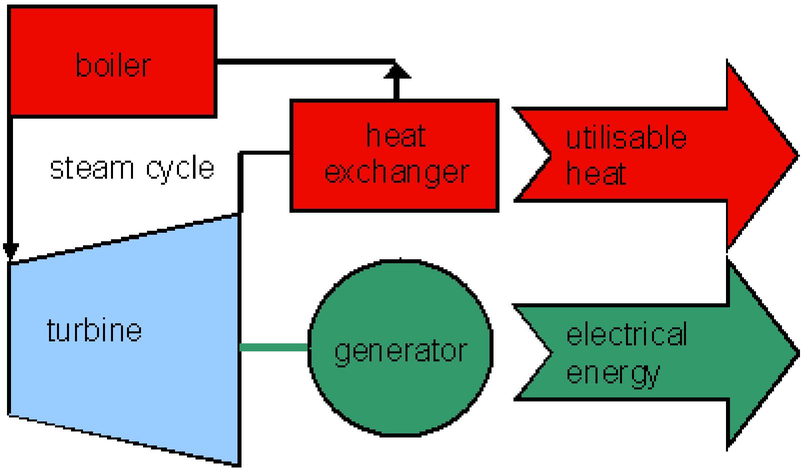


Figure 6. Steam turbine systems (Cogeneration (CHP) Technology (Bosgti, et al., 2009: 58).

There are two types of CHP which function on the principle of steam cycles: back pressure turbine and extraction condensing turbine.

Back pressure turbine: This type of plant is used along with a boiler at a constant temperature for electricity generation and district heating with a range of 0.5 to 30 MW of electricity (Bogsti, et al., 2009).

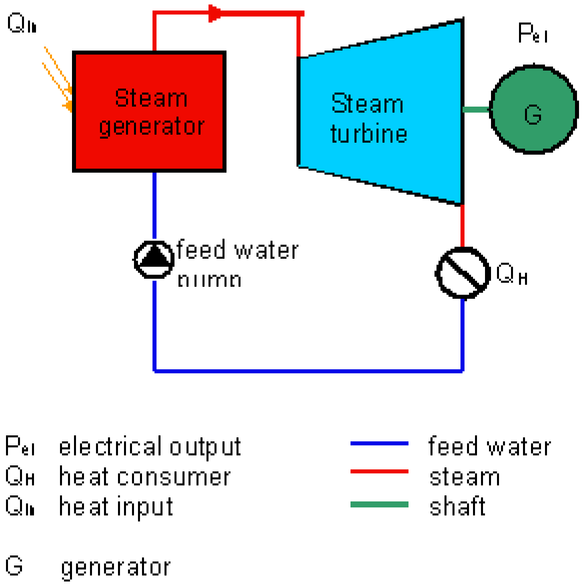


Figure 7. Steam cycle with back pressure turbine (Cogeneration (CHP) Technology (Bogsti, et al., 2009:59).

Extraction condensing turbine: Extraction condensing turbine is the same as back pressure turbine with the exception of control valve for adjusting heat and electricity production to meet different requirements. The plant is mostly used for electricity generation and district heating with range in capacity of 0.5 to 10 MW or higher (Bogsti, et al., 2009).

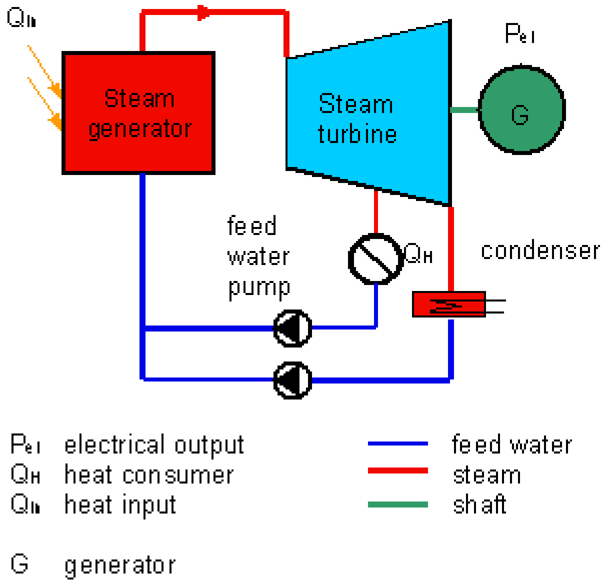


Figure 8. Steam cycle with extraction condensing turbine (Cogeneration (CHP) Technology (Bogsti, et al., 2009:60).

4.3. Heat entrepreneurship in Finland

Municipalities in Finland have a long tradition in investing in wood fuel plant business. District heating networks and CHP plants started spring up in late 1960s in major cities of Finland with the use of milled peat in most inland cities while coal and natural gas are used in coastal cities. Investment in biomass heating system for heating greenhouse farms, municipal buildings, and industries arouse at the beginning of 1990 and that was the beginning of ‘heat entrepreneurs’ in Finland. First three plants started in operation in 1992 and it roses to more than 140 plants in 2002. These plants can be found in western Finland and about 40 of these plants are for district heating (Alakangas, 2003).

4.4. District heating

District heating is a process of heat distribution from central plant to individual buildings through a network of pipes. It offers tremendous opportunities for reducing environmental pollution and also for energy saving. It is a flexible technology which can make use of any fuel including the utilisation of waste energy, renewables and, most significantly, the application of combined heat and power (CHP). Designing of pipes networks varies, but the most commonly use are ring-system and conventional system. The ring-system is more reliable while the conventional is more economical (Bosgti, et al., 2009).

Ring-system: In a ring-system, heat flows can take place in any direction. Figure 9 shows the view of the ring-system, from the diagram, heat flows from the power plant pipes network in red to the consumers through the heat exchanger and back to the power plant via the pipes in blue colour. The advantage of this system is that, heat will continue to flow even if there is obstruction on any of the pipes network (Bogsti, et al., 2009).

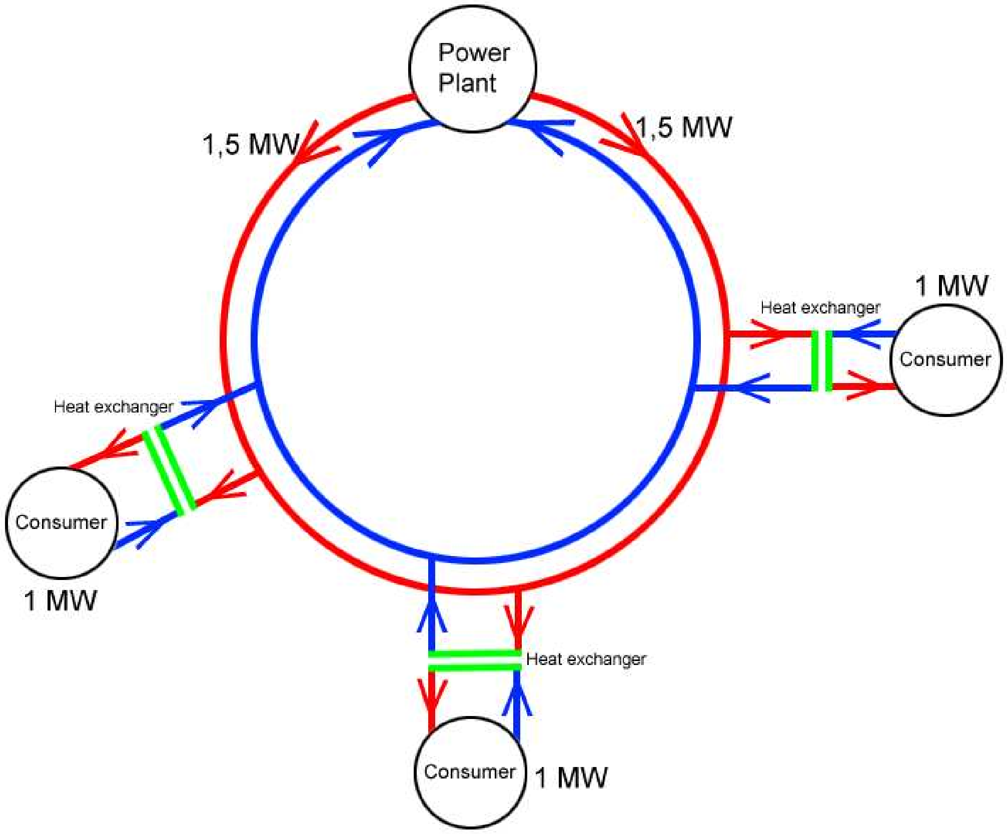


Figure 9. The ring–system (Bosgti, et al., 2009).

Conventional system: Conventional system consist of two pipes, these pipes are of different sizes which depends on the amount of heat required by a consumer. The main disadvantage of this system is that, it does not have backup for unexpected maintenances'. Example of conventional system is shown in figure 10 (Bosgti, et al., 2009).

