

*McCormick, K. & Kåberger, T. (2005) An Innovative Bioenergy System in Action. Proceedings of the International Conference on Environmental Protection is a Must, 3 to 5 May 2005, Alexandria, Egypt.*

## **An Innovative Bioenergy System In Action**

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### **Abstract**

After the oil crises in the 1970s, the local government in the town of Enköping in Sweden was cautioned by the local Swedish military regiment to shift towards domestic energy supplies rather than imported fossil fuels. During the 1980s the local energy companies investigated opportunities in bioenergy. In the 1990s the local energy companies and local government developed an innovative bioenergy system. The purpose of this paper is to explore the bioenergy system in Enköping as an example of success. This paper begins with definitions for biofuels, biomass, and bioenergy; outlines the methods and research process; describes the development of the bioenergy system in Enköping focusing on biofuel resources, supply systems, conversion technologies, and energy demands; and concludes with findings from the research process.

### **Keywords**

Bioenergy, Renewable Energy, Sustainable Development

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## **Introduction**

Bioenergy improves energy security, combats climate change, and promotes sustainable development. However, there are few countries where bioenergy makes a significant contribution to energy supplies. Sweden is an exception. In 2003 bioenergy contributed 105 TWh (378 PJ) or approximately 20 percent of primary energy in Sweden. In the short-term, the Swedish Energy Agency estimates the potential of bioenergy in 2010 at 160 TWh (576 PJ) or 26 percent of primary energy [1]. The Swedish Bioenergy Association argues that the potential is 220 TWh (792 PJ) in the long-term [2].

In order to expand understanding of bioenergy it is helpful to learn from an example of success. The town of Enköping in Sweden has an innovative bioenergy system. In 1994 a CHP Plant was established based entirely on biofuels. In 1997 the remaining oil boiler was converted to use wood powder, and in 2003 it was replaced by a new technology combusting crushed pellets. Bioenergy provides all heat demand for the district heating system in Enköping and 'green' electricity to the Nord Pool market, which includes Sweden, Norway, Denmark, and Finland.

## **Definitions**

In this paper the term biofuels is defined according to the Swedish standard as solid, liquid, and gaseous fuels based on biomass [2]. The fuel may have passed through a chemical or biological process or transformation and may also have a preceding use. The term biomass is defined as material with biological origin, which has avoided chemical or biological transformation, at least to a significant extent [2]. There are 5 categories for biofuels, including forestry fuels, black liquor, agricultural fuels, wastes, and in Sweden, peat fuels. However, peat fuels only contribute a marginal amount of biofuels in Sweden. Municipal solid waste is incorporated under wastes.

Forestry materials, such as felling residues, cuttings, bark, chips, and black liquor, dominate biofuels in Sweden (see figure 1). Agricultural materials, such as energy crops, present possibilities for biomass production [3]. The most prominent energy crops are salix plantations, which provide yields for up to 30 years with harvesting every 3 to 4 years [4]. The term bioenergy is defined simply as energy (heat, electricity, and fuels for transport) from biofuels. However, developing and expanding bioenergy requires an understanding of systems. Bioenergy systems comprise biofuel resources, supply systems, conversion technologies, and energy demands [5].

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### **Methods**

The research process was framed through the case study approach, which is founded on the assumption that understanding context as well as details is important [6]. The case study approach offers multiple perspectives by considering the voice of many individuals and the strategies of organisations [7]. The methods employed in the research process included the collection of primary and secondary data through a literature review, interviews, and site visits. The combination of different methods formed the foundations of the case study approach.

### **Description**

In the early 1970s the town of Enköping in Sweden constructed a district heating system (see figure 2). The local government operated oil boilers to satisfy the heat demands. However, concerns regarding energy security surfaced when the local Swedish military regiment approached the local government about imported fossil fuels and the need for domestic energy supplies. Bioenergy was suggested as presenting opportunities for development. *Enköpings Värmeverk* was started in 1972 by the local government and in 1979 woodchip boilers were constructed and experimentation with biofuels continued through the 1980s, building up knowledge and skills in the local energy companies [9].

In the 1990s the local government realised that heat production for the town needed improving, primarily because Enköping was growing towards 20,000 residents [9]. With the town situated close to lake Mälaren and nearby Stockholm, the expression “the most central town in Sweden” comes from the fact that over 30 percent of the Swedish population lives within a radius of 120 kilometres from Enköping [9]. In conjunction with the need for electricity and heat were concerns over climate change and energy security. Renewable energy was discussed as a solution to these problems and bioenergy emerged as the most promising alternative for Enköping.

