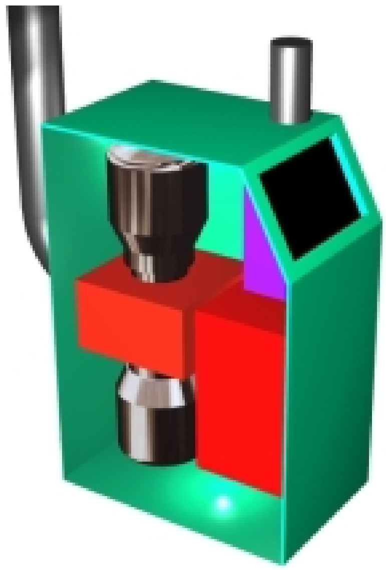
A Case Study of

Micro-Cogeneration for Single-Family Dwellings

Evaluating the European Sales Potential of External Power's Wood Pellet Fuelled 1Twin



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Preface

Micro-cogeneration is the small-scale generation of both electricity and heat, a technology which is experiencing rapid development in the recent years. The present thesis is a case study dealing with a certain wood pellet fuelled micro-cogeneration device designed for installation in a single-family home where it will work as a small-scale heat and power plant, satisfying household energy needs. An Ohio-based U.S. company, External Power LLC, is developing the product, which it expects to commercialise in 2003. The company plans to launch the product in Europe, in addition to other markets. The purpose of this project is to examine areas that can give a preliminary understanding of the European sales potential of the product.

As External Power's micro-cogeneration product is fuelled by wood pellets, the product also belongs to biomass energy technologies, a category of renewable energy technologies. This is a field which receives increasing interest for a number of reasons. Firstly, the use of renewable energy does not contribute to global warming, an issue which has become an increasing global concern especially in the recent years. Secondly, the supply of fossil energy sources such as coal, oil and natural gas is finite meaning that eventually it will be necessary to look for other energy sources.

The thesis is written as a part of the M.Sc. in International Business Administration and Modern Languages at Copenhagen Business School and accordingly should not be regarded as a consultancy report. However, it is my hope that the information about the European market contained in this report can provide useful intelligence in connection with marketing decisions.

Acknowledgements

I would especially like to thank Mr. Edward Corcoran (Centech Ltd.) for introducing me to the subject of biomass energy; Mr. Lyn Bowman (External Power LLC.) for providing me with information about 1Twin and External Power; Mr. Ole Strömgren (Copenhagen Business School) for initial support; and Mr. Peter Larsen (Card Bro) for advice during the writing.

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1 Introduction

A micro-cogeneration product being developed by External Power LLC of Ohio, U.S.A. will enable users to generate their own electricity and heat directly in their home. External Power, specialising in Stirling engine based cogeneration systems, expects to commercialise the product, which they refer to as *1Twin*, in 2003. The company's target markets are North America, Japan and Europe; this report, however, deals only with the European target market. Moreover, although External Power is working on developing both natural gas fuelled and wood pellet fuelled models of 1Twin, this report is restricted to the wood pellet fuelled 1Twin which gives a maximum electric output of 3 kilowatt.

1.1 What is Examined in this Report?

As a preliminary investigation of the European sales potential of External Power's wood pellet fuelled 1Twin, this thesis examines selected uncontrollable variables in the European marketing environment that may affect the sales potential. Merely on the basis of the selected factors, it is not possible to conclude anything definite about the European sales potential but it may give a better understanding of the complex issues surrounding a launch of the product in Europe. The purpose of this report is to create an enhanced basis for marketing decision-making in this specific case and to guide further research. Marketing framework as described in various standard marketing textbooks has guided the research.

1.1.1 Research Problem

We define the research problem of this thesis as follows:

What is the European sales potential of External Power's wood pellet fuelled 1Twin when the product is launched in 2003?