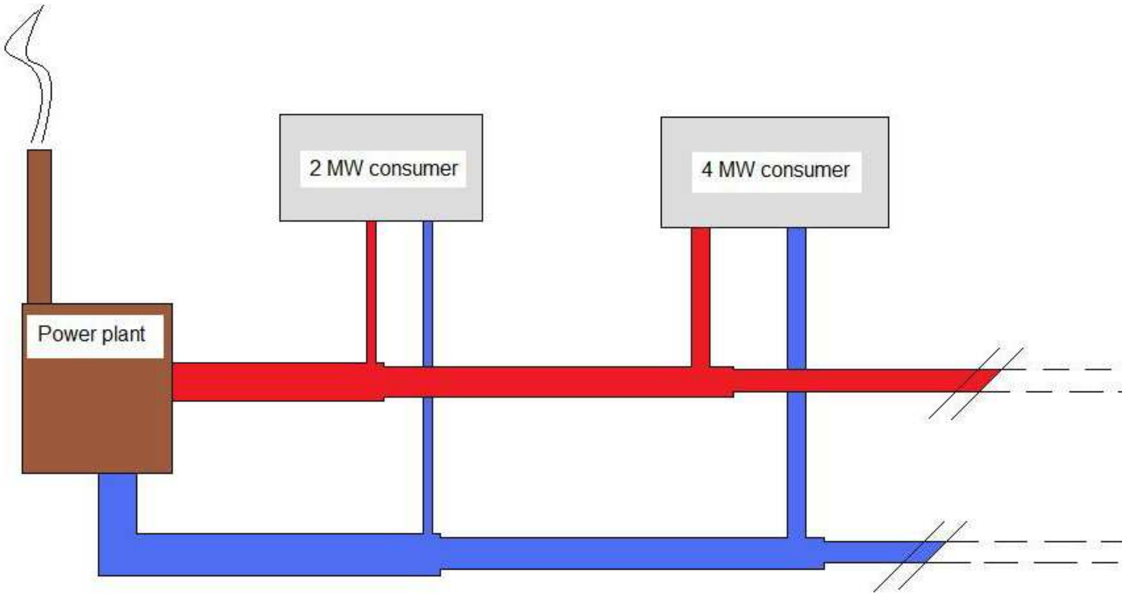
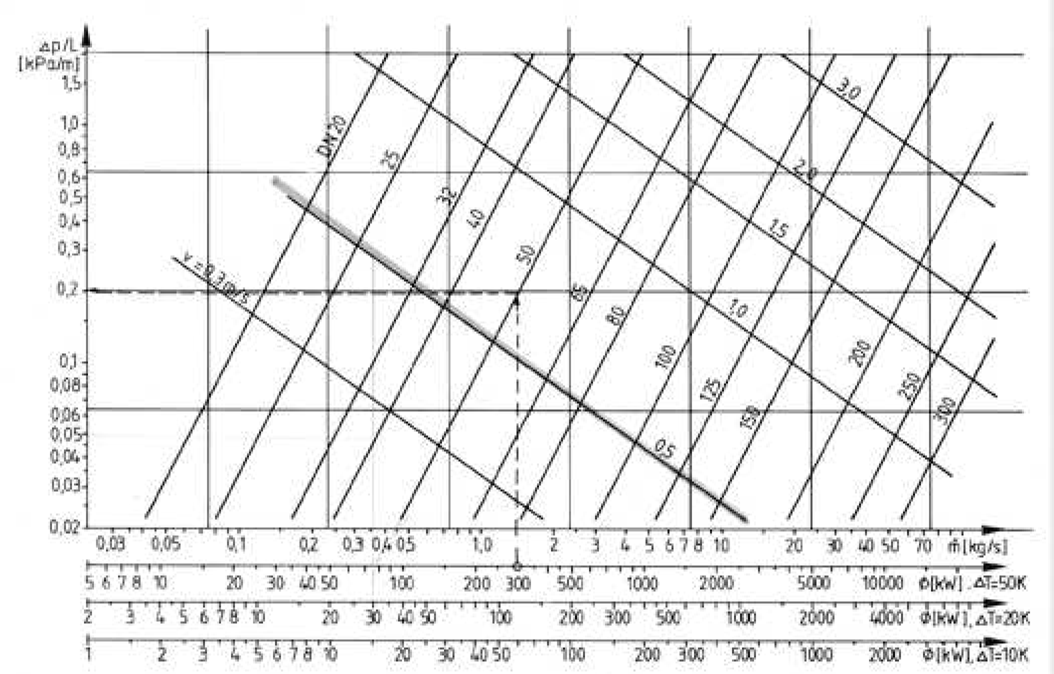


Figure 10. Conventional system (Bosgti, et al., 2009:86).

4.4.1. Pipe dimension

The type of pipe used in district heat network depends on the energy needs of the consumers that make up the network. Also important in district heating is change in temperature (ΔT) for inflows and outflows as well as the pressures drops. Initial setting for both is very important when considering pipes dimension, future expansion is put into consideration when designing the piping system (Bosgti, et al., 2009).

Table 15. Table for determining pipe sizes (KWH pipe, 2009 in Bosgti, et al., 2009:83).



4.5. Lead users' identification

There are about twenty greenhouse farmers spreading across community of Pörtom. Out of these twenty farmers, only nine were interested in NORDEX 2009 project. Farmers name will not be revealed in this thesis; this was due to an agreement on their privacy before the commencement of NORDEX 2009 project. Rather their names shall be coded. This thesis shall also refer to these greenhouse farmers as lead users. Lead user's name has been represented with letters A to I. (Bosgti, et al., 2009).

4.5.1. Lead users' location

The lead users' are located at different locations of Pörtom. The attached map on appendix 1 and 2 shows the position of lead user. These lead users have proven knowledge about energy production technologies with varying capacity. As is shown on the map, five major lead users' were located in north-east, two lead users' were located in south-west, and two lead users' were located in the eastern area of the community

(Bosgti, et al., 2009). Also on the lead users' list are the municipality building and some private house owners within Pörtom community.

4.6. Lead users' energy needs

The energy needs of the leads user' were calculated based on the data received from them during the interviews. Those data received can not directly be used for the stimulation of the actual needs of the lead users'. All the data were converted to kilowatt-hour (kWh). The data received are based on monthly oil burned for heating greenhouse, monthly electricity consumption for those greenhouses that are illuminated, size of the greenhouses (m^2). The more important of the two data is the monthly oil burned. From the above information, peak needs of each greenhouse can be calculated (Bosgti, et al., 2009).

4.6.1. Calculation of energy needs

There is variation in energy needs of greenhouses per day. Greenhouse required very little energy during the day, at sundown the energy requirement increases. Mostly good ventilations are required during the day to eliminate moisture and excess heat that are not needed. Greenhouse energy needs will be in two fold that is annual energy needs and peak needs (Bosgti, et al., 2009).

4.6.2. Annual energy needs

Annual energy needs of greenhouse focus on the amount of oil used per year which is then converted to kWh. Table 3.1 below shows the conversion rates.

Table 16. Energy content in various fuel types (Bosgti, et al., 2009:16).

Energy densities (kWh/kg)	
Hydrogen	38
Petrol	14
Flywheel	0.9
Thermal storage	0.12
Lead Acid Batteries	0.04
Capacities	0.0003
Hydrostorage (100m high)	0.0003
Compressed air	2 (kWh/m3)

Heavy duty oil has an energy content of 40,80MJ per kg.

One kWh equals 3,6MJ

Then conversion factor is:

$$Factor = \frac{40{,}80MJ}{3{,}6MJ} = 11{,}33$$

The above conversion factor is used in the annual calculation of the greenhouse energy needs. This value is used because most of the greenhouses use heavy oil in their energy generation. Simulation for annual energy lead user’ D will be used for the analysis of data for other lead users’ (Bosgti, et al., 2009).

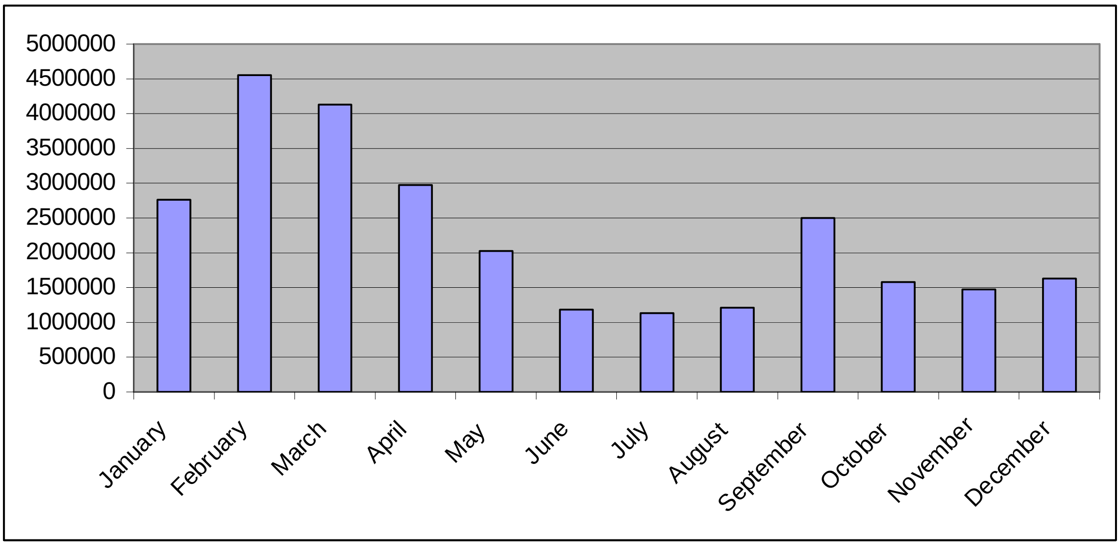
Table 17. Annual energy need for lead user' D (Bosgti, et al., 2009:17).

Heavy Oil			
2007	**Kg**	**Oil energy kWh**	**Exploitable energy from oil (kWh)**
January	5,000	56,665	50,999
February	65,000	736,645	662,981
March	63,000	713,979	642,581
April	43,000	487,319	438,587
May	32,000	362,656	326,390
June	14,000	158,662	142,796
July	14,000	158,662	142,796
August	20,000	226,600	203,994
September	35,000	396,655	356,990
October	5,000	56,665	50,999
November	2,000	22,666	20,399
December	2,000	22,666	20,399
Total	**300,000**	**3,399,900**	**3,059,910**

Considering the efficiency at 90% of the oil burner used by greenhouse for their energy generation, the below table shows the total annual energy need of all the greenhouses (Bosgti et al., 2009). The calculation shown in table 18 were done for every greenhouse and combined into overall table and graph over all the greenhouses (Bosgti, et al., 2009).

Table 18. Total annual energy needs (Bosgti, et al., 2009:17).

2007	**Total amount of heat (kWh)**
January	2,752,532
February	4,555,584
March	4,131,807
April	2,961,636
May	2,035,381
June	1,182,696
July	1,135,135
August	1,211,663
September	2,506,352
October	1,568,438
November	1,469,277
December	1,637,990
Total	**27,148,490**



Graph 1. Total heat needs on monthly basis (Bosgti, et al., 2009:18).

Change in temperature: According to the information about temperature received from Finnish Meteorological Institute (F.M.I., 2007) web site, the data in table 19 below shows the minimum temperature on monthly bases for the year 2007 (Bosgti, et al., 2009).

Table 19. Lowest temperature for 2007 on monthly bases information from F.M.I., 2007 web site (Bosgti, et al., 2009:19).