During the 1990s market conditions for bioenergy were improved when the Swedish government imposed taxation on the emission of carbon dioxide from the combustion of fossil fuels to produce heat, commonly known as the carbon tax [10,11]. The carbon tax only applies to heat and not electricity. The carbon tax affected district heating systems encouraging the switch from fossil fuels to biofuels. In 1994 a CHP Plant was established in Enköping and commissioned to use only biofuels. *ENA Kraft* was created to operate the CHP Plant, which was established by *Enköpings Värmeverk* and *Mälarenenergi*. *ENA Kraft* delivered heat to Enköping and electricity to the

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neighbouring town of Västerås. *Enköpings Värmeverk* since gained control of the CHP Plant and *ENA Kraft*.

The CHP Plant launched the shift towards an innovative bioenergy system. The capacity of the CHP plant is 45 MW of heat and 24 MW of electricity [11]. The CHP Plant supplies 85 percent of the heat demand in Enköping, primarily for the district heating system, which is connected to nearly all the buildings in the town [11]. The 'green' electricity is for sale on the Nord Pool market, which includes Sweden, Norway, Denmark, and Finland.

In 1997 an oil boiler in Enköping was converted to use wood powder, and then in 2003 it was replaced with a new technology combusting crushed pellets, which resulted in all heat production for the district heating system originating from bioenergy. When the CHP Plant was developed in the town of Enköping many energy companies around Sweden used a combination of fossil fuels and biofuels in CHP Plants. Oil boilers were commonly used to supplement CHP Plants. However, the local energy companies in Enköping decided to completely avoid fossil fuels and make commitments to exploiting opportunities in bioenergy.

The CHP Plant operates during the colder parts of the year. The CHP Plant supplies 85 percent of the heat demand in Enköping. A variety of biofuels are used in the CHP Plant, including bark, sawdust, salix, woodchips, pellets, and methane gas (see figure 3). The boiler converted to use wood powder, which was replaced by a new technology combusting crushed pellets, supplies 15 percent of the heat demand in Enköping and generally operates during the warmer parts of the year [12].

*Naturbränsle* manages and delivers biofuels from forestry in Sweden. The initial stages of developing bioenergy in Enköping required the services and experience of *Naturbränsle*. However, a diversity of biofuels was needed for the expanding bioenergy system. The risks of price fluctuations on biofuels from forestry in the surrounding region encouraged the local government and local energy companies to explore agricultural options. Energy crops were examined and partnerships formed with *Agrobränsle* and the Swedish University of Agricultural Sciences. *Agrobränsle* develops, plants, harvests, and markets salix in Sweden, while the Swedish University of Agricultural Sciences conducts research on salix and provided an independent perspective on activities in Enköping.

The local government and local energy companies initiated a project to develop salix plantations. The objective of the project was to establish 1000

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ha by 2010 [13]. There was little interest from farmers at the beginning of the project. The project set several goals, including transport distance should be less than 20 km from the CHP Plant, salix plantations should be more than 10 ha, and a mixture of bottom ash from the CHP Plant and digested sludge from the Waste Water Treatment Facility should be used as fertiliser (see figure 4). The fertiliser is delivered free of charge to salix farmers. The fertiliser makes the energy crops grow faster. There are 196 ha of salix plantations resulting from the project so far [13].

A spin-off project involving waste water irrigation of nearby salix plantations was unexpected. To fulfil the Baltic Sea Agreement, which requires each local government in Sweden reducing nitrogen leakage to the Baltic Sea by 50 percent, the local government in Enköping decided to use the nitrogen rich water from the Waste Water Treatment Facility on the salix plantations [13]. The Waste Water Treatment Facility financed the irrigation pipes, and the salix farmer entered into an agreement with the local energy companies to provide biofuels. Put simply, the production of energy crops in Enköping combined with the waste water irrigation offers an attractive scenario for all these actors [13].

### **Conclusions**

Concerns expressed by the local Swedish military regiment in the 1970s sparked learning and experimenting with bioenergy in the town of Enköping in Sweden. In the 1990s the local government and local energy companies invested in a CHP Plant based entirely on biofuels and a boiler utilising wood powder, which was replaced by a new technology combusting crushed pellets.