1.1.2 Research Objectives

The results of the research is presented in a systematic way, covering in turn the following six areas:

- *Based on the availability of wood pellets in Europe, where in Europe could the wood pellet fuelled 1Twin be launched?*
- *How can the wood pellet fuelled 1Twin be used to satisfy household energy needs in Europe?*
- *What is the potential competition of the wood pellet fuelled 1Twin?*
- *Which laws and policies may affect the sale of the wood pellet fuelled 1Twin?*
- *What is the customer's workload in connection with use of the wood pellet fuelled 1Twin?*
- *To which groups of consumers might the wood pellet fuelled 1Twin be targeted?*

1.2 Methodology

The six areas, which are explored in order to evaluate the European sales potential of wood pellet fuelled 1Twin, are each examined separately in this report and guide the structure of the report.

1.2.1 Structure of this report

Preceding the investigation of the research objectives, background information related to the wood pellet fuelled 1Twin is provided in Chapter 2 and 3. In *Chapter 2*, the product is described. To put the wood pellet fuelled 1Twin into context, External Power's product line is described and a brief profile of the company is given. Next, the development process of the product and its technical features are described. It is not a part of the thesis to make technical assessments of the product. Information about the product and the company was obtained mainly from private correspondence with Lyn Bowman of External Power. It may be a limitation to the study that the author never saw the product. *Chapter 3* deals with energy sources and generation of electricity and heat, with a particular focus on biomass energy and micro-cogeneration. Following the background information, the report is organised on the basis of the research objectives

Chapter 4 examines the availability of wood pellets in Europe. This is important for the sales potential of the wood pellet fuelled 1Twin, as it cannot be launched in markets where wood pellets are not available. As we shall see, Austria, Denmark, Sweden and Germany have wood pellet markets that are well-developed. In other countries such as Finland, Estonia, Latvia, the Netherlands and Norway, wood pellets are manufactured but are mainly for export. Other countries, such as Bulgaria, Hungary and the United Kingdom are in the pioneering stage. Literature and concerning wood pellet availability in Europe was limited. Information has been gathered partly by using two reports by Malisius et al. (2000) and Grübl et al. Furthermore information was gathered systematically via personal inquiries to biomass associations, wood pellet manufacturers, and the like, in addition to documents found on the World Wide Web. To the author's knowledge no complete information on wood pellet availability in Europe had been collected. A list of wood pellet manufactures in Europe was compiled and launched in December 2000 as an on-line version on the World Wide Web,[1] on the account of which additional information was received.

Chapter 5 analyses how the wood pellet fuelled 1Twin can be used to satisfy household energy needs of space heating, hot-water supply, electricity and cooking. As household conditions vary, we identify 3 possible usages: 1. using 1Twin in combination with power supply from the grid with electricity used for cooking, 2. the same but with natural gas used for cooking, and 3. independently of the power grid with gas used for cooking. Average household consumption in selected European countries is described using data from Eurostat's report from 1999, "Energy consumption in households: European Union

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[1] *Wood pellet manufacturers in Europe* <http://home.worldonline.dk/~imuy/woodpellets>.

and Norway, 1995 survey, Central and eastern European countries, 1996 survey". Unfortunately, it was not possible to obtain consumption figures for Central and Eastern Europe. On the basis of the 3 possible usages and average consumption figures, the amount of wood pellets needed for the operation of 1Twin is estimated. We shall see that, excluding warmer countries, it is estimated that approximately 4-7 tonnes of wood pellets are required annually for average household consumption. In the winter, around 30 kg is needed daily and in the summer 2-3 kg daily. We will show how to compare the price of operating 1Twin in terms of fuel use with some common alternatives. How the wood pellet fuelled 1Twin can be used, the amount of wood pellets it requires, and the price of operation compared to other ways of getting heat and power are among the important issues for potential buyers, affecting the sales potential.

Potential competitors are analysed in Chapters 6-9. The threat of competitors will affect the sales potential of 1Twin. *Chapter 6* discusses which types of competitors are relevant to investigate. Three levels of competition are described: brand, industry and form/market competition. *Chapter 7* surveys the micro-cogeneration industry. The chapter will show that there are around 15 companies world-wide in the micro-cogeneration industry. Of these only few have launched any micro-cogeneration products but most are planning to launch products around 2003. Information about the micro-cogeneration industry was not readily available in literature. Information was collected among others from COGEN Europe and other associations, conference material, documents on the World Wide Web and later on personal inquiries to companies. It was not always possible to obtain full information. *Chapter 8* explores the electricity industry in Europe as electricity supplies by this industry is the well-established way of getting electricity. The EC Electricity Directive from 1996 is described since it requires EU Member States to open up their electricity markets to competition, which is changing the way that industries are organised. One of the results are falling electricity prices, which may have an effect on the sales potential of 1Twin. *Chapter 9* examines what heating systems exist for households and what is used in European countries. We will see space heating and hot-water supply systems can be central, local or district heating systems. In this regard, the wood pellet fuelled 1Twin can be considered a close substitute to central heating systems.