Month	**Minimum temperature**
February	-20
March	-17,6
April	-8,5
May	-6,4
September	2,3
January	-20
June	2,9
July	7
August	2
December	-12,3
November	-10,3
October	-4,4

Greenhouse area: The total sum of greenhouse area is 55,228m^2 but because some greenhouse farmers were seasonal farmer, some are not in operation during the coldest months, a simulation of assumed area of operation for every month is shown in table 20 below (Bosgti, et al., 2009). The square meter of the area shown in table 20 below was assumed (Bosgti, et al., 2009).

Table 20. Amount of square meters operational every month (Bosgti, et al., 2009:20).

Month	**Area** (m^2)
February	55828
March	55828
April	55828
May	55828
September	55828
January	27914
June	55828
July	55828
August	27914
December	13957
November	13957
October	13957

4.7. Location of CHP power plant

Yang and Lee (1997) stated that facility location is a process which involves an organisation or individual seeking to locate, relocate or expansion of an existing facilities which encompasses the identification, analysis, evaluation and selection among the alternatives. Example of facilities to locate is power plant, warehouses, retail outlets, terminals, and storage yards (Bosgti, et al., 2009).

Every enterprise is faced with the choice of selecting the appropriate place for location of power plants (Ko, 2005). Yang and Lee (1997) argued that power plant location selection commence with recognition of the needs for addition capacity. Yang and Lee (1997) stated that plant location selection starts from with the recognition of a need for additional capacity (Bosgti et al., 2009). However, there are many factors that are put into consideration before reaching the optimal solution for the plant location (Bosgti, et al., 2009).

Plant location is refers to as the choice of region or industrial site and the selection of the best location for a power plant. But the choice is made only after considering cost and benefits of different alternative sites. Facility location is a strategic decision that cannot be changed once taken (Bosgti, et al., 2009).

An ideal location is one where the cost of the product is kept to minimum, with a large market share, the least risk and the lowest unit cost of production and distribution (Ko, 2005). For achieving this objective, location analysis is highly needed. Yang and Lee (1997) supported statement made by Ko, (2005) by recognising that plant location as we are working on has an important strategies implications for the plant to be located, because location decision normally involves long-term commitment of resources and be irreversible in nature (Bosgti, et al., 2009).

Extensive effort has been devoted to solving location problems employing a wide range of objective criterion and methodology use in the decision analysis, for instance, includes decomposition, mixed integer linear programming, simulation, Analytical Hierarchical Process (AHP), scoring model, and heuristics model that may be used in analyzing location problems (Bosgti, et al., 2009). Ko, (2005) argued that a suitable methodology for supporting managerial decisions should be computationally efficient, lead to an optimal solution, and be capable of further testing (Bosgti, et al., 2009).

Many have solved the location problem for minimum total delivery cost with nonlinear programming. Others have incorporated stochastic functions to account for demand and or supply. Also other approaches that have been employed include dynamic programming, multivariate statistics using multidimensional scaling and heuristic and search procedures (Ko, 2005). In many locations problem, cost minimization may not be the most important factor. The use of multiple criteria has been thoroughly discussed in the literature (Ko, 2005).

Ko, (2005) enumerates numerous criterions for locating a new or an existing power plant which include availability of transportation facilities, cost of transportation, availability of labour, cost of living, availability and nearness to raw materials, proximity to markets, size of markets, attainment of favourable competitive position, anticipated growth of markets, income and population trends, cost and availability of industrial lands, proximity to other industries, cost and availability of utilities, government attitudes, juridical, tax structure, community related factors, environmental considerations, assessment of risk and return on assets (Bosgti, et al., 2009). Ko, (2005) stated that qualitative factors are crucial but often cumbersome and usually treated as part of management's responsibility in analyzing results rather than quantified and included in a model formulation of the facility location problem (Bosgti, et al., 2009).

Qualitative decision factors can be readily incorporated into plant location problems, analytic hierarchical process can be employed by combining decision factor analysis and AHP, but this study will analyze the evaluation of the plant location by focusing on the use of scoring model (Bosgti, et al., 2009).

4.7.1. Scoring Model

Scoring model is a method mostly used for selecting among several alternatives. There are several ways of scoring models, decision criteria are weighted in terms of their relative importance, while each decision alternative is graded in terms of how well they satisfy the criteria. (Taylor, 2002).

$$S_i = \sum g_{ij}\, w_j$$

Where

w_j = the weight between 0 and 1.00 indicating relative importance, 1.0 is extremely important and 0 is not important at all. The sum of the total weight equal 1.00.

g_{ij} = a grade between 0 and 100 indicating how well the decision alternative i satisfied criterion j, where 100 indicate extremely high satisfaction, and 0 indicates virtually no satisfaction.

S_i =the total score for decision alternative i , where the higher the score is, the better.

For proposing the location of power plant at Pörtom, the following criteria shall be considered. Although these criteria will depend on the type of power plant proposed in which the technology adopted will influence these criteria as well (Bosgti, et al., 2009:74).

Transportation of raw materials
Nearness to customers
Environmental effects (emission downfall)
Juridical aspect

The following scoring was done based on the map provided and the available data on the heat consumption rate of customer calculated (Bosgti, et al., 2009:74).

Table 21. Scoring model (adopted from Taylor, 2002) (Bosgti, et al., 2009:76).

Decision Criterions	**Weight (0 to 1.0)**	**Grades for alternatives (0 to 100)**			
		Region 1	**Region 2**	**Region 3**	**Region 4**
Transportation of raw materials	0,25	70	70	80	80
Nearness to customers	0,40	95	40	30	40
Environment issues	0,20	50	50	50	40
Juridical issues	0,15	30	30	30	30
Total scores	**1,00**	**70,0**	**48,0**	**46,5**	**48,5**

Based on the above scoring model, Region 1 will be selected for the power plant site, due to its highest score. The selection was based on scoring factors in relation to the region.

Ko, (2005) argue that facility location decision is a more difficult problem due to the insecurity and unpredictability of distribution environments. The location decision process involves qualitative as well as quantitative factors. Decision makers can no longer ignore the influence of sensitive factors such as the population status of a candidate region, transportation conditions, market surroundings, location properties and cost factors relating to the alternative location (Bosgti, et al., 2009).

4.7.2. Reason for the present location of CHP power plant

The use of scoring model was used for locating the present alternative 1. Region 1 was better than others regions going by the calculation. Looking at region one, it was discovered on Pörtöm map that a small river cut across part of the region, (appendix 3) with this river, it is not possible to locate the power plant on other side of the river in which will incur more costs on the project (Bosgti, et al., 2009).

Bosgti, et al., (2009:77) suggested that, the power plant can be located on any available land between the four major greenhouse farms on region 1 provided the following conditions are met:

1. Permission from the land owner
2. Permission from the municipality regional planner
3. Square meter of land needed for power plant (size of the plant)
4. Traffic situation on the available road.
5. Wind direction.

4.7.3. Emission downfall

Finland Location. According to Finland Metrological Institute, Finland is located between the latitudes 60N and 70N in the Northern Europe. Its climate is, in spite of the northern location, very favourable to living conditions due to the warming effect of the Gulf Stream which orientates the cyclone tracks towards northeaster directions (Bosgti, et al., 2009:78).

According to FMI, Finland average wind speed is 3 to 4 m/s inland, slightly higher on the coast and 5 to 7 m/s in maritime regions and wind speeds are typically highest in winter and lowest in summer (Bosgti, et al., 2009:78).

Wind direction for Pörtom area. A wind rose is a graphical tool used to get a picture how the wind speed and direction are distributed at a certain location (Bosgti, et al., 2009: 78).

In Finland, it's most common that the wind blows from southwest and the least common that the wind blows from northeast. Finnish Meteorological Institute, Climate research and applications gave information about how wind directions are distributed in Finland, the table below shows the typical wind direction information (Bosgti, et al., 2009:78).

Table 22. Wind distribution in Finland (Bosgti, et al., 2009:79).

The distribution of wind in Finland		
Station	Porvoo, Emäsalo	
Start of measures	01.01.1971	
Start of measures	01.01.1971	
End of measures	31.12.2000	
Direction	Speed (m/s)	% - Share
Average	6,1	
North	4,2	11
Northeast	4,1	9
East	5,9	10
Southeast	6,2	11
South	7	11
Southwest	7,7	19
West	6,9	16
Northwest	5,6	13
Calms		1
Number of measures	47345	times

As shown in the table above, winds from southwest are once again the most common ones.

5. FINDINGS

The main purpose of this chapter is to express the response of the lead users to research questions raised in chapter one. Explanation given here are the views of the interviewee, based on their level of understanding of those questions. As already mentioned in chapter three, all of these farmers speak Swedish language, hence some of the group members of NORDEX 2009 project team had problem understanding what those farmers were saying. Therefore, this chapter will be very brief on the response to questions posed to these farmers as interpreted by NORDEX 2009 project members that speaks both English and Swedish language.

Farmers were asked the same set of questions at different times of the visitation to their greenhouses. Question (a) and (b) were split into sub-questions for better understanding of the farmers. However, their response to these questions will be summarised in this chapter. Question (d) will be answered in chapter six as solution to the lead user energy needs, while question (c) will be answered in this chapter.

5.1 Question (a): What is the future of renewable energy in the dynamics of innovation?

Question (a1): What do you know about renewable energy?

Renewable energy according all the lead users is the type of energy, which naturally occurs, except the use of energy from coal, oil, and gas. They believe that, renewable energy should be that types which are economically viable and sustainable to the environment.

As earlier explained, renewable energy is said to be that type of energy which in future should not be irreparably or irreversibly damaging the eco-system.

Question (a2): Is renewable energy reliable?

The lead users have different opinions concerning reliability of renewable energy. Some of the farmers believe that, renewable energy is reliable provided that the cost of generation of the energy is minimal. But some still believe that the cost of generation is high compared to other sources of energy. One of the interviewee (D) said that availability of renewable energy technology will determine the reliability, he emphasized further by claiming that, people are ready to adapt to the use of renewable energy but because most of the available technologies are very expensive for common man to avoid.

In his own contribution lead user (A) suggested that significant market growth in renewable technologies can result from combination of polices that address barriers to the adoption of renewable energy.