Agricultural options for biofuel resources are important in Enköping. The development of energy crops in Enköping to supplement biofuels from forestry provides more control for the local government and local energy companies over the supply of biofuel resources and price fluctuations.

Transporting and handling are important issues for biofuels. In Enköping energy crops are established near the CHP Plant to reduce transportation costs. The role of *Naturbränsle* in supply systems for biofuels from forestry facilitates bioenergy systems in Sweden.

The experience and competences with biofuels and conversion technologies developed by the local energy companies in Enköping since the 1970s encouraged the investment by the local government in the CHP Plant, the

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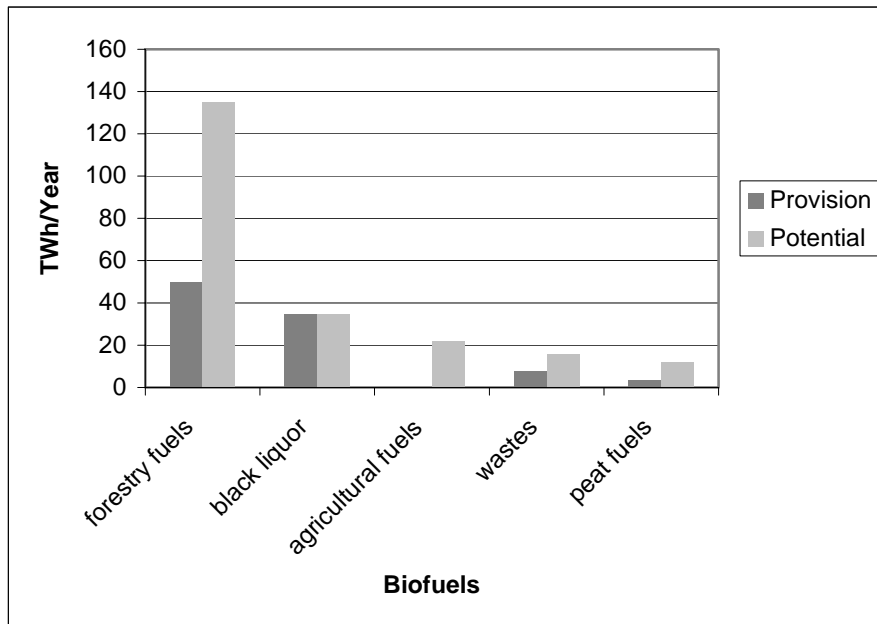
boiler utilising wood powder, and a new technology combusting crushed pellets.

The extensive district heating system in Enköping (widespread in Sweden) provides a demand for heat along with the growing demand for electricity. Furthermore, concerns over energy security and climate change are shifting attention to renewable energy. The investment in bioenergy in Enköping was therefore supported on several fronts.

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**Figure 1: Provision and Potential of Bioenergy in Sweden in 2001 [2]**

This figure depicts the provision and potential of bioenergy in Sweden, as estimated in 2001. Agricultural fuels include salix, and wastes include municipal solid waste.

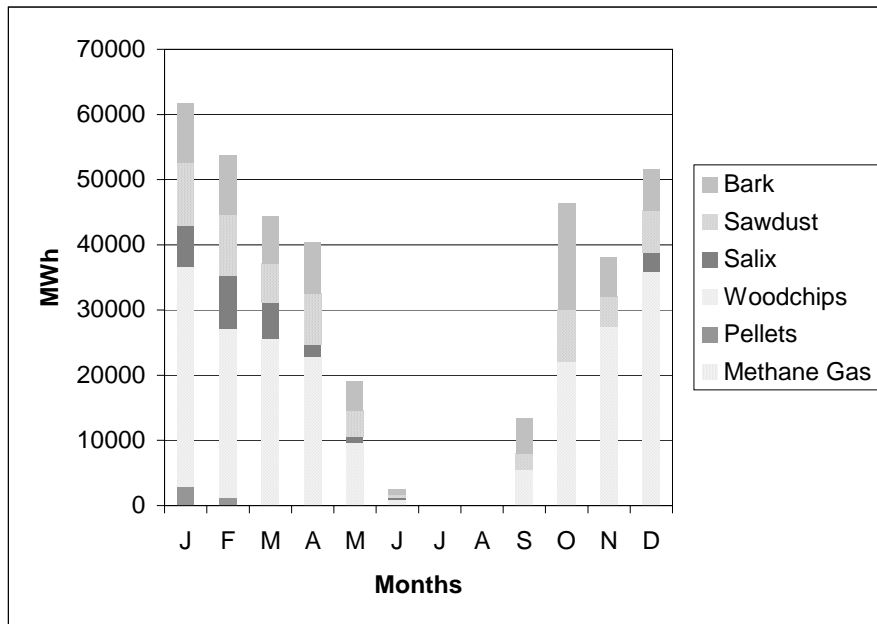
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**Figure 2: Location of Enköping in Sweden [8]**

