On Sustainable Local Energy Planning

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Thesis for the Degree of Licentiate in Engineering

Division of Efficient Energy Systems
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Abstract
Energy is fundamental to human communities and their sustainable development. The complex relationship of community energy systems and environmental, economic and social aspects of human life highlights the role of planning in future developments. Meanwhile, the conventional energy planning methods hardly address the aspects of sustainable development. This study is carried out in order to explore the limitations of conventional energy planning methods with regard to sustainable development goals. Another question is to investigate the approaches to the enhancement of sustainability dimensions in community energy planning.

Considering the fact that community energy planning has a tradition in Sweden for more than 30 years, the country’s experiences particularly at the local level have been used as a valuable resource for this research. An overall status of the Swedish municipal energy planning and the energy planning process within the municipality of the city of Lund has been analyzed. The results indicate that the conventional community planning methods are not sustainable. It is also shown in this study that new dimensions are necessary to be considered within the energy planning process towards a sustainable society.
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Finally, my deep gratitude comes to my parents, my brother and my sister for all their loving support.
1. Introduction

The principles of sustainable development have increasingly been accepted in societies throughout the last decades. Human well-being and improvement of social welfare greatly depend upon affordable access to energy services. Almost all the goods and services that are necessary for communities’ development are linked to the provision of commercial energy. Energy is also among the important factors which can affect the environment both by extraction of energy from natural resources and by energy use.

The global concerns on climate change and the negative environmental impacts of energy use are now leading many countries to prepare for transition towards more sustainable energy systems. Setting strong environmental targets by the European Council in March 2007 such as 20% reduction of greenhouse gas emissions by 2020, is an example of this new trend. Implementation of recent European programs, such as 3-NITY\(^1\) and WISE-PLANS\(^2\), with the aim of integrating local/regional energy strategies with the sustainable development goals indicate the increasing willingness of setting long-term energy strategies by the decision makers. The strong relationship of energy with the environmental, social and economic aspects makes the community energy system to be more complex and complicated to run. The importance of energy for achieving the sustainable development goals has been a major driving force towards new approaches to community energy planning (Ferreira, 2007). In spite of conventional energy planning methods which were generally focused on energy supply, distribution and use from technical and financial points of view, the new approaches to energy planning are comprised of wider perspectives with additional energy related components including environmental, economic and social issues. These newly developed energy planning procedures are not dealing only with matching future energy supply and demand as Van Beeck (2003) defines the energy planning; they actually aim to provide the community with more efficient energy use, secure and reliable energy supply, limited emissions driven from energy use as well as access to affordable modern energy services. The new approaches to energy planning procedure assist the decision-makers to set the future strategies towards community development in a more sustainable manner.

This thesis will discuss the general framework of sustainable energy planning with regard to conceptual descriptions of the term “Sustainability”. Thereafter, an overview of Swedish energy planning and particularly the energy planning process at the local level (municipal level) is presented in order to provide a deeper insight towards sustainable energy planning.

1-1. Objectives

The overall objective of this research has been to develop a new approach to community energy planning by evaluating the existing planning methods. Given that, there are some valuable experiences in the Swedish local energy planning, this study aimed to provide a new conceptual framework for community energy planning in regard to sustainable development goals. This study attempts to investigate:

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\(^1\) More information is available on: [http://www.iceprojects.net/treenity.html](http://www.iceprojects.net/treenity.html), (2008-09-23)

\(^2\) More information is available on: [http://www.wiseplans.eu/](http://www.wiseplans.eu/), (2008-09-23)
• How to integrate energy with environmental, economic, social, technical and institutional aspects in a sustainable manner
• What are the weaknesses of the existing community energy planning methods
• To provide an appropriate methodology of transition towards a sustainable society

1-2. Limitations
The complexity of the community energy system led this study to deal with a broad range of interdisciplinary fields including economic, environmental, technical, social and institutional subjects. Although, it is attempted, in this study, to establish rational inter-connections between the components of the community energy system, the broad perspective to this issue causes the possibility of partial conflicts to emerge.

Another limitation was lack of available information which was scattered among different organizations e.g. energy companies, the municipalities, the energy related Local authorities and the Swedish Energy Agency.

1-3. Method
In this study, the local energy planning in Sweden is investigated. For this purpose, a background on traditional energy planning in Sweden at the local level, the municipal energy plan, and its development over the time is provided. To examine legal requirements for the municipal energy plans and their effectiveness on the improvement of the local energy system is another step taken towards making a general picture of the Swedish energy planning process. All the necessary data needed for this part of the study is collected from the National Swedish Statistical Data (Statistiska centralbyrån), Swedish energy agency (Energimyndigheten) and Swedish Association of Local Authorities and Regions (Sveriges Kommuner och Landsting). However, to narrow down the scope of research, energy planning at Lund municipality (1977-present) was selected as the focus of this study.

The next part of this study aims at clarifying the characteristics of a sustainable energy plan. For this purpose, an overview of the concept of “sustainability” is investigated. Based on this conceptual framework, the key sustainability dimensions that are necessary to be considered in the energy planning process are discussed.

1-4. Outline
The thesis consists of 7 chapters:

Chapter 1 provides a background, the objectives for this thesis, the study limitations, and the methodology.

Chapter 2 describes the theoretical approach of the research by clarifying the strong relationship between energy and dimensions of sustainable development.
Chapter 3 shows the overall status of community energy planning in Sweden. Moreover, the significant changes of the country’s energy policy which have influenced the planning process over the time are presented in this chapter.

Chapter 4 presents the case study chosen in this thesis which is the municipal energy planning of the city of Lund in 1980, 1991 and 2001.

Chapter 5 investigates the conceptual framework of the term Sustainability, and its major dimensions.

Chapter 6 discusses the main characteristics to be considered in sustainable energy planning. A comparative analysis of the three Lund’s energy plans from a sustainability point of view is presented in this chapter.

Chapter 7 contains the main conclusions of the thesis.
2. Theoretical approach

This research benefits from theories of planning and principle of sustainable development in order to clarify sustainable energy planning framework as a systematic process. First, a brief overview of different planning theories as well as their advantages and disadvantages is presented. Then, a short introduction to the relationship between energy and the key elements of sustainable development is made.

2-1. Planning for energy systems

There are several planning theories which have been used as the basis for different planning purposes e.g. energy planning. Each traditional planning theory has strengths and weaknesses per se. For instance, Synoptic Planning, or Rational Comprehensive Planning which is the dominant planning theory “typically looks at problems from a systems viewpoint, using conceptual or mathematical models relating ends (objectives) to means (resources and constraints) with heavy reliance on numbers and quantitative analysis” (Hudson, p. 389, 1979). Hudson continues, “The synoptic planning tradition is more robust than others in the scope of problems it addresses and the diversity of operating conditions it can tolerate. But the approach has serious blind spots, which can only be covered by recourse to other planning traditions”. Synoptic planning based on models and simulations is “unrealistic” (Lindblom, 1959). “It is technically troublesome and politically controversial …The data required for rational planning are hard to obtain and even harder to interpret” (George A. Boyne et al., 2004). Hoch (2007) believes the emphasis on rationality, however, generates a separation between thought and other kinds of human activity. He continues “Theory tells us how to think about planning, but not how to do it. Rational theory discerns the truth, but not what to do with it”.

The Incremental Planning theory is based on the accomplishment of public policy through decentralized bargaining processes in a free market and a democratic political economy (Lindblom, 1959). Lindblom states that the incremental planning’s greatest strength is that instead of attempting to be rational and comprehensive it describes decision-making as it actually occurs. The model recognizes that policy is continually being made and re-made, thereby avoiding errors that come with radical change in policy and stays within predictive capability. However, Hudson (1979) argues “The case for incremental planning derives from a series of criticisms leveled at synoptic rationality: its insensitivity to existing institutional performances capabilities; its reductionist epistemology; its failure to appreciate the cognitive limits of decision-makers, who cannot "optimize" but only "satisfice" choices by successive approximations”.

Planning theories share similar characteristics regarding their strength and weaknesses. Each theory can be used to describe a part of planning procedure. While one theory provides a comprehensive model; another theory gives a realistic view. Hudson believes that “No single tradition of planning can do everything” and he concludes, “Parallel application of more than one theory is usually necessary for arriving at valid, three-dimensional perspectives on social issues and appropriate action implications”. Regarding the characteristics of various planning theories, almost all energy planners benefit from a combination of these theories, with some small changes, for their planning.
The implementation of the energy planning process is different in developed and developing countries as well as energy importer countries compared to energy producer ones. Several important factors affect the energy planning process such as economic, social and cultural context, environmental conditions and political system of the community. The administrative body is playing a significant role in choosing and implementing the planning methods. Planning systems in democratic and liberalized countries are different from those in countries with closed and state-controlled market systems. However, in general, all of them are benefiting from one or more of the above mentioned planning methods depending on the circumstances.

2-2. Energy planning and sustainable development

In 1980s, when the term “sustainable development” came into the global consideration, with no doubt, energy became the key element for the community development regarding the three main topics, environment, economy and social equity. Adequate and affordable energy supplies have been playing an important role in economic development and the transition towards modern industrial and service-oriented societies. Energy is a key element for improving social and economic well-being, and is vital to most industrial and commercial wealth generation. It is necessary for improving human welfare and living standards. Both the energy exploitation from natural resources and energy use can affect our living environment. It is obvious that energy has a strong relationship together with sustainable development. Some of the main energy-related goals of the sustainable development are:

- The improvement of access to reliable, economically viable and environmental friendly energy services.

- Development of alternative energy technologies and increasing the share of sustainable energy resources (renewable).

- Improving the living standards of the poor people by developing modern energy services.

- Developing affordable renewable energy technologies.