However, the futures of renewable energy in the dynamic of innovation, greatly depend on the national and international government initiatives that will support the individual, group, or organisation that are into creating new knowledge or developing an idea that can lead to innovation. As was seen in chapter two, innovation is not static rather it is kinetic in nature and also depends on what perspective one is looking at it. Lead User (E) said that, nature of innovation is changing away from local R & D teams to global combined teams; he said further that innovation is moving away from central innovation to combine innovation. From his view it means that renewable energy technology dynamic is on the same velocity as innovation technology.

5.2 Question (b): How has innovation influenced technology diffusion within the field of renewable energy technology?

Question (b1): How often do you adopt new technology?

Most of the lead users’ answers to question (b1) are almost on the same tract; the reason is that, all answers given revealed their perception when an innovative technology is in place. They want to see how a new technology works and what is so special in the new technology compare to the incumbent technology, they are also curious about the cost of the innovative technology. However, lead user H deviated from other lead users opinion, lead user H was much concern about the lifecycle of the new technology couple with the cost. Lead user H perception about technology lifecycle was much about the life span of the new innovative technology, H want to be sure that both the life span and the cost of the product merit investing in it.

Answer to question (b) shows that, for innovation to influence technology diffusion within the field of renewable energy technology, there must be good policies in place to address some vital issues. Innovation technology diffusion most of which lies on the part of the government, institutions or organisation, and the users of the innovative technology, during this study, it was understood that, cost of purchasing a renewable energy technology is so high that it is not always easy for lead user to change to new technology over night. In addressing some of these issues, lead user I suggested that there should be more research and development centres with subsidies. There should also be tax incentive for both the user and innovator of this new technology; lead user I concluded that new technology will be able to compete effectively with the incumbent technologies.

5.3 Question (c): What is the energy problem encountered by greenhouse farmers and the municipality buildings of Pörtom?

The present economic crises and fluctuating price of fossil fuels does not favour the farmers. They all claim that situation at present does not favour them as a farmers. Their first major concern was the position of Finland on the globe. Finland as whole is cold and it has been a problem to farmers. All of these farmers have invested in different types of technology on their farms for generating the needed energy. Some of these technologies use fossils fuels in operating them. Now that the price of the fuels is going up and down on frequently, they think that having a centralize power plant for generating their heat and electricity will be of great benefit. With this, the cost incurred by an individual will be reduced.

As already stated above the answer to question (d) will be solution to farmers' problem and that will form part of chapter six.

6. SOLUTION TO ENERGY NEEDS IN PÖRTOM

This chapter will be answering question (d) of the research question and as well focusing on proposal to the centralized CHP for the leads user and community of Pörtom with regards to their energy needs. The proposed capacity of the centralised power plant will be determine at the end of this chapter. All calculation in this chapter is extracted from NORDEX 2009 project report, which serves as solution to the farmers and occupants of municipality energy needs.

6.1. Peak energy needs

Due to position of Finland, the climate is very cold as result of that there is time during the year when farmers need more energy to warm their greenhouses; this period is referred to as the peak.

Formula for calculating peak energy need:

$P = A \times K' \times (T_1 - T_0)$

Where P = the peak need for greenhouse (kW)

A = Area of the greenhouse (m^2)

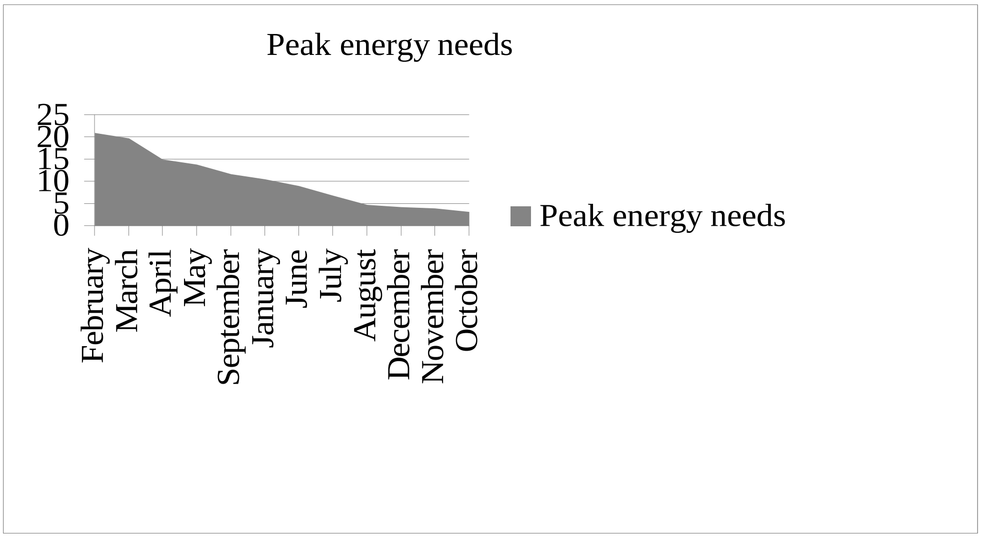
K = Thermal conductivity coefficient ($W/m^2/^0C$)

$(T_1 - T_0)$= change in temperature in − out (^0C), calculated with maximum of 40^0C (Bosgti, et al., 2009).

Thermal conductivity (K'): The greenhouses in Pörtom uses difference structures seven out of the nine greenhouse farmers that are mention made their greenhouses with glass while the remaining two greenhouses use modern block. Thermal conductivity of a building depends on type of material used on the building. 9,4 $W/m^2/^0C$ was used in this calculation. The peak needs on monthly base after calculation is shown in table 21 (Bosgti, et al., 2009).

Table 23. Greenhouse monthly peak-heat needs (Bosgti, et al., 2009:21).

Month	**Peak energy needs**
February	20,99
March	19,73
April	14,96
May	13,85
September	11,70
January	10,50
June	8,97
July	6,82
August	4,72
December	4,24
November	3,98
October	3,20



Graph 2. Green house monthly peak heat needs (Bosgti, et al., 2009:20).

Municipality: The below formula was used along with the information from the municipality to arrived at the amount of energy needs during the peak period

$P = \frac{AxW}{1000}$ **A =** Area of municipality building = 56,000 m^2

W = Rated power need per m^2 for old public houses = 32 W
Municipality peak energy need is 1,792 MW approximate to 1,7 MW (Bosgti, et al., 2009:21).

Calculating the annual energy needs for municipality, involves the following type of oil used, amount of oil used, conversion factor, efficiency of oil burner used (Bosgti, et al., 2009).
Oil used is light oil, amount of oil used is 360,000 kg, conversion factor is 10,2 efficiency of burner is 90%. The entire above estimate the annual energy needs of municipality to be 3330 MWh (Bosgti, et al., 2009).

Simulation of energy consumption: Simulation of the energy consumption was based on the data received from a similar greenhouse who had been keeping records of their energy consumption during the year. Thermal energy for the proposed was set at 8 MW in these simulations to see how the production will look like (Bosgti, et al., 2009).

In order to make the simulation of the energy consumption easier, average factor was calculated on an hourly basis for a period of three days with different temperatures in February in order to create three different types of simulation. The month of November was also put into consideration to see how the simulation for this less energy period will be. Simulation of the month of February required historical data about temperature of Vaasa in February, 2009 (Bosgti, et al., 2009).

There are two method applied in the energy needs simulation:

1. The peak method
2. The average method

The peak method: Peak method involve the use of absolute peak consumption value of 100% as a reference from one consumer while other consumptions were divided by the consumer peak value and multiplied by the absolute peak (Bosgti, et al., 2009). Table 22 shows an example of the peak method.

Table 24. Example of peak method (Bogsti, et al., 2009:23).

Absolute peak	21	MW	
Lead user peak	432	kW	
Time	Used [kW]	Use / peak	Up scaled use [MW]
03:00	432	1	21
04:00	253	0,585648	12,29861

The average method: Average method involves the uses of the monthly average consumption calculated to scale up monthly average consumption of lead user to system level. Average consumption of all data is divided by the monthly average and the result is then multiply by the total average factor (Bosgti et al., 2009). The example is shown in table 23 below.

Table 25. Example of average method (Bogsti, et al., 2009:23).

Monthly system average	7000	kW	
Monthly consumer average	195	kW	
Time	Use[kW]	Use/average	Up scaled use [MW]
03:00	432	2,215385	15,51
04:00	253	1,297436	9,08

6.2. Simulations of energy needs

The amount of heat produced by the power plant is set to 8 MW, the following graph illustrates the amount of heat consumed as it is placed in front of the heat produced, the actual visible part of the column is the amount of excess heat produced (Bosgti, et al., 2009).

February: With reference to data for the month of February, three days were selected to represent the month: these days are peak day, a variable day, and over average day. Average temperature for February is about -7,5^{0}C (Borg, Bäckström, Majabacka, Majabacka, Ohils, and Olofsson, 2008 sited in Bogsti, et al., 2009).

Peak day: 4.2.2006 was selected as the peak day with a stable temperature of -20 ^{0}C for 24 hours (Bosgti et al., 2009).

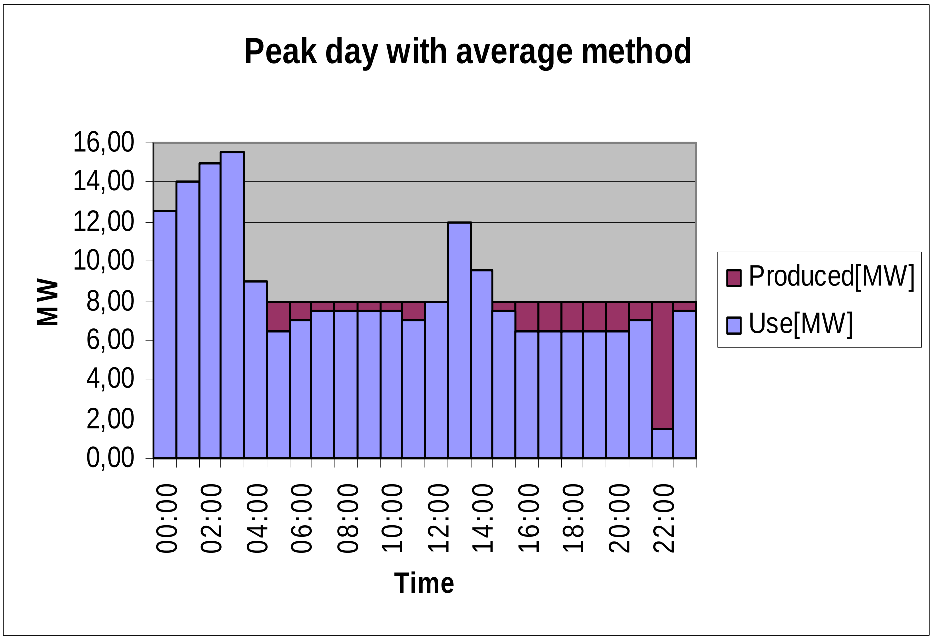
Over average day: Peak day selected was 15.2.2006 with a temperature of -3,5 ^{0}C during the day and -5,5 ^{0}C at night (Bosgti, et al., 2009).