This figure shows the location of Enköping in Sweden, which is close to lake Mälaren and nearby Stockholm.

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**Figure 3: Mix of Biofuels in the CHP Plant in Enköping in 2003 [12]**

This figure depicts the mix of biofuels used in the CHP Plant in Enköping, which highlights the range of biofuel resources available and the versatility of conversion technologies.

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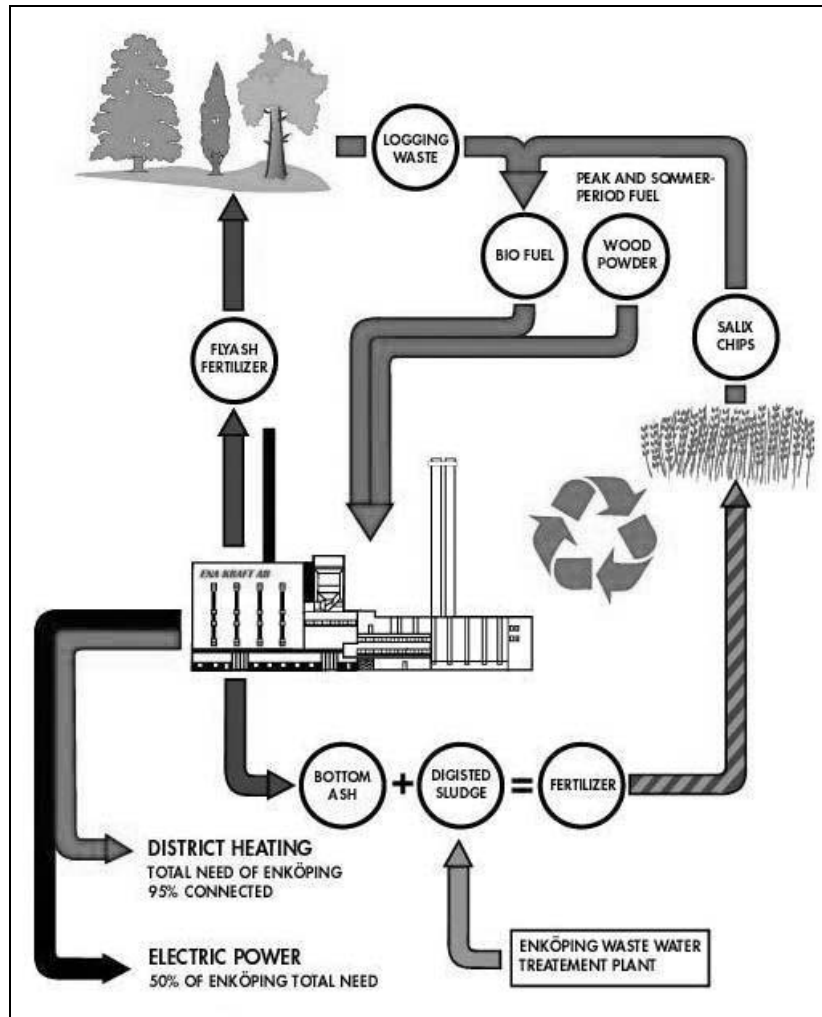


Figure 4: Flows of Materials and Energy in the Bioenergy System in Enköping [13]

This figure shows the flows of materials and energy in the bioenergy system. The boiler converted to use wood powder, which was replaced by a new technology combusting crushed pellets, operates in the warmer parts of the year. The CHP Plant operates in the colder parts of the year. A mixture of bottom ash from the CHP Plant and digested sludge from the Waste Water Treatment Facility is used as fertiliser on the salix plantations. The fly ash is also used as fertiliser.