Chapter 10 focuses on international environmental laws and EC laws regarding climate change, the reason being that these favour energy efficiency and a reduction in CO_2 emissions, which is relevant to look at since the combustion of wood pellets is CO_2-neutral. We shall see that Europe as a whole is greatly committed to reducing CO2 emissions, but that some are more active than others. National laws and policies are not examined, but it will be necessary to examine these, e.g. whether state subsidies or support are provided for renewable energy technology products such as the wood pellet fuelled 1Twin, since these may provide an incentive for consumers to purchase the wood pellet fuelled 1Twin.

Chapter 11 deals with the possible extra workload that may be imposed on customers using the wood pellet fuelled 1Twin. The chapter focuses on wood pellet supply, how to store wood pellets and on ash disposal. Some consumers may consider it too much work to use the wood pellet fuelled 1Twin and this will affect the sales potential. Among other things, we shall see that the most common distribution form of wood pellets is direct supply of loose wood pellets at the consumer's house, that storage rooms or silos are the most commonly used storage solutions. The chapter is mainly based on information from reports by Grübl et al. and Malisius et al.

Chapter 12 discusses potential target users of the wood pellet fuelled 1Twin. It shows that further research on consumers is necessary in order to get a better picture of groups of consumers which might be targeted. We suggest a number of variables, which might be relevant in segmenting the market. Furthermore, we show that it is important to examine the process that potential consumers may go through in deciding to buy the wood pellet fuelled 1Twin.

2 Product: the Wood Pellet Fuelled 1Twin

The purpose of this chapter is to give a general description the wood pellet fuelled 1Twin, which is one of External Power's micro-cogeneration products. The characteristics of the wood pellet fuelled 1Twin might be viewed according to 3 broad levels[2]: benefits (what it does for the customer), tangible product (e.g. features, quality, design, brand name, packaging, size) and augmented product (e.g. services, warranties, delivery, installation, after-sale service). However, this is difficult at the time of writing because it is still not for sale and all attributes of the product have not yet been finally decided. 1Twin is not a brand name but is entitled 1Twin in this report, as External Power internally calls it by this name.

In order to put the product into context, first the planned product line of External Power is described and a brief company profile of External Power is given. Next, an account is given of the development process of 1Twin. The wood pellet fuelled 1Twin is then described with a focus on benefits and technical features. As its engine, the Stirling engine, is special and not very widespread, the last section deals with this subject in order to provide a basic understanding of it. Information concerning the product and the company was obtained mainly from private correspondence with Mr. Lyn Bowman of External Power and from documents which External Power has made available on the Internet[3].

2.1 Product Line of External Power: 1Twin, 2Twin and 4Twin Units and Systems

The wood pellet fuelled 1Twin is the first in a series of micro-cogeneration products that External Power is planning to launch. Micro-cogeneration, discussed in Chapter 3, is the simultaneous generation of electricity and heat on a very small scale. External Power's micro-cogeneration products will be available in three different power ranges, generating approx. 3 kW, 6kW and 12 kW of electrical energy, respectively: External Power is talking