Variable day: 11.2.2006 was also selected with a temperature of -3,5 ^{0}C to -18 ^{0}C (Bosgti, et al., 2009).

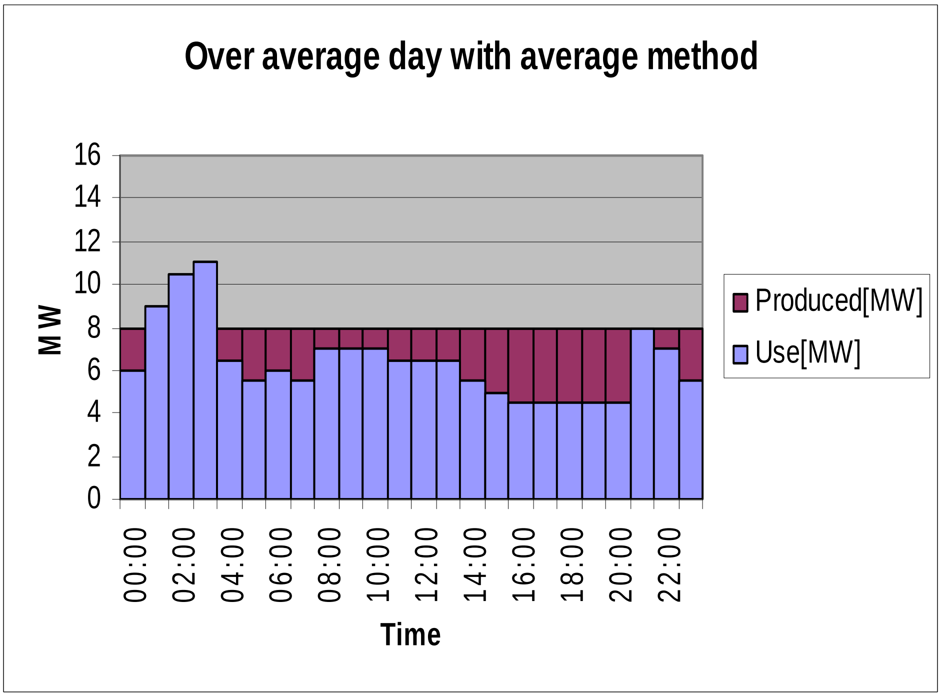
November: 10.11.2005 was selected due to available data and a stable temperature of about 7,5 ^{0}C (Bosgti, et al., 2009).

6.2.1. Simulation using average method

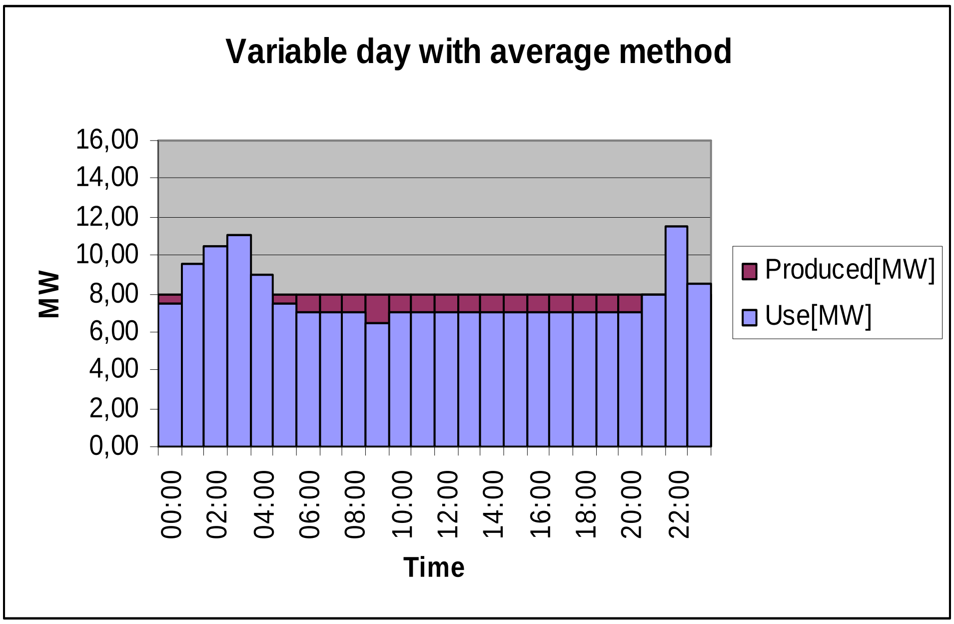
Below graphs illustrate simulation of heat needs using both average methods and peak method. The blued colour represents the amount of heat used while the red shows the amount of heat produced over a period of time (Bosgti, et al., 2009).



Graph 3. Simulation of February with average method (Bosgti, et al., 2009:24).

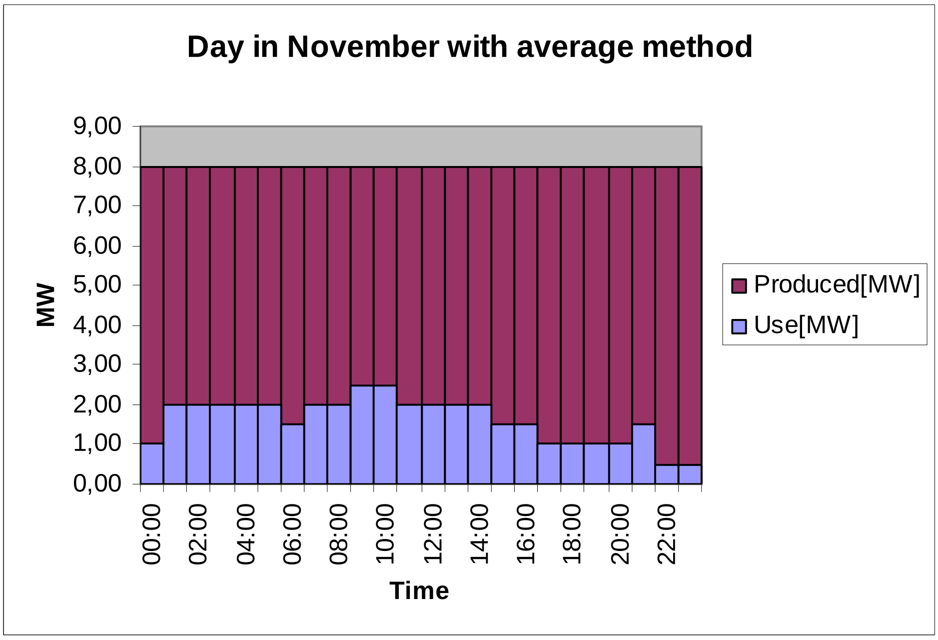


Graph 4. Simulation of an over average day (Bosgti, et al., 2009:24).



Graph 5. Simulation of variable day (Bosgti, et al., 2009:25).

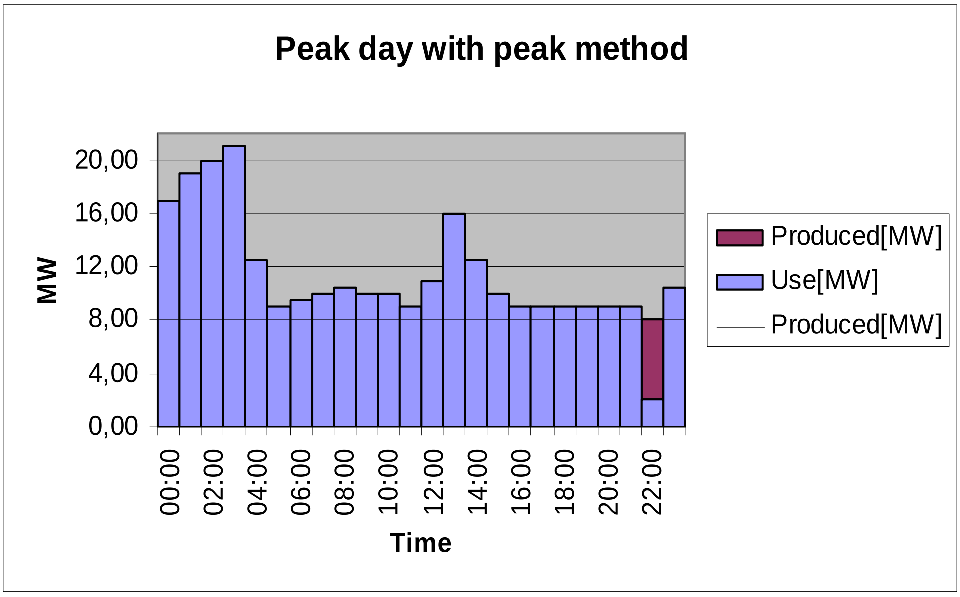
Simulation for November



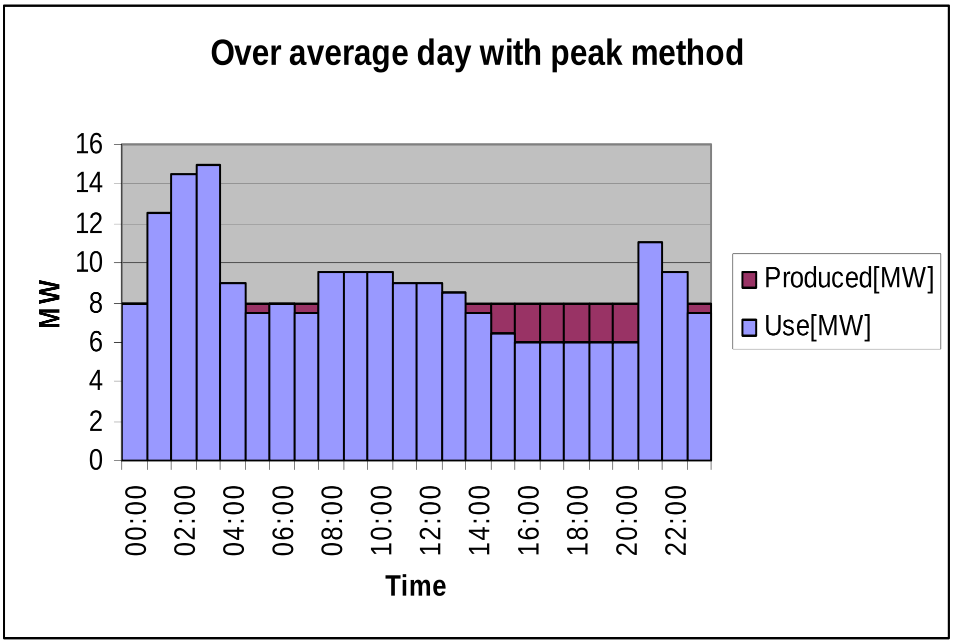
Graph 6. Simulation of day in November (Bosgti, et al., 2009:25).