2-2-1. Energy and economic development

The role of energy in the development process from an economic point of view contains a broad area from supply to use of energy in communities. Strong relationship between energy and economic activities influence almost all parts of the society from macro to micro levels including infrastructures, transportation, markets, manufacturing, social welfare, etc. The concept of economic growth, in most cases, usually refers to the supply side of the communities that concerns the production of commodities and services. The ratio of total energy use per unit of Gross Domestic Products (GDP), which is defined as Energy Intensity, is a proper evaluating tool for the energy efficiency of a nation's economy. In order to gain a better understanding of the real nature of the relationship between economy and energy use, it is important to assess the most energy-intensive side of the economy which is the production sector. Considering the fact
that, energy is central to the activation of the industrial sector and manufacturing process, the rate of consumed energy for production, which commonly is referred to as energy per GDP ratio, is an appropriate index for the economic growth rate of a country and indicates the significant relationship of energy and economic development. High ratios of energy intensities indicate a high price of converting energy into GDP and vice versa. Dincer (1997) argues the energy per GDP ratio can be different among countries regarding different circumstances such as climate, diversity of the natural resources and even monetary valuations of GDP; hence, it cannot be considered as a reliable economic index but is useful as a preliminary indicator of energy demand. The use of energy per GDP ratio for a country could be more reasonable for comparing the economic development growth situation and providing the picture of energy demand over the time (ibid). Hwang et al. (2008) argue that the relationship between energy consumption and economic growth differs among countries and is depending on the corresponding income levels. They indicated that: (a) in the low income countries, there is no casual relationship between energy consumption and economic growth; (b) in the middle income countries, economic growth leads energy consumption positively; (c) in the high income countries, economic growth leads energy consumption negatively.

Although, the rate of energy use per GDP is expected to decline over time due to adoption of more efficient technologies, however, even with a tendency towards more efficient energy use, the ratio of energy per GDP may continue to increase within the context of a possible rebound effect (Ockwell, 2008).

The willingness for continuous economic growth by the governments worldwide and the strong linkage between the use of energy and economic activities is referred by Ockwell (2008) to indicate the importance of energy as a fundamental factor in the development.

2-2-2. Energy and environment

There is a vast literature explaining the relationship between energy, environment and sustainable development. The negative environmental impacts of energy use have been discussed in almost all of them. While energy is essential for a sustainable development process, the negative interactions between energy use and environmental degradation have increasingly become as an important issue among nations. Several regional and international organizations have been working on this issue since last two decades. For instance, on the fourteenth session of the United Nation’s Commission on Sustainable Development (CSD) in 2006, the CSD focused on the area of energy with respect to industrial development, atmosphere/air pollution and climate change. Another example is the recent European Commission energy policy in 2007, which proposed an integrated energy and climate change package to cut emissions for the 21st century by increasing the share of renewable energy resources and saving total primary energy consumption by 2020.

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3 Hwang et al. used the panel data of energy consumption and GDP for 82 countries from 1972 to 2002 based on the income levels defined by the World Bank.

4 The rebound effect refers to the idea that increases in energy efficiency might result in increases in energy consumption.
All these global and regional activities, international commitments for the environment protection as well as increasing public awareness about environmental degradations such as ozone layer depletion, global warming, deforestation, pollution of land, water, etc., indicate existing energy supply/use patterns are not functioning in an appropriate environmental friendly manner. In most cases, human activities are introduced as the main source for environmental degradation driven from energy use. On the other hand, it is obvious that energy consumption, which is vital to human life and is central for the implementation of sustainable development, have some negative environmental impacts which should be reduced. However, the question is to what extent human activities are responsible for that? Another group of scientists argue that human activities are not the main source that influences some environmental phenomenon such as global warming. They believe other natural phenomenon such as solar activities, volcanic activities, etc., have more contribution to global warming. However, studying the energy-related impacts on the environment is not a focus of this study. The aim of this section is to emphasize the important relation between the energy and environment.

2-2-3. Energy and social welfare

It is clear that energy is playing a significant role in the improvement of social welfare in developed and developing countries. Spending just a few days without electricity and fuel for transportation, heating, cooling and cooking can lead to a huge disorder. Quality of life, poverty and health are among the major related social subjects to energy use. Access to basic energy services at affordable rates are still one of the main social problems of some developing countries. Around 2 billion people have no access to modern energy services and most of them are still meeting their essential energy needs for cooking and heating from natural resources such as wood and crops (Johansson, 2002).

Social equity and health are two principal themes that are considered under the social dimension of sustainable development. The rate of fairness and inclusiveness in distributing energy resources and accessing to affordable energy services are underlying the social equity (Vera, 2007). Energy is supporting the social health from several points of view e.g. food provision and controlling indoor temperature at a comfortable level. Moreover, almost all medical centers and health care services are depending on energy for implementation of their activities.
3. Energy planning in Sweden

In this section, a general overview of the energy planning process is presented. Given that energy plans basically follow the principal energy policies of the country, the next step contains an outline of the Swedish energy policy and its transition over the time. Moreover, a background of the country’s energy policy is introduced in order to assist to a better understanding of the energy planning effectiveness. In the next step, an overview of the municipal energy planning in Sweden is presented.

3-1. Energy planning procedure - An overview

In general, energy planning “is a matter of assessing the supply and demand for energy and attempting to balance them now and in the future” (Kahen, 1995). The procedure of energy planning consists of setting energy related goals and policies, gathering and evaluating information, developing alternatives for future actions based on the evaluated information and policies and finally, proposing the best energy plan. Thörnqvist (1975) use seven basic elements for the planning process (Table 1).

<table>
<thead>
<tr>
<th>Introduction</th>
<th>Presentation</th>
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<tbody>
<tr>
<td></td>
<td>Background</td>
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<td>Frames of planning</td>
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<td>Previous energy plan follow-up</td>
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<td>Energy goals of the community</td>
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<td>Service level</td>
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<td>Energy conservation</td>
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<td>Flexibility and adaptability</td>
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<td>Plan alternatives</td>
<td>Forecasting alternatives</td>
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<td></td>
<td>Main program selection</td>
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<td></td>
<td>Emergency program selection</td>
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<tr>
<td>Guidelines for realization</td>
<td>Action proposals</td>
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<td></td>
<td>Control function</td>
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</tbody>
</table>

Table 1- Basic elements of the planning process
Energy plans can structure procedures for provision, transmission and distribution of energy in national, regional and local levels within a defined time range. Although, the implementation of energy planning procedure is different depending on the economic, political, social and environmental characteristics of the communities, it is often conducted using integrated approaches that consider both the provision of energy supplies for meeting the energy needs as well as reducing energy consumption by increasing the efficient energy use. The implementation of the energy planning process differs from developed to developing countries and from energy importer countries to energy producer ones. Energy planning in democratic and liberalized countries is more decentralized and more market oriented compared to countries with state-controlled markets using central planning systems.

In spite of these differences, energy plans can be seen as a tool for the decision-makers that facilitate setting the future energy strategies. Van Beeck (2003) defines a planning process as the process of making choices between alternatives. She considers energy planning as the decision making process of selecting the preferred local energy infrastructure to invest in (p. 22). Although utilization of energy planning as a tool for the decision making process can be different depending on the circumstances, in general, the planning outcome is to balance the community’s energy supply and demand. The energy planning procedure can be done through different methodologies and models.

Cormio et al. (2003), classify energy planning methods depending on the planning level (local, regional or national) and required time scale (short, medium or long-term) in three categories:

1- **Planning by model**, including econometric model and optimization model, generally based on mathematical and statistical methods, such as market allocation model (MARKAL)\(^5\) and or energy flow optimization model (EFOM)\(^6\).

2- **Planning by analogy**, which is the process of making a new plan based on the structure of an existing successful plan. This method simulates the quantitative data and checks the outputs with the other methods.

3- **Planning by inquiry**, which is a method based on the statistical evaluated and optimized answers of selected experts (Delphi method).

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\(^5\) The MARKAL model “is a large scale, technology oriented activity analysis model, which integrates the supply and end-use sectors of an economy, with emphasis on the description of energy related sub-sectors” (EIA, 2006).

\(^6\) EFOM is an engineering oriented bottom-up model of a national energy system, which is a network of energy flows to meet the demand for energy services.
Van Beeck (2003) classifies energy models by the model characteristics which can support local energy planning (Table 2).

<table>
<thead>
<tr>
<th>Classification</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perspective on the Future</td>
<td>Forecasting, exploring, backcasting</td>
</tr>
<tr>
<td>Specific Purpose</td>
<td>Energy demand, energy supply, impacts, appraisal, integrated approach, modular build-up</td>
</tr>
<tr>
<td>The Model Structure: Internal Assumptions &amp; External Assumptions</td>
<td>Degree of endogenization, description of non-energy sectors, description end-uses, description supply technologies</td>
</tr>
<tr>
<td>The Analytical Approach</td>
<td>Top-Down or Bottom-Up</td>
</tr>
<tr>
<td>The Underlying Methodology</td>
<td>Econometric, Macro-Economic, Economic Equilibrium, Optimization, Simulation, Spreadsheet/Toolbox, Backcasting, Multi-Criteria</td>
</tr>
<tr>
<td>The Mathematical Approach</td>
<td>Linear programming, mixed-integer programming, dynamic programming</td>
</tr>
<tr>
<td>Geographical Coverage</td>
<td>Global, Regional, National, Local, or Project</td>
</tr>
<tr>
<td>Sectoral Coverage</td>
<td>Energy sectors or overall economy</td>
</tr>
<tr>
<td>The Time Horizon</td>
<td>Short, Medium, Long Term</td>
</tr>
<tr>
<td>Data Requirements</td>
<td>Qualitative, quantitative, monetary, aggregated, disaggregated</td>
</tr>
</tbody>
</table>

Table 2- Classification of energy models by characteristics (van Beeck, 2003)