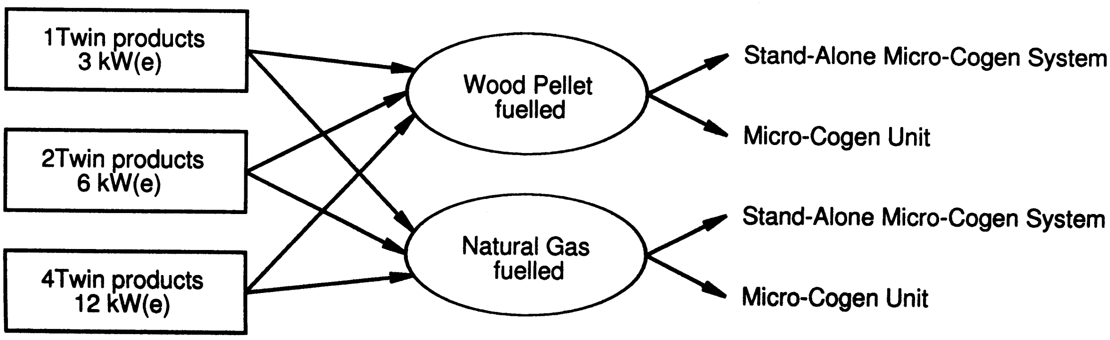

Fig. 2.1 Planned product line of External Power.

[2] See for example Czinkota and Ronkainen (1998) *International Marketing*, 5th edition, p. 307.
[3] See <ftp://209.239.142.78/Public_Information>.

about the 1Twin, 2Twin and 4Twin, where the figures refer to the number of pairs of Stirling engines in each machine. The diagram above shows an overview of the planned future product line.

External Power's three sizes of products are aimed at different target groups.[4] 1Twin micro-cogeneration products, with the least electrical output (3 kW), are designed for "most single family homes equipped with all of the modern conveniences", while the larger scale 2Twin products (6 kW) are for "a remote community of 10 modest homes". Finally, 4Twin with an electrical output of 12 kW may be used by light industrial businesses, restaurants, schools, by social service missions in developing countries, etc.

Stirling engines operate on any heat source as long as the temperature is sufficiently high. Therefore it is possible to develop product variants that burn fuels such as natural gas, cordwood, wood pellets, wood chips, saw dust, rice husks and bagasse. The variants that External Power plans to offer depend on the emergence of market demand. At present (2000), External Power concentrates on wood pellet fuelled and natural gas fuelled models, which are expected to be commercially available, beginning in 2003. The first product that External Power will commercialise in 2003 is the 1Twin.

For sales purposes, the products will be offered either as a package/system, comprising a micro-cogeneration unit, batteries and an inverter (*Stand-Alone Micro-Cogen System*), or unbundled, comprising the micro-cogeneration unit only (*Micro-Cogen Unit*). Estimated prices are: USD 9,090 F.O.B. factory for the 1Twin Micro-Cogen Unit and USD 11,886 F.O.B. factory for the 1Twin Stand-Alone Micro-Cogen System. As for the Micro-Cogen Unit, according to External Power, some customers already have batteries and an inverter and will not need to buy the whole system but only the unit.

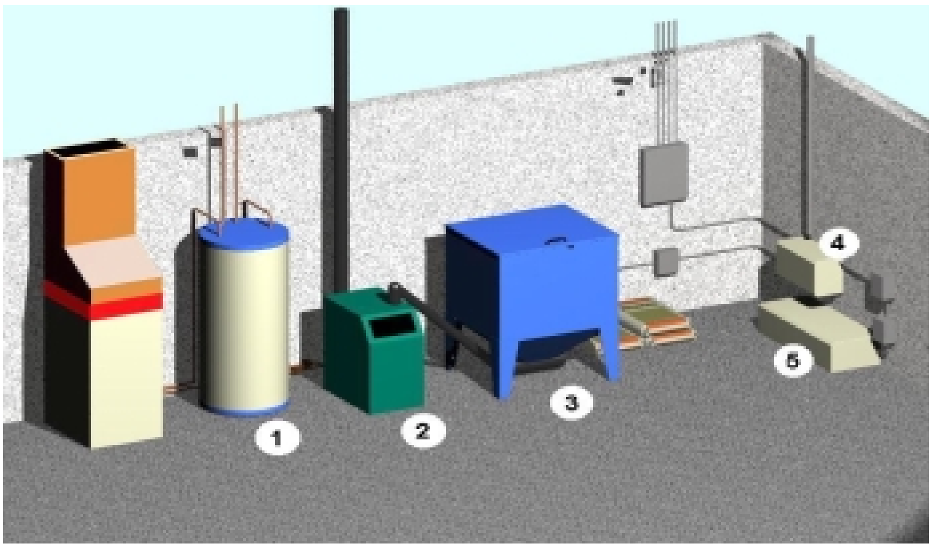

Fig. 2.2 Example of an installation of the wood pellet fuelled 1Twin Stand-Alone Micro-Cogen System. The components seen are: 1) hot water tank, 2) Micro-Cogen Unit, 3) wood pellet bin connected to Unit with auger, 4) inverter and 5) battery. (By courtesy of External Power LLC)

[4] External Power, *External Power LLC.* Document (22 March 2000).