6.2.2. Simulation using peak method

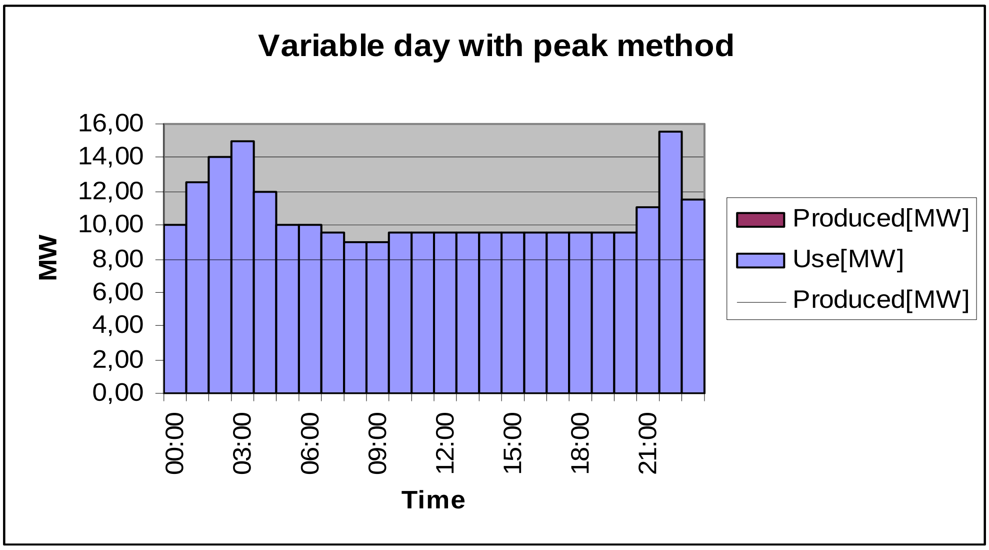
February



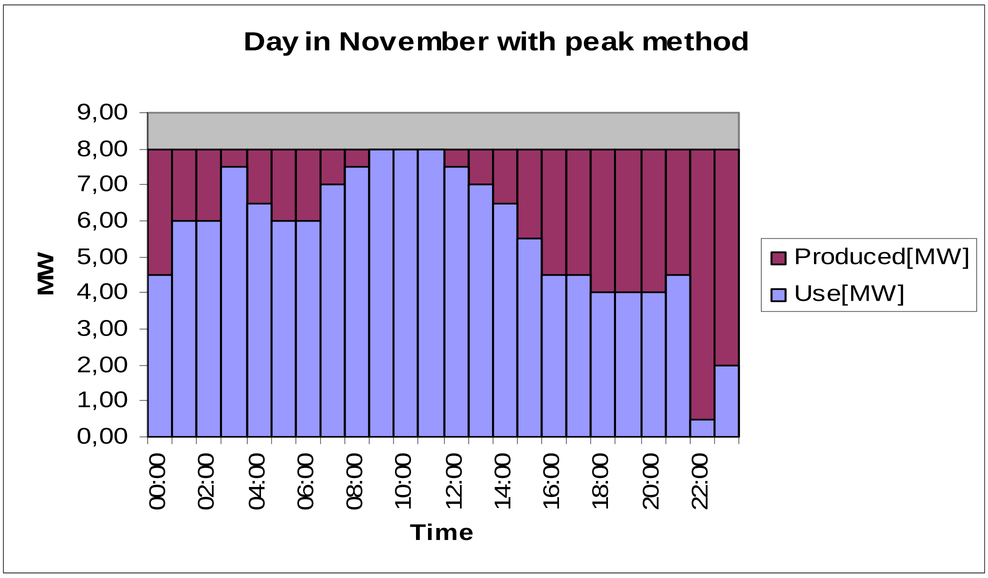
Graph 7. Simulation of peak day (Bosgti, et al., 2009:26).



Graph 8. Simulation of an over average day (Bosgti, et al., 2009:26)



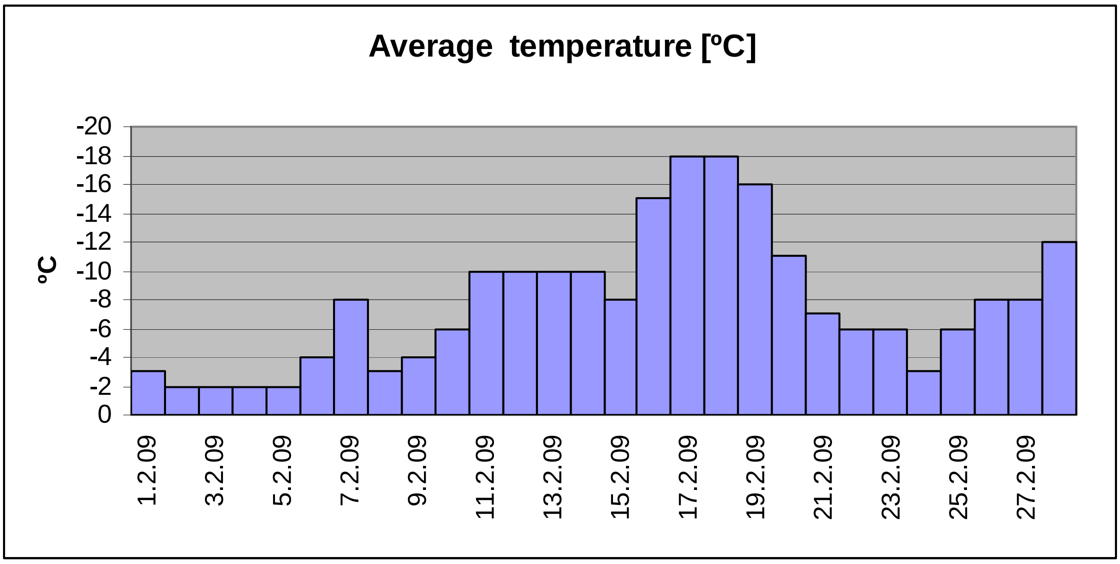
Graph 9. Simulation of a variable day (Bosgti, et al., 2009:26).



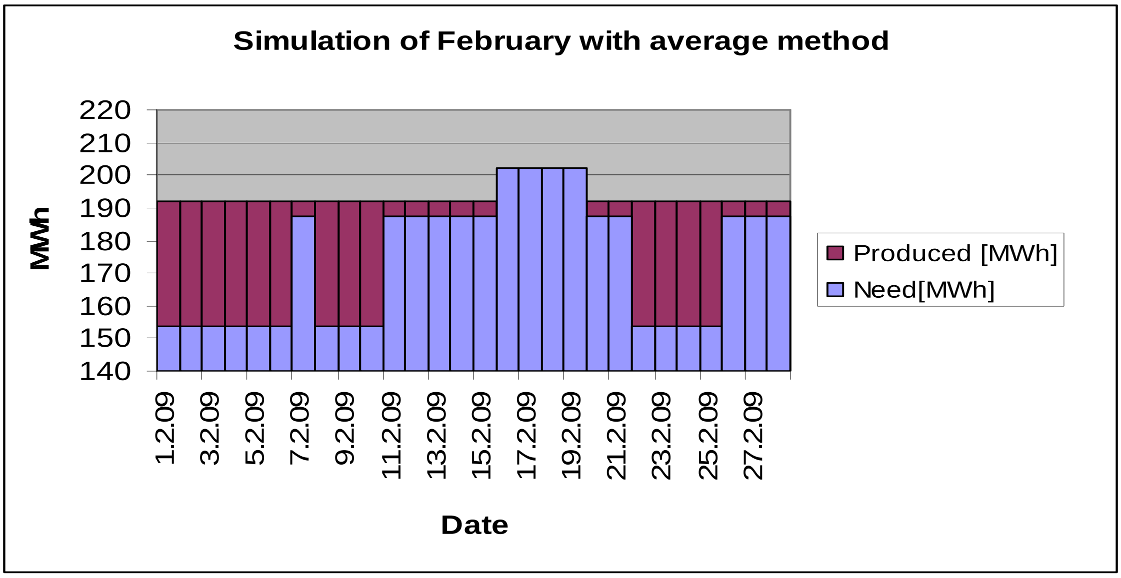
Graph 10. Simulation of November with peak method (Bosgti et al., 2009:26).

The use of peak method for simulation of energy needs for the month of February shows that, the heat produced is underproduction most of the hours of the day for all the type of days selected. While in November there is overproduction except for three hours from 9.00 to 11.00, during these periods the production matches the heat need. Absolute peak need for one hour is 21 MW which is just only for one hour during the peak period (Bosgti, et al., 2009).