Throughout the last decades, various energy models were developed as decision support tools for energy planning with the aim of providing energy forecasts. Assessment of the impact of energy use on the natural environment was another important aim of these energy models. The main energy models (often computerized) with some of their characteristics are presented in Table 3. Although energy models were developed to assist policy makers in the framing of appropriate policy directions, their effectiveness on achieving the planned goals are still in the debate. For instance, Laitner et al. (2003) argues that such models provide biased estimates that tend to reinforce the current situation, inadequately inform policy-makers about new market potential, and bound the development of innovative policies. The major constraints of existing energy planning tools are discussed in chapter 6.
<table>
<thead>
<tr>
<th>Energy Model</th>
<th>Specific purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>MARKAL</td>
<td>Energy supply with constraints. The objective includes target-oriented integrated energy analysis and planning through a least cost approach</td>
</tr>
<tr>
<td>ENERPLAN</td>
<td>Energy supply, energy demand, matching demand and supply</td>
</tr>
<tr>
<td>MESSAGE-III</td>
<td>Energy demand and supply, environmental impacts. Modular package. The objective includes generation expansion planning, end-use analysis, environmental policy analysis, investment policy</td>
</tr>
<tr>
<td>LEAP</td>
<td>Demand, supply, environmental impacts. Integrated approach. The objective includes energy policy analysis, environmental policy analysis, biomass- and land-use assessment, pre-investment project analysis, integrated energy planning, full fuel cycle analysis. Applicable to industrialized as well as developing countries</td>
</tr>
<tr>
<td>EFOM-ENV</td>
<td>Energy supply, subject to technical, environmental and political constraints. Detailed description of (renewable) technologies possible. Appraisal through cost-effectiveness analysis. The objective includes energy and environment policy analysis and planning in particular regarding emission reduction</td>
</tr>
<tr>
<td>MARKAL-MACRO</td>
<td>Demand, supply, environmental impacts. Integrated approach for economy-energy-environmental analysis and planning. The objective is to maximize utility (discounted sum of consumption) from a neo-classical macro-economic perspective</td>
</tr>
<tr>
<td>MESAP</td>
<td>Modular package. Demand, supply, environmental through different modules: ENIS = database; PLANET/ MADE = demand which can be coupled to supply module; INCA = comparative economic assessment of single technologies; WASP = generation expansion based on least-cost analysis; MESSAGE = integrated energy systems analysis</td>
</tr>
<tr>
<td>ENPEP</td>
<td>Energy demand, supply, matching demand and supply, environmental impacts. Detailed analysis for electricity based on least cost optimization. Integrated approach. Allows for energy policy analysis, energy tariff development, investment analysis, generation expansion planning and environmental policy analysis</td>
</tr>
<tr>
<td>MICRO-MELOIE</td>
<td>Energy demand, supply, environment. Integrated approach. The objective includes an analysis of macro-economic energy and environment linkages</td>
</tr>
<tr>
<td>RET screen</td>
<td>Energy supply. Specially designed for renewable energy technologies</td>
</tr>
</tbody>
</table>

Table 3- The main energy models and their specific purposes (Van Beek, 2003)
3-2. Swedish energy system

The Swedish energy system has undergone a major transformation throughout last decades. In 1970, around 80 percent of the total energy supply was from imported fossil fuels. This figure changed by reducing the fossil fuel imports to 30 percent today, which indicates significant changes in the structure of the Swedish energy system (Swedish National Energy Agency, 2001). The country’s energy supply increased by 36.5 percent from 457 TWh in 1970 to 624 TWh in 2006 (Figure 1).

![Figure 1- Total energy supply in Sweden 1970-2006 (TWh)](image)

*Source: Swedish National Energy Agency 2007

*Gas works gas covers all types of gas produced in public utility or private plants, whose main purpose is the manufacture, transport and distribution of gas. It includes gas produced by carbonization (including gas produced by coke ovens and transferred to gas works), by total gasification (with or without enrichment with oil products), by cracking of natural gas, and by reforming and simple mixing of gases and/or air. This heading also includes substitute natural gas, which is a high calorific value gas manufactured by chemical conversion of a hydrocarbon fossil fuel.*

The increasing energy use in Sweden between 1970 and 2006 mainly was resulting from increases in the transportation sector; while the demand from residential, commercial, service and industrial sectors has remained basically stable (Silveira, 2001). Today in Sweden, the industrial sector with the share of 25 percent of the total energy demand is the largest energy consumer. The residential and commercial sectors, energy losses in nuclear power plants, internal transport, conversion and distribution losses (excluding nuclear power) as well as International marine bunkers plus use for non-energy purposes have the share in the total energy demand of 23, 20, 16, 8 and 7 percent respectively (Figure 2). Electricity production in Sweden is basically fossil-free. Around half of the electricity production comes from hydropower and the rest is provided by nuclear power. The energy use patterns in Sweden changed based on shifting from the dominant fossil fuels to the other energy sources. For instance, development of district heating systems has led to a significant reduction of utilizing fossil fuel based furnaces used for space heating. Sweden has an extensive district heating sector. District heating accounts for about 40 %
of the Swedish heating market. Use of district heating increased by approximately 280 percent from 14.6 TWh in 1970 to 55.4 TWh in 2006 (Swedish Energy Agency). Compared to 1970, the fuel mix of district heating has changed dramatically. Today, oil accounts for only a few percent while more than 62 percent of district heating fuel today is biomass.

![Figure 2- Total energy use in Sweden 1970-2006 (TWh)](source)

Source: Swedish National Energy Agency 2007

### 3-3. An overview on energy policy in Sweden

In Sweden, political decisions upon energy related issues backslide to 19th century when the Swedish politicians together with the industrialists began investigating various ways of reducing dependency on imported coal (Kaijser, p.62, 2001). The government has also influence on energy related matters by approving laws and regulations such as the electricity act in 1902\(^7\) and water act in 1918\(^8\) (ibid). Moreover, Sweden was the world’s first country to set up a state-owned power board in 1909, known as Vattenfall. Despite the vast exploitation of hydro power as well as the imports of coal and oil, Sweden experienced the vulnerability to energy supply during World War II, why energy questions entered the political agenda again. In the mid 1950s, a governmental commission proposed an ambitious development program on nuclear power.

Although the Swedish government was influencing the country’s energy system, energy related matters had not really been considered as political issues until oil price crises in 1970s. Before that, the whole structure of Swedish economic well-being assumed sustained based on supply of cheap electricity and profligate use of imported oil (Vedung, 2001). The oil price shocks of 1973 revealed Sweden’s extreme dependence on imported oil (Kaijser, 2001). The rapid increase of the country’s energy demand as well as high oil prices were the challenges that brought nuclear energy into the political agenda. As a result, the first priority of the Swedish government was

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\(^7\) The 1902 electricity act was about obtaining permission for constructing high-voltage lines

\(^8\) This act was about development of water resources for power generation
reducing oil consumption. Available alternative energy resources to oil were nuclear energy and hydropower. However, hydropower expansion was stopped by the Swedish parliament in the late 1960s because of environmental concerns. Whether nuclear power as an alternative energy source to oil should have an important role in reducing oil consumption, it became an issue of intense political disagreement (Kaijser, 2001). Development of nuclear power became the hub of conflictive debates among political parties, which played a significant role in Swedish energy policy from 1973 (Vedung, 2001).

The first comprehensive Swedish energy policy was introduced in 1975. The country’s Parliament decided upon starting a national energy conservation program. In general, the 1975 Swedish energy policy aimed the reduction of accelerating increase of energy supply (Vedung, 2001). Based on that, the growth rate of total energy supply of the country was limited to an average of 2 percent per year until 1985. Additional limitation should be made between 1985 and 1990 in order to reach zero growth in energy demand by 1990 (ibid).

The 1975 decision led to more reliance of the Swedish energy system on nuclear energy. The most important reason for development of nuclear energy was reducing the dependency on imported oil. Implementation of this policy was successful and as a result the country’s capacity of nuclear electricity increased from 7 TWh in 1973 to 173 TWh in 1985 (Figure 3).

![Energy supply trend in Sweden 1973-1985 (TWh)](source)

Source: Swedish Energy Agency 2007

After a national referendum’s outcome\(^9\) in 1980 was no further expansion of nuclear power foreseen. The country’s nuclear capacity, however, doubled from 6 to 12 power plants in a few years (Vedung, 2001). Six years later in 1986, a core meltdown in a nuclear reactor at Chernobyl in

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\(^9\) The accident of the Three Mile Island nuclear power plant in the USA (March 1979) opened the debate about nuclear power security in Sweden which brought the nuclear issue into a national referendum.
Ukraine led to making decision in 1988 by the Swedish government on decommissioning two nuclear reactors by 1995. However, the 1988 phase-out decision was dismantled in 1991 because of the new energy policies adopted in the country’s Parliament, which was emphasizing on the security of electricity supply and competitiveness of the energy prices (Vedung, 2001). The market competition after deregulating the Swedish electricity market in 1996 has an immediate effect on reducing the electricity prices and increasing efficiency (Bergman, 2001). However, the prices started to rise from 2002 (Figure 4).

![Figure 4- Average price on electricity (include grid charges, taxes, VAT and charge for green certificate) for household and industrial consumers (Source: Statistics Sweden)](image)

In 1997, the Swedish Parliament adopted a new energy policy towards creating a sustainable energy system. Development of ecologically and economically sustainable energy supply mainly through renewable energy resources, as well as improving energy efficiency were the major goals of this new policy (Swedish Parliament, 1996/97:84). Moreover, two nuclear reactors should be phased out, one in July 1998 and the other one in July 2001. As a result, the first reactor (Barsebäck 1) was shut down in 1999 and the second one (Barsebäck 2) was shut down with delay in 2005.

Today, the aim of the Swedish government’s energy policy is to safeguard a reliable energy supply at internationally competitive prices, both for the short and the long terms. This energy policy should create conditions for efficient and sustainable energy use, with minimum adverse effect on health, the environment and the climate, as well as assisting transition towards an ecologically sustainable society (The Swedish Ministry of Enterprise, Energy and Communications, 2007).
3-4. Municipal energy planning

In Sweden, the municipalities have traditionally their own self-governing local authority with certain responsibilities (Swedish Association of Local Authorities and Regions). They are responsible for providing a wide range of public services such as health and environmental protection, water and sewerage, physical planning and building issues, social services, waste management, etc. Energy is among the fundamental factors to provide these services. Sweden's municipalities are key operators when it comes to the adaptation of the energy system. They can act as public operator, real-estate owners, as employers and/or as owners to an energy company. They also can influence on strategic development of energy system by benefiting from an energy plan (Swedish Energy Agency ER 2006:40).