Company Profile: External Power, LLC

External Power LLC of Athens, Ohio, U.S.A., is a designer and developer of on-site electricity generation and cogeneration systems utilising free-piston Stirling engines. External Power was founded in 1996 by Wood-Mizer Products Inc., but operations did not begin until July 1999. Since the start of operations, the company has been growing and many changes have taken place. The present (2000) number of employees is over 15 people in three locations: Athens, Ohio; Burlington, Washington; and Indianapolis, Indiana. President of External Power is Jerry Whitfield.

The mission[5] of External Power is:

- to be the world-wide leader in the manufacture of reliable and high-quality free-piston Stirling engines (FPSE)
- to offer a range of FPSE-based products that provide unique and economical solution to specific world-wide power and heating needs using the customer's preferred primary energy source
- to collaborate with all stakeholders to produce a superior return on investment

Many companies and people have been involved in the start-up of External Power. In 1994, the American engineering R&D company, Sunpower Inc. of Athens, Ohio, licensed its free-piston Stirling engine technology to Wood-Mizer Products Inc. Sunpower, founded in 1975 by Professor William Beale of Ohio University's Department of Mechanical Engineering, inventor of the free-piston Stirling engine, specialises in research and prototype development of free-piston Stirling engines and coolers, etc. Its 37 employees (1999)[6] include design and test engineers, technicians, machinists, and business support staff.[7] Sunpower has been granted over 30 patents and describes[8] its technology as innovative, cost effective, environmentally friendly and durable. In order to take advantage its technologies commercially, the company offers licenses to manufactures, or forms joint ventures and partnerships. The clients of Sunpower are mainly governments and industries.[9] In 1996, Wood-Mizer Products Inc. assigned the licence to the start-up company External Power, and until July 1999 External Power functioned as a holding company, which financed engine development at Sunpower Inc.

According to Lyn Bowman,[10] in Sep. 1999, External Power was awarded USD 3 million in support from the U.S. Department of Energy (DOE) to match USD 3 million from Wood-Mizer to finance the start-up of External Power. These funds are spent on developing manufacturing processes and on building strategic partnerships in North America and Europe. External Power's current (2000) strategic partners include Sunpower Inc., Wood-Mizer Products Inc., Energidalen i Sollefteå, Sweden (a bioenergy R&D company), and Stirling Engine Co. Japan. Energidalen is working on assessing market opportunities, developing distribution channels and finding European joint venture partners. External Power has the possibility of using Wodd-Mizer's existing distribution channels.

Ownership and Organisation of External Power

The majority, 85%, of External Power is owned by Chairman of the Board and CEO Donald R. Laskowski, founder and former CEO of Wood-Mizer Products Inc. The remaining 15% of the company is owned by Wood-Mizer Products Inc., a manufacturer of portable and stationary

[5] External Power, *External Power LLC*, Document (22 March 2000).
[6] 1999 American Business Information
[7] *Sunpower, Inc. Company profile* <http://www.sunpower.com/sunpower/profile.html> (31 May 1999).
[8] NBIA (1997), *NBIA membership directory*, p. 13. The National BioEnergy Industries Association (NBIA) is a trade association that represents the U.S. biomass-electric and thermal industry. Members include "equipment manufacturers, component suppliers, project developers, design and engineering firms, independent power producers, and consultants". Sunpower is a member of NBIA.
[9] *Sunpower, Inc.* <http://www.sunpower.com>
[10] E-mail from Lyn Bowman (26 Oct. 1999).

sawmills, sawmill accessories, etc.,[11] founded in 1978. Wood-Mizer's world headquarters are located in Indianapolis, Indiana, U.S.A. and the company has branches and representatives world-wide. The European region is handled by the factory in Kolo, Poland[12].