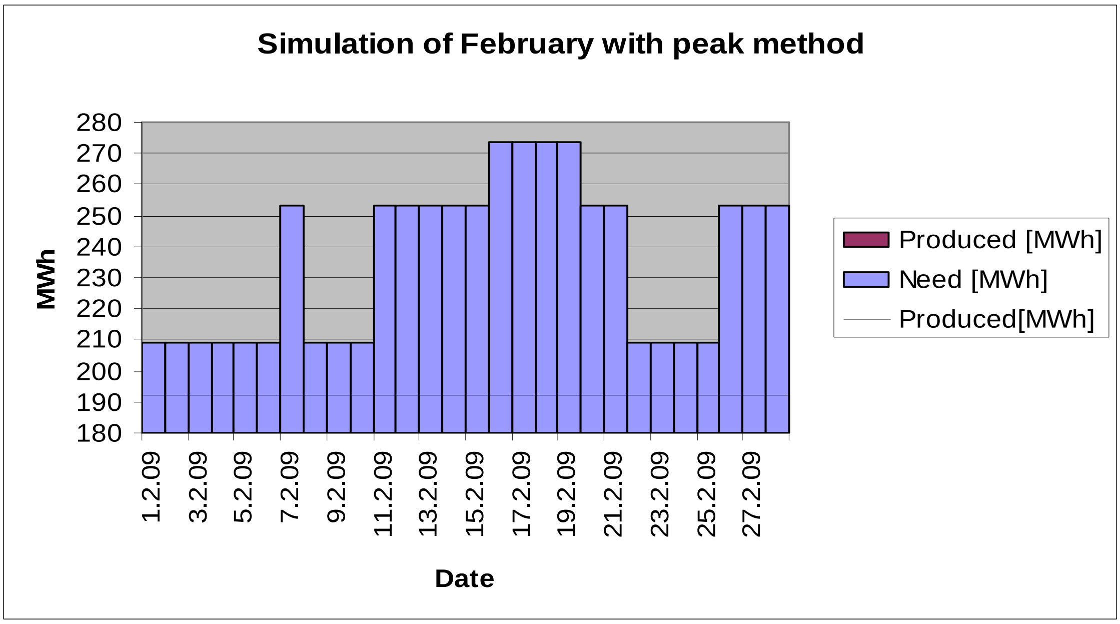
Analysis of temperature: With reference to types of day selected, each of the days in February is grouped based on the properties of temperature from weather registry for 2009 (Weather Underground, 2009). Days with average temperature of -7 ^{0}C are term over average, days with average temperature of -15 ^{0}C are also referred to as peak period while days with temperature between -7 ^{0}C to -14 ^{0}C are term variable temperatures (Bosgti, et al., 2009). The daily temperature in the month of February 2009 is shown in graph 11 below.



Graph 11. Daily average temperature in February, 2009 (Bosgti, et al., 2009:27).



Graph 12. Simulation of February with average method (Bosgti, et al., 2009:28).



Graph 13. Simulation of February with peak method (Bosgti, et al., 2009:28).

6.3. Final analysis of simulation finding

The simulation of the month of February shows that, with peak method heat was underproduction throughout of the month. Average method shows a slight change on a daily basis with overproduction. It was notice that only 4 days of the month have underproduction of 10 MWh. However, the two methods gave different outcome, although the curves are similar, with peak method energy needs are much higher compare with the average method. The use of the outcome of these simulations would be based on their weight as to the lead users (Bosgti, et al., 2009).

The average energy need of the lead user was based on the amount of oil used on a monthly basis while the peak was based on a formula with consideration to the size of the greenhouse, the outdoor temperature and leaves uncertainties (Bosgti, et al., 2009).

The calculated average needs in February was 7,2 MW, the average method gave a result of 7,25 MW while result of peak method was 9,82 MW The result from average method was loser to the real consumption of the lead users (Bosgti, et al., 2009). The result from peak method was 36% higher than the actual consumption of the lead user.

The average calculated for November was 2,5 MW, the peak method gave an average result of 5,65 MW, and average method gave 1,63 MW with a daily average temperature of 7 ^{0}C. November average temperature was 0,2 ^{0}C, it was expected that heat consumption should be lesser than the calculated average need. Also peak method gave consumption needs of 3,15 MW higher than the average in November. From this comparison, it shows that average method gave a result closer the expected need while peak more than required. Table 24 below shows the comparison chart of the two methods.

Table 24. Comparison chart (Bosgti, et al., 2009).

	Calculated Energy needs	Peak method	Average method
February			
Monthly consumption	4830 MWh	6600 MWh	4900 MWh
Monthly average consumption	7,20 MW	9,82 MW	7,25 MW
Absolute peak	21 MW	21 MW	15,5 MW
November			
Average consumption	2,5 MW	5,65*	1,63 MW*

*daily temperature of 7 ^{0}C, average temperature of 0,2 ^{0}C

Simulation shows that more heat is needed at night than day time due to temperature differences within the greenhouse and outside the greenhouse; therefore there is need for flexibility in the amount of heat generated from the power plant. The capacity of the power plant with variation in the amount of heat needs from the lead users is a serious issue. For proper optimisation of the power plant, proposed power plant should be running at full capacity, if over sized, it will produced more than required that is running at a lost.

From the simulation, the size of the power was set to 8 MW of heat. The capacity can still cover most of the consumption of the lead user in February; the actual heat produced is 500 MWh more than the heat consumed in the month of February based on the monthly simulation, however about 15,5 MW is needed during part of the days. This need is only reached within four days and only in one hour.

The heat peak need is 202 MWh and this is 10 MWh more than the heat produced from the power plant. The amount of heat produced is 192 MWh while the amount of heat underproduction on daily production is about 5,2%. In February underproduction is 40 MWh while 500 MWh was overproduction, and the total production is 5376 MWh. In order to meet the heat needs heat storage tank can be used as a buffer to avoid waste of heat.

6.4. Question (d): How can the greenhouse farmers and inhabitants of the municipality buildings solve their energy problem?

In solving energy problem encountered by the greenhouse farmers and inhabitants of the municipality buildings, it will require proposing to them a viable CHP power plant which will solve their problem now and in the near future. From the above simulation analysis its shows that a power plant with substantial amount of energy will be required to meet their peak needs and there after. CHP power plant with a capacity of 8MW of heat and 3.5 MW of electricity will be a solution to their energy needs.

This CHP power plant will be operating on straw as its main energy sources since there is an abundance of straw within this community. The design of the power plant will as well allow the use of other renewable energy sources such as peat and wood chips.

7. DISCUSSION AND CONCLUSIONS

This chapter will give a general overview of the whole work presented in previous chapters including a proposed solution to the energy needs by the farmers and the community of Pörtom.

The use of energy can not be overlook due to its significant contribution to a nation's development. Using fossil fuels as energy sources has negative effects on the atmosphere; and because of these, many nations are sourcing for an alternative energy form, which will not contribute to the destruction of their environment at large. However, that brings the thought about renewable energy; it can contribute to diversification of energy carriers for production of heat, fuels and electricity via the use of combination of production heat and power (CHP).

The purpose of this research was to look at the future of renewable energy in the dynamic of innovation. Also focus on how renewable energy influence technology innovation diffusion within the field of renewable energy. This research as well tries to find solution to energy problem encounter by greenhouse farmers and municipality occupants in the community of Pörtom.

In finding solutions to the problems stated above, this thesis tries to look into various research methods that are available. Due to the nature of this work, and the ways information such as data was collected from greenhouse farmers, operation analytical approach was then used for analysing the available data received.

The use of renewable energy was analysed and found to vary based on the availability of the source of energy within the locality where it is needed. There are various types of renewable energy sources namely hydropower, biomass, solar, wind, and geothermal. All of these energy sources have different types of technology that goes along with them. In recent times, the growth in use of renewable energy as sources of energy has been on an increasing rate. These increments occur as a result of national and local policies which have been in support of the growth of the adoption of the use of renewable energy. The adoption of renewable energy as energy source significantly depends on how the adopter opinion on the energy source compared to their needs and how innovative it is to them.

Using renewable energy as innovation source was reviewed by looking into the meaning of innovation as defined by different scholars. It was discovered that to some people innovation is regarded as newness. But the degree of the newness depends on the adoption and diffusion of the innovative technology. As for the greenhouse farmers of Pörtom and the user of the municipality building, the combination of power plant with heat generation and power (CHP) is new technology to the farmers and occupants of municipality building due to different technologies used by them. None of these farmers and occupants of municipality buildings generate electricity with their current used technology.

In conclusion there is an opportunity to use renewable energy as an innovation source in the community of Pörtom by building a power plant in Pörtom with the possibility to solve the energy problem of lead users and occupants of municipality buildings. The proposed power plant will then replace their current used oil-burners and give the lead users and municipality as a whole green energy at a competitive price. With regard to the present oil-market, it will also bring safety to the lead user with more sustainable energy and a cheaper energy prices for the future.

The proposed power plant is best located in north east of the community of Pörtom with capacity of supplying 8 MW of heat and 3.7 MW of electricity sold to the grid. Straw will be the main source of the renewable energy due to its availability in the community.