3-4-1. Legal perspective

According to Swedish law, municipalities are legally required to provide an ‘energy plan’ (Municipal Energy Planning Act, Swedish parliament, SFS 1977:439). Based on the act, local authorities are required to promote the efficient use of energy in their planning and work for reliable and adequate energy supply. Moreover, every municipality must have an up-to-date plan for the supply, distribution and use of energy. The act is emphasizing on collaboration of the local authorities with other municipalities and/or the other energy related stakeholders such as energy companies in order to resolve the important issues on energy efficiency and energy supply. According to the act, the Municipal Council is responsible to decide upon the energy plan.

The act has been amended several times since 1977. These revisions and complementary legislations were added to the act based on new circumstances of the country’s energy policy (Olerup, 2000). For instance, in 1981, providing a plan for reducing oil consumption in each municipal area was added to the act, following the 1979 oil crisis. In 1985, it was decided that energy should be integrated into the municipal master development plan (Stenlund, 2006). Another amendment was made to the act in 1991 when the Swedish Parliament decided the municipal energy plans should be supplemented by an environmental impact study (Swedish National Energy Administration, 1998). The last amendment was made to the act in 2004 which was emphasizing the environmental assessment of both the energy plan and its implementation.

3-4-2. Facts and figures

Sweden has 290 municipalities. According to a survey by the Swedish Energy Agency in 2006, 73 percent of the country’s municipalities have an energy plan. The energy plans for 41 percent of these municipalities are from the year 2003 or even the previous years (Swedish Energy Agency,
The survey indicates that 69 percent of those municipalities with no energy plan intended to provide one in the nearest year (Figure 5).

In addition to plan for the development of community energy systems, energy plans can be used as tools for follow up of the planned procedures. It is important to know whether planned targets are achieved, and if not, how to resolve the problem. In Sweden, around half (49 percent) of the municipalities are following up their energy plans annually (Swedish Energy Agency, ER 2006:40).

According to the municipal energy planning act, the environmental impacts of energy plan must be assessed. At the present, less than half (46 percent) of the energy plans are environmentally assessed (ibid). Moreover, in many municipalities the relationship between energy plans and the other municipal tasks such as setting climate strategies and/or environmental policies are vague. According to the Swedish energy agency, 24% of the country’s municipalities have climate strategies with no linkages to their energy plans.

Municipal energy plans are also playing an important role as a guideline for setting the other energy-related strategies such as city transportation and climate strategies. As an advisor, they are responsible for delivering the basic knowledge and information on energy efficiency and the impacts of energy use on climate (SFS 1997:1322).
4. Energy planning in Lund Municipality

There are three energy plans published by the Municipality of Lund in 1980, 1991 and 2001. In this chapter, Lund’s energy plans as a sample (case study) are overviewed in order to gain a better understanding of local (municipal) energy planning procedure in Sweden. Moreover, the effects of the country’s energy policy changes on the local planning procedure are investigated, from 1977 until today, by comparing both the planned strategies and target achievements.

4-1. Lund’s energy plan 1980

The planning procedure for Lund’s energy system was started by the municipality in 1978. One year later, the Municipal Planning Committee decided upon considering the energy saving aspects as well as energy issues related to environment and traffic, within the energy plan. Lund’s energy plan was published in 1980 consisting of the local energy balance (energy supply and energy use for all sectors), a district heating plan, as well as proposals for future developments of the energy system. Table 4 shows Lund’s energy use in the residential/commercial, industrial and transportation sectors.

<table>
<thead>
<tr>
<th>Energy Use 1980</th>
<th>Gross</th>
<th>Net</th>
<th>Losses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential Buildings</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electricity</td>
<td>311</td>
<td>292</td>
<td>19</td>
</tr>
<tr>
<td>District Heating</td>
<td>375</td>
<td>339</td>
<td>36</td>
</tr>
<tr>
<td>Oil</td>
<td>267</td>
<td>174</td>
<td>93</td>
</tr>
<tr>
<td></td>
<td>953</td>
<td>805</td>
<td>148</td>
</tr>
<tr>
<td>Commercial and Public Buildings</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electricity</td>
<td>75</td>
<td>70</td>
<td>5</td>
</tr>
<tr>
<td>District Heating</td>
<td>368</td>
<td>333</td>
<td>35</td>
</tr>
<tr>
<td>Oil</td>
<td>117</td>
<td>76</td>
<td>41</td>
</tr>
<tr>
<td></td>
<td>560</td>
<td>479</td>
<td>81</td>
</tr>
<tr>
<td>Total Buildings</td>
<td>1513</td>
<td>1284</td>
<td>229</td>
</tr>
<tr>
<td>Industries</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electricity</td>
<td>146</td>
<td>136</td>
<td>10</td>
</tr>
<tr>
<td>District Heating</td>
<td>38</td>
<td>34</td>
<td>4</td>
</tr>
<tr>
<td>Oil</td>
<td>186</td>
<td>130</td>
<td>56</td>
</tr>
<tr>
<td></td>
<td>370</td>
<td>300</td>
<td>70</td>
</tr>
<tr>
<td>Transportation</td>
<td>484</td>
<td>131</td>
<td>353</td>
</tr>
<tr>
<td>Grand Total</td>
<td>2367</td>
<td>1715</td>
<td>652</td>
</tr>
</tbody>
</table>

Table 4- Lund’s energy use by sector - GWh

The overall goals of Lund’s energy plan which were set for the period of 1980-1990, were:

- The gross energy use of the municipality was allowed to increase maximum 1 percent per year.
- The municipality’s dependence on oil should be reduced up to 40 percent throughout the mentioned period.
- Energy needs for district heating should be reduced by 10 percent of the year 1980’s value.

- Energy supply should be based on several energy resources and energy carriers, considering reliability and security of supply.

- The district heating system should be expanded at least to the extent of prescribed heating plans.

- Wasted heat from the other energy resources such as geothermal, solar energy, natural gas, etc. should be used to the extent it is motivate of economical, technical and/or supply reasons.

The major goals of Lund’s first energy plan were focused on strategies for more energy conservation as well as increasing the efficiency of the energy system, which were following the 1977 municipal energy planning act’s requirements. Achievement to the planned goals is discussed at the end of this chapter.

In 1980, Lund’s total energy supply was 2367 GWh of which 1715 GWh was used and the rest were the system’s energy losses. Figure 6 shows the energy balance (energy supply/use) in different sectors.

![Figure 6- Lund's energy balance 1980 (TWh)](image)
In general, the 1980 energy plan was a good sample of classical energy planning, attempting to cover almost all energy-related aspects of the community. For instance, environmental impacts of energy use were considered in the energy plan (chapter 8), at a time when the environmental issues were not highly prioritized as it is today. Giving advices to real-estate owners in order to increase the society’s potentials for energy saving was another instance of energy related issues (social aspects) considered in the plan (Lund’s energy plan, 1980, P.40).

4-2. Lund’s energy plan 1991

In October 1990, Lund’s Municipal Board decided to make another energy plan regarding the amendments of the 1977’s Municipal Energy Act. According to new amendments, the municipalities were required to provide a local plan for supply, distribution and use of energy, as well as, to assess the environmental impacts of their energy plans (Lund’s energy plan, 1991, p.2). The most significant difference of the 1991 energy plan was in the method of goal setting, which was a classification of the goals by energy sectors, while in the previous energy plan (1980) the goal setting was generally based on the overall improvements of the energy system. The following introduce the goals of the 1991 energy plan:

- **Industrial sector:** Lund Municipality shall work (or be active) on sufficient energy supply for the industrial sector. Meanwhile, the municipality contributes to efficiency improvements in this energy use dominating sector. The energy use should be limited to around 12 MWh/person/year for both 1995 as well as 2000.

- **Residential sector:** Lund Municipality shall attempt to diminish the residential energy use to 9 MWh/person/year for both 1995 and 2000.

- **Transportation sector:** Lund Municipality shall attempt to control the energy use in the transportation sector not to exceed more than 1989’s level of 6 MWh/person/year.

- **Energy supply:** Lund’s energy supply within its territory shall be safe (secure), effective and environmental friendly.

- **Emissions from energy use:** Lund Municipality shall attempt to control the emissions driven from energy use in the industrial, residential and transportation sectors not to exceed more than the following amounts:

<table>
<thead>
<tr>
<th></th>
<th>1995</th>
<th>2000</th>
</tr>
</thead>
<tbody>
<tr>
<td>SO2 ton/year</td>
<td>480</td>
<td>240</td>
</tr>
<tr>
<td>NOx ton/year</td>
<td>1500</td>
<td>540</td>
</tr>
<tr>
<td>CO2 Kton/year</td>
<td>330</td>
<td>330</td>
</tr>
</tbody>
</table>
In 1991 energy plan, assessment of the environmental impacts of energy use was more advanced compared to the previous energy plan. Explicit future targets were set in order to control SO2, NOx and CO2 emitted from the energy use (Table 5).

<table>
<thead>
<tr>
<th></th>
<th>1989</th>
<th>1995 (expected)</th>
<th>2000 (expected)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SO2</strong> (ton/year)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy Companies</td>
<td>215</td>
<td>110</td>
<td>125</td>
</tr>
<tr>
<td>Transportation</td>
<td>20</td>
<td>20</td>
<td>25</td>
</tr>
<tr>
<td>Others</td>
<td>135</td>
<td>75</td>
<td>35</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>370</td>
<td>205</td>
<td>185</td>
</tr>
<tr>
<td><strong>NOx</strong> (ton/year)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy Companies</td>
<td>125</td>
<td>160</td>
<td>175</td>
</tr>
<tr>
<td>Transportation</td>
<td>1280</td>
<td>1000</td>
<td>760</td>
</tr>
<tr>
<td>Others</td>
<td>115</td>
<td>120</td>
<td>115</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>1520</td>
<td>1280</td>
<td>1050</td>
</tr>
<tr>
<td><strong>CO2</strong> (Kton/year)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy Companies</td>
<td>65</td>
<td>120</td>
<td>125</td>
</tr>
<tr>
<td>Transportation</td>
<td>140</td>
<td>145</td>
<td>150</td>
</tr>
<tr>
<td>Others</td>
<td>115</td>
<td>105</td>
<td>105</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>320</td>
<td>370</td>
<td>380</td>
</tr>
</tbody>
</table>

Table 5- Emissions from Lund’s energy system

Total energy supply increased from 2367 GWh in 1980 to 2400 GWh by around 1 percent while the net used energy was increased from 1715 GWh to 2287 GWh by 25 percent. The 1991 Lund’s energy balance is shown in Figure 7.
Another important improvement of the 1991 plan was adding a chapter entitled “The energy plan implementation”, which was including the instructions, measures and people or departments.
responsible for achieving the planned goals. This measures and instructions were categorized into energy use, energy supply, transportation and emissions from energy use.

4.3. Lund’s energy plan 2001

The last energy plan of Lund was rather different from the previous ones. In fact, it was more like a revision of the 1991 energy plan with some new amendments. The added items to the energy plan were based on the newly approved Swedish energy policy in 1997. Development of ecologically and economically sustainable energy supply mainly through renewable energy resources, as well as improving energy efficiency were the major goals of this new policy (Swedish Parliament, 1996/97:84). Lund’s 2001 energy plan was proposing general statements about more exploitation of renewable energy resources.

Although, the publication date of the energy plan was 2001, there were no up to date information about supply and use of energy within the Lund’s municipality. The sectoral energy balance is not there. It is written in the energy plan that the information about transportation sector is in another document named ‘LundaMaTs’12. This was actually unusual for an energy plan to miss an important part of the energy system which uses about 98 percent of the imported fossil fuel. The data for energy supply and use within both the residential/commercial and industrial sectors are in the energy plan; however, almost all presented data were from 1995.

The future strategies of the 2001 energy plan were formulated mainly based on Lund’s Agenda 21, which was an action plan adopted by the Municipal Council in 1997. These strategies were summarized in three categories:

- **Efficient energy use**: Energy use (for transportation and other purposes) should be reduced at least 25 percent of its 1995 level by 2005.

- **Renewable energy resources and new technologies**: At least 75 percent of energy resources used within the Lund’s municipality should be from renewable energy resources by 2010.

- **Carbon dioxide reduction**: CO2 emissions from the transportation sector should be diminished at least 25 percent from its 1995 level by 2005.

The energy plan was also including measures about the role of the municipality in the implementation of the plan as the local authority, owner (of land, buildings and share holder of the local energy company) as well as energy advisor.

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12 This document is about sustainable transportation in Lund, published by the technical department of Lund’s municipality in 2004. The project has been approved by the board of the municipality in 1996
4-4. Analysis of the local energy plan

Local energy plans and in this study Lund’s energy plan, can be used in order to analyze how much the local energy policies can contribute in pursuing the national energy strategies. Moreover, the results from implementing the local energy plans can specify the effectiveness of the energy policies on improving the local energy system. In this study, the municipality of the city of Lund is chosen for the reason that Lund energy plans are covering the municipal energy planning period from 1977 up to now; therefore, they are appropriate for getting an idea of the effectiveness of the 1977 Swedish municipal energy planning act over the time. It can be seen in all Lund energy plans that local authorities are attempting to follow the national energy policies over the above-mentioned period of time. As a result, shifting from fossil fuels to other energy resources for reducing oil dependency, which was one of the main energy policies of the country, has been successfully done in Lund (Figure 8).

Figure 8- Lund's energy supply by energy source

The 1985 amendment to the act about integration of energy into the municipal master development plan made the 1991 Lund energy plan strategies to be different compared to those in 1980. Lund’s 2001 energy plan is also considering the 1991 amendment to the Municipal Energy Act about assessing the environmental impacts of the energy plan. Although the last energy plan of Lund was not as strong as the previous ones, at least from a methodological planning perspective; however, from an energy policy point of view the national energy policies have been generally considered in the planning process from 1980 up to 2000.

The effectiveness of the energy plan can be analyzed by measuring the achievements to the planned goals. The energy plan’s outcomes can be used as a measure for evaluation of the energy system improvements. In case of Lund’s municipality, it is actually difficult to evaluate the expected results of planned goals since there is no concrete report or information about achievement of the goal. For instance, it is planned in Lund’s 1991 energy plan that the emissions from the energy sector should be reduced in two stages of 1995 and 2000 (Figure 9).
Although, in both the 1991 and 2001 energy plans, a chapter is allocated to describe the achievement of some anticipated goals (not all of them) from the previous energy plan, the overall goal achievement is not clear. According to the Municipality of Lund, almost all the planned goals have been achieved. However, the accuracy of the reported data has not been confirmed since no national agency had been appointed to approve or control the municipal energy plans (Stenlund, 2006). This study does not intend to discuss the accuracy of the energy planning results of the city of Lund while emphasizing the importance of supervision in national policies.

Lack of such controlling levers or supervision strategies have resulted in the existing circumstances of the municipal energy planning act, which still is not considered by 27 percent of the country’s municipalities after more than 30 years.

As it mentioned before, the aim of the Swedish government’s energy policy is to safeguard a reliable energy supply at internationally competitive prices, both in the short and long terms. This energy policy should create conditions for efficient and sustainable energy use, with minimum adverse effect on health, the environment and the climate, as well as assisting transition towards an ecologically sustainable society. Regarding the background of the Swedish municipal energy planning act as well as the country’s future policies, it would be interesting to know how the Swedish government is preparing the basis needed for creation of a sustainable energy system. Sweden’s experience on municipal energy planning act indicates the need for some changes in implementation of the national energy policies. The municipalities still are the key actors towards a national sustainable energy system.
5. Sustainability, a new step for energy planning

Increasing energy prices during 1970s led to the development of energy planning as an instrument for promoting both the community energy management and the stability of the energy systems. Planning for a sustainable energy system became of interest for both energy planners and decision-makers particularly after increasing public awareness by presenting the concept of *Sustainable Development* in 1980s. Technological improvements as well as environmental, social and economical concerns led the energy systems to be more complex. In response to meet this increasing complexity, new approaches introduced by planners and integrated with the conventional energy planning in order to adapt them for the new sustainability paradigm by e.g. increasing the share of renewable energy resources in energy supply systems, focusing on more efficient energy production i.e. co-generation and CHP utilization, etc.

An overview of the conceptual framework of the term “Sustainability” can provide a deeper understanding of the sustainable energy planning process.

5-1. What is sustainability? A background

Sustainability is not a new concept. It can be seen as a desire for stability and permanence of civilizations in the ancient historical records of various cultures around the world. The term in the present context appeared during 1970s, discussing the development of human lifestyle particularly after publishing “*Blueprint of survival*”\(^{13}\) and “*Limits to growth*”\(^{14}\). After The United Nation’s conference on human environment (Stockholm, 1972), which emphasized the need for a common outlook and principles of enhancing the human environment, the sustainability concept has evolved and became a buzz word for both environmentalists and industrialists, with little agreement on the definition (Khator R., 2006).

It became a significant issue among various academic disciplines particularly after the Brundtland Report in 1987. Although, the Brundtland commission did not invent the notion of sustainability, it was the most widely cited source of ‘sustainability’ definitions (Molnar et al., 2001). Following the Brundtland Report, hundreds of research programs started, articles were published and several definitions of sustainability were introduced and applied to almost all human activities. Different people have discussed different visions about the sustainability concept depending on their community background.

Today, sustainability is still applying to many different things because of its broad conceptual framework. For instance, the environmentalists are dealing mostly with the environmental dimensions of sustainability while the businesses have adopted the sustainability terminology in such a way that they can benefit from it as tools for (economic) profit maximization (e.g. efficiency of energy/material use); and saw environmental benefits as a side effect, not the targeted goal (Molnar et al., 2001). “You can’t see sustainability as a premium product; you need to make it something in day to day business” said Shaun McCarthy, chairman of sustainable

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\(^{13}\) by Edward Goldsmith (1972), [http://www.edwardgoldsmith.org/](http://www.edwardgoldsmith.org/)

\(^{14}\) by the Club of Rome (1972), [http://www.clubofrome.org](http://www.clubofrome.org)
London 2012. Different semantics of the sustainability concept has led to conflictive debates on economic (growth), environmental (degradation/protection) and social (poverty/well-being) dimensions of human’s lifestyle development (Lele S., 1991).