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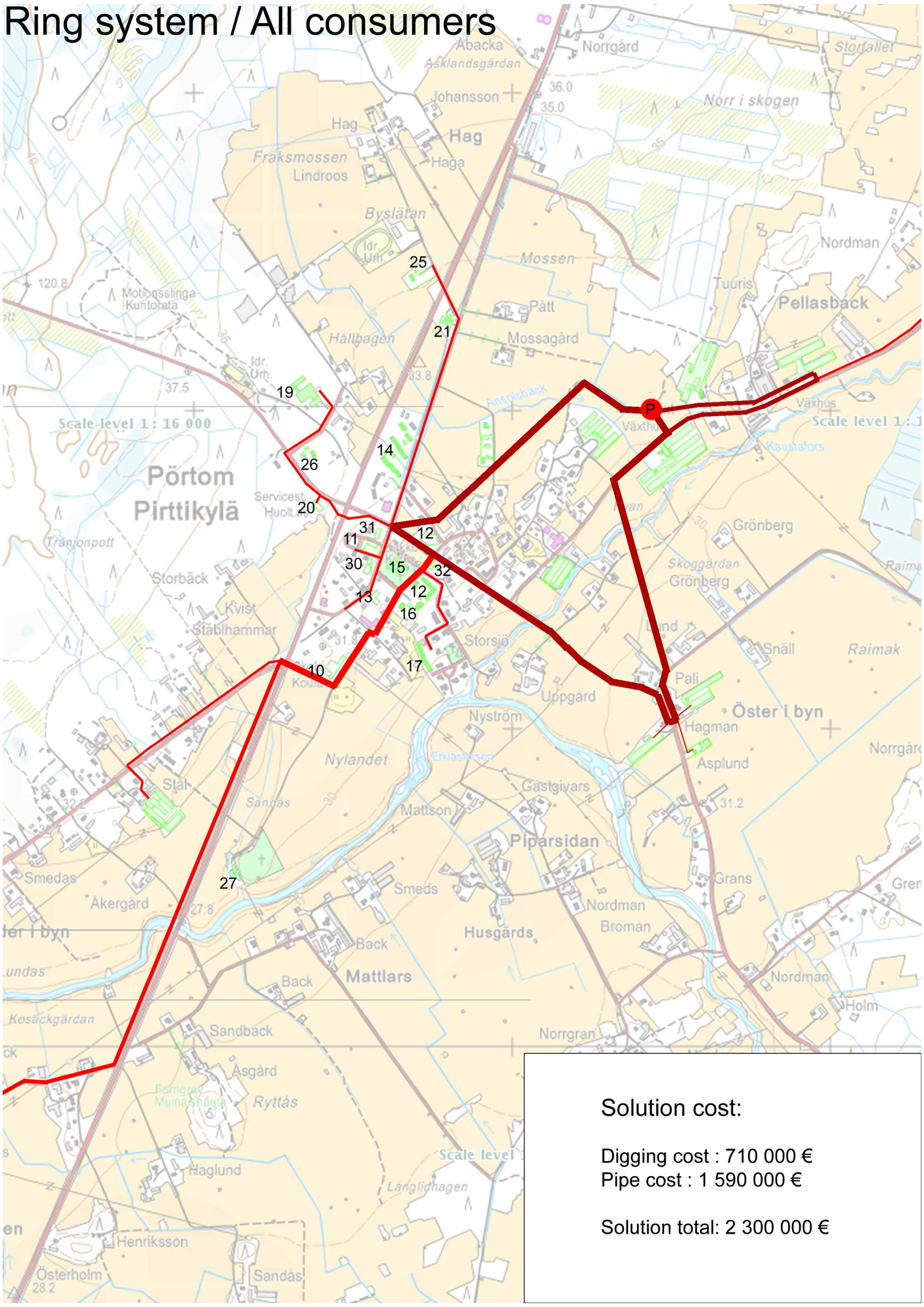
APPENDICES

Appendix 1

Ring piping system



Ring system / All consumers

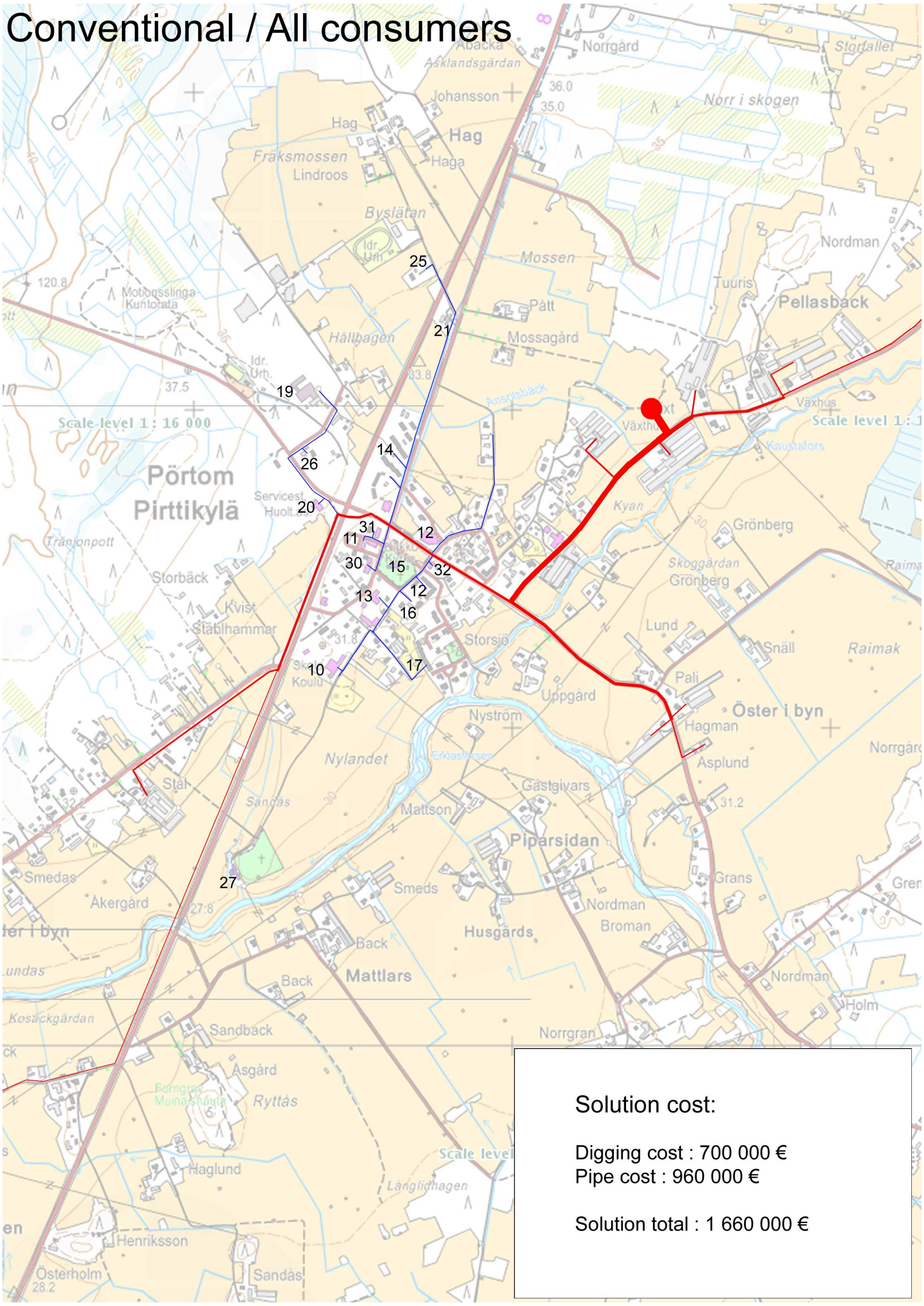
Solution cost:

Digging cost : 710 000 €
Pipe cost : 1 590 000 €

Solution total: 2 300 000 €

Appendix 2

Conventional piping system



Conventional / All consumers

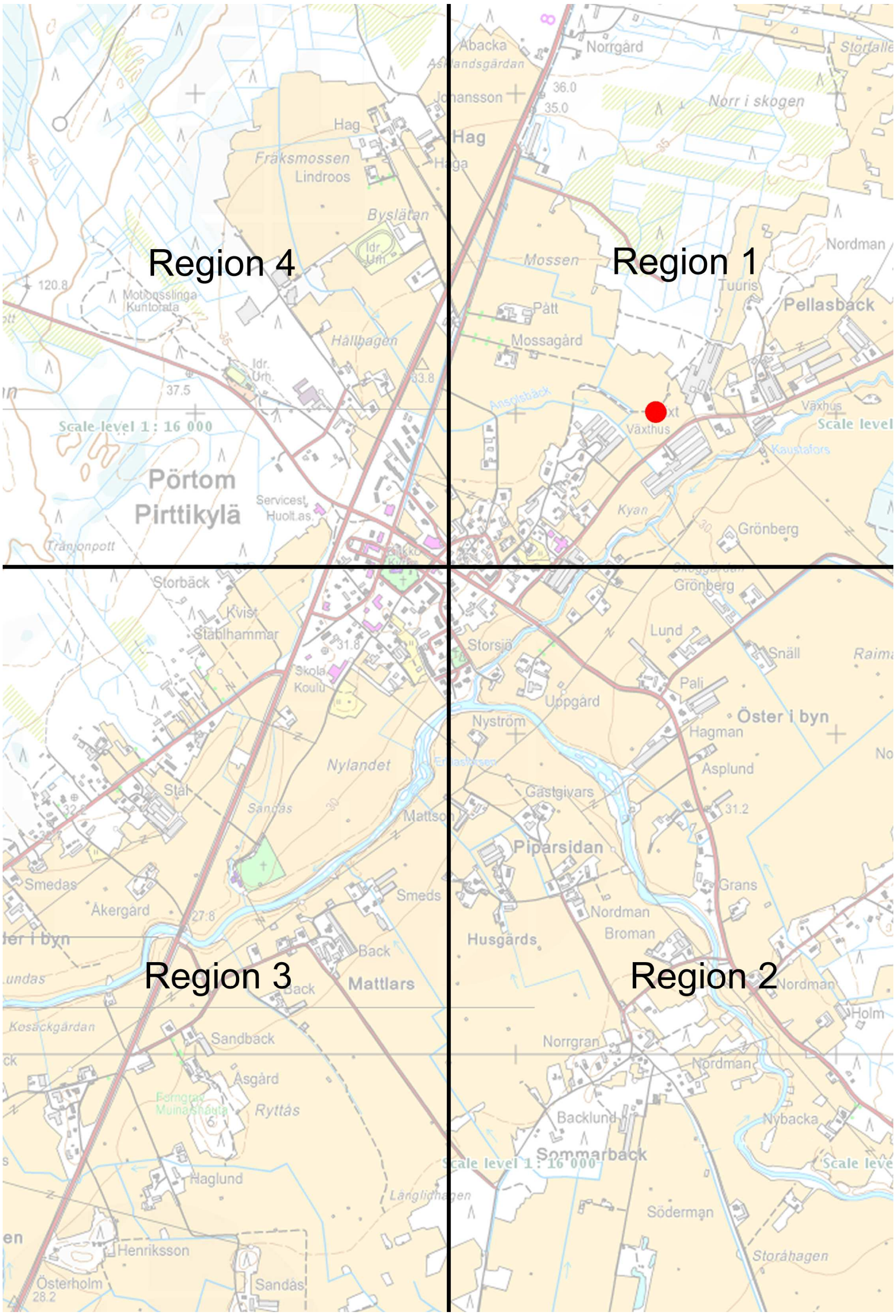
Solution cost:

Digging cost : 700 000 €
Pipe cost : 960 000 €

Solution total : 1 660 000 €

Appendix 3

CHP Power plant location



Appendix 4

Emission downfall direction