5-2. Concepts and definitions

The word ‘sustain’ means to keep in existence, to supply with the necessities, to support from below; keep from falling or sinking and sustainability can be referred to any activity or system which is capable of being continued (The American Heritage Dictionary, fourth edition, 2000). The Merriam-Webster dictionary defines the term sustainability, in use since around 1727, as a method of harvesting or using a resource so that the resource is not depleted or permanently damaged. Although, sustainability is just one word, there are more than hundreds of definitions. Most of them originate from the relationship between humans and the resources they use (Voinov, 1994). According to Pears (2000), sustainability reestablishes a close relationship between the omnipresent human drive to improve our quality of life with the limitations imposed on us by our global context. Pears continuous, sustainability requires unique solutions for improving human welfare that do not come at the cost of degrading the environment or impinging on the well-being of other people. Yet there is no precise agreement on the sustainability definition and people use it in the ways that suit their particular applications (Voinov, 1994). In order to be more familiar with different ideas about the meaning of sustainability, some of its definitions are presented as follow:\n\n- “In general terms, the idea of sustainability is the persistence of certain necessary and desired characteristics of people, their communities and organizations, and the surrounding ecosystem over a very long period of time (indefinately). Achieving progress toward sustainability thus implies maintaining and preferably improving, both human and ecosystem wellbeing, not one at the expense of the other. The idea expresses the interdependence between people and the surrounding world” (Hardi and Zadn, p. 8, 1997)

- “Sustainability refers to the ability of a society, ecosystem, or any such on-going system to continue functioning into the indefinite future without being forced into decline through the exhaustion or overloading of key resources on which that system depends” (Gilman, p. 1, 1992)

- “Sustainability is a vision of the future that provides us with a road map and helps to focus our attention on a set of values and ethical, moral principles by which to guide our actions, as individuals, and in relation to the institutional structures with which we have contact – governmental and non-governmental, work-related, and other” (Viederman, p. 2, 1995)

\n\n15 For more information see: http://www.csllondon.org/
16 There are more than 245 definitions for sustainability here:
http://maven.gtri.gatech.edu/sfi/resources/pdf/definitions.pdf
www.utoronto.ca/envstudy/sustainabletoronto/resources/SustainableTorontoDefinitionsPaper-FinalDraft.doc
(2008-09-28)
The sustainability of ecosystems, future durability and socio-economic stability is undeniably necessary for promoting the quality of human lifestyle; however, it has argued that the concept of sustainability is too indistinct to be applicable in the real world. “Yet of course one has to consider that sustainability is a complex and challenging concept, which is not open to simple technical solutions” (Ulrich Steger et al., p.24, 2005).

Some believe that the environmental sustainability is in contrast with the economical sustainability (economic growth). For instance, Mark Williams believes development at the global level has become unsustainable, largely due to patterns of overconsumption in the advanced industrial countries. He continues “sustainability cannot be managed within a capitalist world economy… due to the values, interests, and power behind the capitalist international division of labour” (Williams, p.4, 1998).

Mitcham (1995), describes the concept of sustainability as “one of those ideals which like love or patriotism, points towards something necessary and even noble, but can also readily become a cliche and be misused by ideologues”… “It is not exactly clear, however, to what extent sustainability has to mean continued growth. The concept entails some studied or creative ambiguity, which is precisely what makes it useful for bridging the gap between no-growth environmentalists and pro-growth developmentalists. In order to explore this ambiguity, it is useful to consider some of the near neighbors of the concept of sustainability and its permutations.” (pp. 1, 7)

Martens (2006) in his explanation of the sustainability concept refers to Richard Feynman’s statement: …“Whoever says that he understands quantum theory, in all probability does not” and Martens continues “Whoever says he knows what “sustainability” is, in all probability does not. In a certain sense, a sustainable world is a fiction”. (p. 5)

Thus, the concept of sustainability is applicable to a broad range of different aspects from natural to social sciences, it is rather appropriate for a positive evolution of human lifestyle and viable living environment. The important thing is how and in what directions the capacities for community development should be improved towards these viable conditions. This study is not aiming to discuss these improvements, and as it is mentioned before, it attempts to provide a broader view to the concept of sustainability which can assist to find more appropriate ways for transition towards sustainable energy systems. However, this transition would be a difficult task due to the ambiguity of the concept of sustainability. Attempting to find a comprehensive definition for sustainability seems to be quite vain since there are too many aspects rising from the particular applications and implementations of the term (Voinov, 1994). Instead, it might be more helpful if we try to develop the conditions which help to achieve sustainability. These

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17 http://www.isis.unimaas.nl/personal/pim.html
18 one of the greatest physicists of the last century,(1918-1988), for more information see http://www.britannica.com/eb/article-9034161/Richard-P-Feynman
conditions can be developed by establishment of rational connections between different sustainability dimensions.

5-3. Dimensions of sustainability

The general concept of sustainability deals with the relationship between human activities and the living environment. These activities, with the aim of developing the human well being, affect the natural environment. Sustainability is actually a balancing act between the social, environmental and economic dimensions of human needs. These balanced dimensions are constantly changing as a consequence of growing human population and their needs. Therefore, since the dimensions of sustainability are not independent of one another, the ever balancing act of sustainability makes it a dynamic concept rather than a static state (Pears, 2000). The dynamic characteristic of sustainability requires decision makers to be flexible in their approaches according to changes in the human needs and desire, environment or technological advances (ibid). Hence, a new important dimension which is good to be added to sustainability is the institutional dimension. Managing the necessary policies in an ever changing living environment requires strong institutional arrangements towards a dynamic balance of sustainable development. The schematic relationship between the four dimensions of sustainability corresponding to ecological/environmental, social, economical and institutional is shown in Figure 10.

![Figure 10- Schematic balance of sustainability dimensions](image)

Every society can be described as comprising the economical, social, environmental and institutional dimensions (Spangenberg, 2005). For any society to be sustainable, each of these dimensions has to maintain its potential to survive and develop, while stay balanced with the other dimensions.
5-3-1. Environmental dimension

The natural environment is the context that any human being is depending on for its existence. The ecological systems of the earth provide us both with the necessary resources of life (food, energy, raw material...) as well as the natural recycling system to absorb the residual material. The sustainability of the earth’s natural environment is vital for the human being. The natural environment is the physical context within which we live, and sustainability requires that we recognize the limits of this environment (Pears, 2000).

There are two important issues regarding the environmental sustainability. The first one is that the available natural resources of the earth are limited. Some of them such as trees and wildlife can be regenerated in a shorter time compared to minerals, soil and fossil fuels. The environmental sustainability depends on protecting resources and conserving biological diversity (Pears, 2000). Therefore, achieving the environmental sustainability requires a rational use of our natural resources. The second key environmental issue is the protection of the ecosystem by minimizing the negative impacts of our activities on it. The natural ecosystem may recover from some small impacts; however, the larger ones can harm the ecosystem health. Environmental pollutions, natural resource degradation and loss of biodiversity affect the ecosystem health by increasing the ecological vulnerability.

The ecological dimension of sustainability focuses on natural biological processes, ecosystem’s health and functionality as well as continuous productivity with minimum environmental impacts.

5-3-2. Economic dimension

Economics, as a social science, is important for a sustainable community since it deals with a broad range of human activities such as production, distribution and use of commodities and services (Pears, 2000). These activities are depending on both finite and renewable natural resources. Exploitation of raw material, transportation and use of products may have negative impacts on the environment. According to the United Nation’s (WCED)\textsuperscript{19} explanation of sustainable development, every generation should use the natural resources in such a way that the future generation may be able to meet their needs. From an economic point of view, some believe that this approach may not be the ultimate method for a sustainable development. Solow (1993) defines sustainable development “as an obligation to conduct ourselves so that we leave to the future the option or the capacity to be as well off as we are”, (p. 181). Solow believes that since resources are fungible in certain sense, goods and services can be substituted for one another. Moreover, Solow says we do not know about the technology that will be available to the future generation and what resources they will require. Therefore, he believes we do not owe any particular thing to the future generation. He defines sustainability as sharing of well being between present people and future people, and in other words, it is about distributional equity.

\textsuperscript{19} World Commission on Environment and Development
Another perspective on economic sustainability is the discussion about the limitation of the natural capital which prevents an efficient substitution of goods and services. Herman Daly (1992) believes that fungibility and substitutability is not a true picture of the real world since productivity of manmade capital can be affected by the decreasing supply of complementary natural capital. In other words, although one resource can substitute for another, the substitution process cannot be perfect since both are raw materials undergoing transformation into a product and both play the same qualitative role in production.

In addition to the environmental aspects, the social aspects should be addressed in an economically sustainable society. An economically meaningful definition of sustainability should focus on sustaining well-being or utility (Weitzman, 2003). Sustainability as an overall guideline for economic development should be based on generalized well-being and equivalent utilities (ibid).

5-3-3. Social dimension

There are many components and principles needed for a society to function and be sustainable. Meeting the basic needs of all groups in the society is one of the most fundamental aspects of equity (Baines et al. 2005). A socially sustainable community must have the ability to maintain and build on its own resources and have the resiliency to prevent and/or address problems in the future (Gates et al., 2005). Resources that are required to build a sustainable society are mainly from individual or human capital and social capital. Individual capitals such as health, education, skills, values and leadership can contribute to their own well-being (and to the well-being of the society as a whole) while, the social capital is including services, networks, relationships and norms that facilitate cooperation towards improving the quality of life (ibid). Goodland (2002) believes the creation and maintenance of social capital, as needed for social sustainability, is not yet adequately recognized. He continues social, sometimes called moral, capital requires maintenance and replenishment by shared values, equal rights and cultural interactions which are essential for social sustainability.

According to Gates et al. (2005), social sustainability can be made up of the following guiding principles:

1. “Equity – when individuals have access to sufficient resources to participate fully in their community and have opportunities for personal development and advancement and there is a fair distribution of resources among communities to facilitate full participation and collaboration. Inequities can be minimized by recognizing that individuals and groups require differing levels of support in order to flourish, and that some individuals and groups are capable of contributing more than others to address disparities and promote fairness of distribution. Lower levels of disparity in societies result in longer life expectancies, less homicides and crime, stronger patterns of civic engagement and more robust economic vitality.
2. *Social inclusion and interaction* – both the right and the opportunity to participate in and enjoy all aspects of community life and interact with other community members; where the environment enables individuals to celebrate their diversity and react and act on their responsibilities. Social exclusion limits the levels of involvement and impedes optimal healthy development of individuals and the community as a whole.

3. *Security* - individuals and communities have economic security and have confidence that they live in safe, supportive and healthy environments. People need to feel safe and secure in order to contribute fully to their own well being or engage fully in community life.

4. *Adaptability* – resiliency for both individuals and communities and the ability to respond appropriately and creatively to change. Adaptability is a process of building upon what already exists, and learning from and building upon experiences from both within and outside the community”.

5-3-4. Institutional dimension

Institutions are defined as “commonly devised constraints that shape human interactions. In consequence they structure incentives in human exchange, whether political, social, or economic. Institutional change shapes the way societies evolve through time and hence is the key to understanding historical change” (North, p. 69, 1999). Accordingly, institutional sustainability can be identified from political, social and economic perspectives.

The political science approach to the institutional sustainability focuses on the politically relevant aspects of the role of organizations, decision-making processes and orientations, as well as their impacts and consequences (Spangenberg et al., 2002). This approach, in fact, assists the global development in a sustainable manner. Based on this, institutions can be defined as structured rules for political decision making and implementation, which have to take aspects of sustainable development into consideration (ibid). Institutions are including both people as actors and systems of rules that shaping the social behaviors. According to Goldsmith et al. (2002), institutions as politically relevant social rules can be subdivided into institutional orientations (societal norms), institutional mechanisms (procedures, legal norms) and organizations. He continues that institutions can assist the decision making process, serve a range of implicit and explicit goals of the sustainability paradigm, and/or they facilitate the implementation of such political decisions.

The social perspective of institutional sustainability is dealing with impacts and effects of institutions on social relationships and how they can change the behavior of actors. From a sociological point of view institutions on the one hand are influenced by actors and their activities, and on the other hand, they also considerably influence actors by shaping their interests and behavior (March and Olsen, 1984). There is a mutual relationship between institutions and actors in such a way that social values can shape institutional structures and as a response,
institutional values appear as a measure for rational evaluation of actors. Consequently, institutions act as an entity between actors and structures, [to] creating new value orientations or reference points, which influence actors and their behavior (Spangenberg et al., 2002).

From an economic point of view, institutional sustainability can be defined as “the ability of an organization to produce outputs of sufficient value so that it acquires enough inputs to continue production at a steady or growing rate” (Goldsmith et al., 1992). This definition underlines the dynamic character of institutional sustainability as an ongoing input-output process (ibid). Stable institutions are playing an important role in the cost-benefit assessment of actors since they can contribute to lower transaction costs by creating security (Spangenberg et al., 2002). Moreover, institutional reliability reduces uncertainty in the decision making process which consequently enable actors to take faster and cheaper decisions.
6. Sustainable energy planning

Increasing energy prices during 1970s led to increasing use of energy planning as an instrument for promoting community energy management. Planning for a sustainable energy system became of interest for both energy planners and decision-makers particularly after increasing public awareness by presenting the concept of Sustainable Development in 1980s. Technological improvements as well as environmental, social and economical concerns led the energy systems to be more complex. In response to meet this increasing complexity, new methods introduced by planners and integrated with the conventional energy planning in order to adapt them for the new sustainability paradigm by e.g. increasing the share of renewable energy resources in energy supply systems, focusing on more efficient energy production i.e. co-generation and CHP utilization, etc.

Several mathematical models such as Multiple Criteria Decision Aid (MCDA), Preference Ratio In Multiattribute Evaluation (PRIME) have been developed to facilitate the decision making process through a complex energy system. These comprehensive optimization models are useful for making a complete picture of all energy flows and energy conversions within a well-defined energy system. Wene (1988) emphasizes the need for a comprehensive model of the community energy system from a “rational” planning point of view. However, he argues that “a model can be a technical success but still fail to make any impact on the planning process” (p.213). Wene points at technical issues (substantive) and the procedural aspects of planning which may give raise to conflicts in the actual process of planning. He believes although comprehensive mathematical models are useful for solving technical (substantive) problems of an energy system; they fail to cope with the procedural aspects of planning for energy systems since they do not belong to a unique system. The community energy system consists of many subsystems e.g. electricity, district heating, fuels, etc. with different managements and organizations which makes it difficult for a comprehensive energy model to fit in (ibid). Yet, no mathematical model is presented with the capability of integrating technical issues with organizational aspects of the planning process. Biswas (1990) argues that models are only applicable for what can be modeled (i.e. the quantifiable aspects), implying that qualitative aspects such as people behavior cannot be taken into account. Van Beeck (2003) states that many social and environmental aspects of energy systems, albeit well known, are not incorporated in models since they cannot be quantified in a satisfactory manner. Van Beeck continues that capturing every aspects of reality in a model is impossible, “At best, models provide a (highly) simplified representation of parts of reality” (p.23).

Although, the models may assist to make proper decisions, they cannot determine what decision is ‘good’ or ‘best’ and in fact the model users (decision makers) ultimately determine what the ‘best’ option is (ibid). Biswas and Van Beeck argue that context-related issues are neglected in the decision support models in general and energy models in particular. They believe most models mainly are focusing on financial and technical aspects and are not designed to include the interest of actors other than investors. In reality, the key actors in decision making are different parties involved in the decision process that have their own objectives and interests, and normally, decisions are some compromise (Thörnqvist 1975, Arrow et al. 1996, Van Groenendaal 1998).
Therefore, focusing only on the (financial) interests of investors can easily lead to exclusion of the other actors’ interests, or, at the other end, rejection of the model itself.

The comprehensive planning models may be used as an instrument to meet the technical complexity of energy systems. However, in reality, energy strategies are set within a network of public authorities, energy companies and the other related stakeholders. Each member of this network as a subsystem of the community energy system has its well-established organization, management and adequate experience of how to run the subsystem and how to act in relation to or against influences from the other subsystems (Wene, 1988).

Decisions upon the future energy strategies are normally taken through these organizations which Beer (1975) has called ‘Esoteric boxes’. Beer describes the esoteric boxes as a strongly robust subsystem which is in equilibrium with the surrounding environment and the other subsystems. The actual management of the community energy system occurs through the network of esoteric boxes (Wene, 1988). The community energy system can be influenced by political decisions but only throughout the workings of one or more of the esoteric boxes (ibid).

Appropriate relationship and functioning of the network of esoteric boxes is among important factors for stability of the energy system. Other factors which can influence the stability of an energy system are energy markets, useful energy demand, energy technology and natural environment. Hence, the community energy system should be considered as an open system which consists of three main components:

- Technical systems
- Energy management
- System relations (both internally and with its environment)

Stability (and/or sustainability) of the community energy system can only be achieved by balancing the above mentioned components. Although, it is a hard task to do, as a matter of fact it can be done through the planning process. This process is not just based on mathematical models; in fact, it is including a set of functions dealing with different aspects related to community energy systems such as environmental, social, institutional, etc. The planning group may choose different planning methodologies depending on dominant circumstances. However, the fundamental theme for the planning process is to keep the community energy system stable and balanced. In other words, the planning committee attempts to benefit from all available instruments, policies and resources towards a sustainable energy system. The planning process aims to integrate energy with environmental, social, economical and institutional dimensions of sustainable development. This is what we call Sustainable Energy Planning.

Figure 11 presents a schematic diagram based on what we defined as a sustainable energy planning methodology. The diagram indicates the role of the planning process in relation to three different components of the community energy system. It should be mentioned that the energy management in this diagram is not a unique subsystem and actually consists of the network of esoteric boxes mentioned before.
6-1. Characteristics of a sustainable energy plan
The first thing that comes in mind when we talk about sustainable energy planning is to ask what makes it different from the conventional (traditional) energy planning methods. A brief overview of the weaknesses of traditional planning methods can assist to better understand what characteristics a sustainable energy plan should have.

As it is mentioned in chapter 3, conventional energy planning methods were generally focusing on energy supply and use within the community, ending with a scenario or a pattern for meeting the future energy needs. They did not deal with the other aspects related to the energy system such as social or economical issues. In fact, they did not follow up conflicts caused by or related to the community energy system.

The other weak point of the conventional energy planning methods was that they were very sensitive to changes in the surrounding environment. In other words, they easily could be influenced by e.g. energy markets, political system and new technologies. For instance, the increasing energy prices in 1973 changed almost all the calculations in the then quite new energy plan of the city of Malmö. The most important reason for such planning failures was lack of a perspective on a proper relationship between the community energy system and the other systems or subsystems. Traditional energy plans were not considering the community energy system as an open system with connections to the other systems or the surrounding environment.
Another limitation of the traditional energy planning methods was their short time perspective which normally was between 10 to 15 years. Thörnqvist (1980) argues an energy plan should naturally have a long-term planning horizon since the community energy infrastructure such as district heating systems, natural gas pipelines and energy distribution facilities can technically be in service for up to 30 years (p. 21). Although, issues such as new energy supply systems and/or changes in energy use patterns of the community may not possibly be discussed in detail in a long-term perspective, the community energy plan should be prepared and be able to present the future strategies for such changes (ibid). The flexibility of a long-term energy plan can assure the robust development of the community energy system in case of upcoming changes. Given that the community energy systems are open and dynamic systems, they can always be influenced by upcoming changes. For instance, technological and institutional changes can certainly affect the planned goals. An energy plan cannot be sustainable unless it is prepared to cope with the future changes and improvements. From a technical point of view, the community energy infrastructure has better to be planned in such a way that it can be useable (continue to serve) in case of future technological improvements. Although, it may cause more capital investment today, it can prevent a complete re-construction of the community energy infrastructure which may cost much more in the future. The political and organizational changes can also affect the planned goals by changes in decision making process or institutional structures. Therefore, the sustainable energy planning should be adaptable to changes for being a continuous process.

In contrast, the sustainable energy planning has a long term perspective which can be described as: Planning for the present energy needs without compromising the ability of future generations to meet their needs. The need of next generation is actually the basic axis for a long term Sustainable Energy Planning (SEP). The sustainability dimensions as important elements in association with this basic axis are forming the conceptual framework of SEP. To be sustainable, the SEP framework should avoid the above mentioned limitation of the conventional energy planning methods and moreover, should be equipped with robust characteristics needed for making a durable community energy system. These characteristics are the key components of SEP which we call sustainable qualities of the community energy system, and can be identified as:

- Integration of energy with conflicitive environmental, economical, social, institutional dimensions of the society
- Implementation of robust development
- Flexibility for upcoming changes
- Long term planning perspectives

An important issue that should be considered in sustainable energy planning is its functional range from a geographical point of view. A community in national, regional and/or local level is normally recognized by a geographical boundary, and its territory including built up areas (cities and towns) and none built areas such as farms, forests, lakes, etc. Almost all existing municipal energy plans are focusing on the energy systems within built up areas. In Sweden, built up lands which consists of cities, towns, industries, land used for transportation, commercial and technical installations, are only 3 percent of total country’s land areas Figure 12 (Statistics Sweden, 2000).
Energy related issues of the none-built areas are poorly considered in the municipal energy planning. These areas contribute in the municipal energy system (supply and demand) as well as emissions driven from energy use. The actual energy demand for agricultural, horticultural, forestry and fishing activities are not stated in the existing municipal energy plans. It is important to know the future energy outlook within these activities. Energy efficiency within these areas is another important issue, which can improve the quality of local energy systems.

Scattered energy users in these areas lead to utilization of wider energy distribution networks (e.g. electricity grid, natural gas pipeline) and longer distances of energy transportation which consequently impose higher energy expenditure. Buildings within these areas can not benefit from district heating systems for space heating and hot water use; therefore, they need to use electricity, fossil fuels or even biomass for heating purposes.

Non-built areas are not restricted compared to cities and towns and from a physical planning perspective they are more suitable for installation and using micro power generation equipments. Micropower technologies such as micro turbines (powered by wind or naturally flowing water), ground source heat pumps, solar powered technologies (both photovoltaic and solar thermal systems) and micro-Combined Heat and Power (micro-CHP) are for production of energy on the smallest scales which emit low amounts of carbon dioxide, or in some cases, no carbon dioxide at all.

![Figure 12- Land use by sector in Sweden (1000 km2)](image)

From an energy planning point of view, none built areas are more suitable for utilization of renewable energy resources, which can play an important role in promoting the sustainability of local energy system. Today, the environmental impact assessment in the existing municipal energy plans is limited to measuring emissions (CO2, SO2, NOx) driven from energy use within densely populated areas. This environmental assessment can be more accurate by considering the
contribution of non built areas in environmental impacts driven from energy use; and consequently, it can provide both the energy planners and the decision-makers with a better picture of the local energy system which can be more effective in setting the future energy/environmental strategies.

6-2. Sustainable energy planning at local level

The conceptual framework of sustainable energy planning as well as its characteristics are now clear and can be applicable for national, regional and local levels. Although, the methodological approach is almost the same for all levels, application of some elements may be different. For instance, GDP can be used for assessing the economic dimension of energy planning process at national level; however, it may not be as useful at the local level.

In this section, the sustainability of Lund’s energy plans as an example of local energy planning is assessed by application of the above mentioned characteristics of SEP. For this purpose, a comparative analysis of Lund’s three energy plans is done in order to facilitate a better understanding of the SEP methodological approach at the local level.

All Lund’s energy plans have short-time perspectives. The 1980 and 1991 energy plans have been considered for a range of 10 years and the last one (2001) has the actual time range of 5 years. One may say since all of them were planned for Lund’s energy system, it can be considered to represent a continuous planning process, and consequently, they are outcomes of a sustainable energy planning. However, the comparative analysis indicates that the plans are rather different in some cases (Table 6).

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* Energy planning for none built areas
** The transportation sector is not included

Table 6- Comparative analysis of Lund’s energy plans (1980, 1991, and 2001)
The analysis results indicates that the 1980 and 1991 energy plans are much more related compared to the one from 2001. In other words, one can observe an overall picture of the local energy system improvements from plan No.1 to plan No.2, however, not in plan No.3 which indicates some sort of discontinuity in the planning process.

The main reason identified for this problem may be the institutional changes throughout the planning process. In 1980, almost everything related to the community energy system were controlled by the government. The energy policy making, energy companies, distribution network and energy plan implementation was under the responsibility of a unique organization which was the municipality (local government). In 1996, the municipal organization changed and several new departments with their own managing boards were established. These departments were (and still are) responsible for different activities such as technical, environmental and urban planning; however, their internal collaboration (within the municipality) seem to be not sufficiently effective because of these organizational changes. Moreover, deregulation of the energy markets during 1990’s has resulted in diminishing the dominant power of local governments on controlling some parts of the community energy system such as energy companies, energy supply and distribution. Decreasing the quality of inter-organizational communications within the local government together with energy market deregulation seem to be significant reasons for diminishing the effectiveness of energy planning.

The comparative analysis reveals the fact that the conventional methods of Lund’s energy planning were not sustainable. Although, the energy plan implementation has led to some significant technical and environmental developments within the local energy system, the overall planning process was not sustainable since it is almost stopped from 2005.
7. Conclusion
The conventional methods of community energy planning are not appropriate for achieving the sustainable development goals so far. Restructuring of the energy sector and deregulation of energy markets are among the challenges that existing community energy planning methods fail to address. Moreover, these methods poorly discuss the important energy related aspects of environmental, social and economic dimensions, which are necessary for the community development in a sustainable manner.

The new sustainability paradigm makes the community energy systems more complex. Hence, creation and utilization of new planning methods requires a better understanding of what sustainability means. The conceptual framework of sustainable development is in fact too broad to form a certain definition for the term Sustainability. Instead, it might be more convenient if we try to develop the conditions which help to achieve sustainability. It is shown in this study that it is essential for the new energy planning approaches to consider the three main components of a community energy system i.e. technical system, energy management and system relations. The planning process can be sustainable only by continues balancing of the sustainability dimensions that are:

- Environmental
- Economic
- Social
- Institutional

This study has not aimed to formulate a new and unique community energy planning model since different communities use different planning methods. Instead, it aimed to clarify the overall characteristics needed for any planning methodology to be more sustainable.

A sustainable energy plan is not just a plan; it is a continuous improvement process and a useful tool in hands of decision-makers for transitions towards a sustainable society. The significant characteristics of a sustainable energy planning which makes it different from conventional energy planning methods include the following:

- Its comprehensiveness in integrating environmental social and economic aspects with energy systems
- Involvement of the community stakeholders (actors) in both the energy planning process and its implementation
- It is a long-term continuous improvement process
- It is not focusing just on urban areas
- It must be prepared for new forthcoming technologies
- It must be prepared for re-structuring of the energy system
8. Future work

It will be interesting to identify the above-mentioned sustainability conditions for community energy system at the local level. Development of these conditions and keeping them alive will assist transition towards sustainable energy systems. Recent publications\(^\text{20}\) have emphasized the importance of this transition by pointing out the existing challenges such as scarce resources, environmental constraints and political instability. Overcoming these challenges is, in fact, among the main issues of sustainable energy planning. Therefore, the next step for this study is to identify how energy planning can assist the transition towards more sustainable energy systems.

Regarding the fact that energy is central for a sustainable society, a continuous energy planning process together with regular evaluation of the sustainability conditions seems to be necessary. A scientific approach for this evaluation is based on *Energy Indicators for sustainable development* presented by the International Atomic Energy Agency (IAEA) in 2005. The existing energy indicators are generally defined for use at the national level. The future work for this study is to examine the applicability of these indicators at local level. According to investigations through the existing literature, it seems that energy indicators have not been used at local level yet. Therefore, the future work of this study can be summarized as follow:

- Modification of the existing energy indicators and/or creating new indicators (if necessary) that are appropriate for use at the local level
- Evaluation of the sustainability of Lund’s energy system as a case study (indicator validation)
- Presentation of a new pattern of energy indicators for a sustainable development at the local level

\(^{20}\) Analyzing the challenges and tools with respect to transition towards a sustainable energy supply system by Fouquet and Johansson (2008), identification of the barriers to accelerating the transition to sustainable energy systems by Jefferson (2008) and investigation on a ‘transition model’ by Kern and Smith (2008) are some examples. More articles can be found in a special issue of *Energy Policy* (Vol. 36, Issue 11, pp. 4009-4298, November 2008) which is focused on ‘Transition towards Sustainable Energy Systems’.
9. References


Bergman Lars (2001), The economics of Swedish energy policy; in “Building sustainable energy systems”, Silveria Semida (editor), Svensk Byggtjänst and Swedish national energy administrarion, ISBN 91-7332-961-4


Cormio C., Dicorato M., Minoia A. and Trovato M.(2003), A regional energy planning methodology including renewable energy sources and environmental constraints, Renewable and Sustainable Energy Reviews, No. 7, pp. 99-130


Donella H. Meadows, et al. (1972), Limits to Growth, A Report to The Club of Rome


Energiläget i siffror ( Energy in Sweden – Facts and Figures), (2007), Energimyndighetten (Swedish Energy Agency)

Energiplan, Lunds Kommun, (Energy plan of Lund Municipality), 1980
**Energiplan, Lunds Kommun**, (Energy plan of Lund Municipality), 1991

**Energiplan, Lunds Kommun**, (Energy plan of Lund Municipality), 2001


44


Kahen Goel (1995), *Integrating Energy Planning and Techno-Economic Development: A Solid Basis for the Assessment and Transfer of Energy Technology to Developing Countries*, Imperial College, University of London

Kaijser Arne (2001), *From tile stoves to nuclear plants – the history of Swedish energy systems*, in “Building sustainable energy systems”, Silveria Semida (editor), Svensk Byggtjänst and Swedish national energy administration, ISBN 91-7332-961-4


Laitner J.A., DeCanio S.J., Koomey J.G., Sanstad A. H. (2003), *Room for improvement: increasing the value of energy modeling for policy analysis*, Utilities Policy, No.11, pp. 87-94


Molnar Daniella et al. (2001), *Defining Sustainability, Sustainable Development and Sustainable Communities: A working paper for the Sustainable Toronto Project*, The Sustainable Toronto Project


Olerup Brita (2000), *Scale and scope in municipal energy planning in Sweden*, Journal of environmental planning and management, 43(2)


Solow Robert M. (1993), *Sustainability: An Economist’s Perspective*, Massachusetts Institute of Technology


Statistics Sweden (*Statistiska centralbyråns*), http://www.scb.se/


Thörnqvist Lennart (1975), *Energihushållning I tätbygd - planeringsmetodik*, (Energy economy for urban areas – planning methodology), Lund University

Thörnqvist Lennart (1980), *Kommunal Planering* in “Det Oljelösa samhället (the oil-free society)”