Laskowski was president of External Power until Oct. 1999 when he raised himself to Chairman of the Board without participation in day-to-day operations. In July 1999, Laskowski employed Lyn Bowman as External Power's first employee and assigned him the position of Manager.[13] Prior to this, Bowman was employed at Sunpower Inc. as Venture Analysist. Originally from Stanford University's micro-machine laboratory,[14] at Sunpower he was co-inventor of miniature cooling technology.[15] With his assignment to Manager at External Power, Bowman was given the responsibility of increasing the value of the company. Work began on staffing up in order to transfer technology from Sunpower to External Power and to establish manufacturing facilities in Indiana and in Washington. As the company grew, Bowman later became Vice President of Operations and Director of Marketing.

In Oct. 1999, Dr. Jerry Whitfield was recruited from Whitfield-Pyro Industries, Inc. of Burlington, Washington, U.S.A., to succeed Laskowski as External Power's new president. Jerry Whitfield is the inventor of the wood pellet stove, founder and former CEO of Whitfield-Pyro Industries[16], which is a leading manufacturer of wood pellet stoves, owned by the Lennox subsidiary, Hearth Products Inc.

Lyn Bowman is the head of Operations, which is divided into Engineering, Manufacturing, and Testing. The staff in these departments consist of people responsible for combustion systems, burner design, Stirling engine design, electrical design, product design, process development, in addition to technicians, test engineers, etc.

2.2 Development Process of 1Twin

The initial development of External Power's micro-cogeneration products took place at Sunpower, Inc., of Athens, Ohio, U.S.A., from which External Power has licensed its free-piston Stirling engine technology. In these initial development stages, the line of micro-cogeneration products were designed to generate heat and electricity from various biomass energy sources. The trademark of the product line was *Biowatt*™, of which the first prototypes had one free-piston Stirling engine with an electric output of approx. 1 kW and were fuelled by wood pellets or cordwood. It had been under research and development for a number of years, sponsored by the DOE and by Wood-Mizer Products, Inc. One of the reasons why External Power later decided to use a *pair* of opposed Stirling engines as the unit of the 1Twin, 2Twin and 4Twin products, instead of a single Stirling engine, was that it was estimated that a doubling of the electric output capacity would better suit the electrical needs of North American middle-class homes.[17] The electric output capacity of

[11] *Wood-Mizer Products* <http://www.woodmizer.com> (10 Aug. 2000).
[12] *Company* <http://www.woodmizer-europe.com> (10 Aug. 2000).
[13] E-mail from Lyn Bowman (6 July 1999).
[14] *Micro heat engine cools hot processors* <http://www.eet.com/news/97/973news/micro.htm> (24 Sep. 1999).
[15] United States Patent 5,457,956: Microminiature Stirling cycle cryocoolers and engines, patented 1995.
[16] *Whitfield* <http://www.whitfield.com> (1 May 2001).
[17] External Power, *Twin-opposed engine pairs*, Document (no date).

the single engine is being improved to 1.5 kW, so that a pair of engines give approx. 3 kW(e)[18].

Patents

Various parts that 1Twin consists of are covered by many patents, which are listed below. According to Lyn Bowman,[19] Sunpower applied for an additional patent in 1999.

Patents Covering 1Twin

1986

- *US 4,602,174*: Electromechanical transducer particularly suitable for a linear alternator driven by a free-piston Stirling engine.
- *US 4,623,808*: Electromechanical transducer particularly suitable for a linear alternator driven by a free piston Stirling engine.

1989

- *US 4,805,409*: Stirling engine power regulation system.

1995

- *US 5,385,021*: Free piston Stirling machine having variable spring between displacer and piston form power control and smoke limitation.
- *US 5,461,859*: Centering system with one way valve for free-piston machine.
- *US 5,642,088*: Magnet support sleeve for linear electromechanical transducer.

1996

- *US 5,502,968*: Free piston Stirling machine having controllably switchable work transmitting linkage between displacer and piston.
- *US 5,525,845*: Fluid bearing with compliant linkage for centering reciprocating bodies.
- *US 5,537,820*: Free piston end position limiter.

Demonstration

The prototype of the early model, the 1 kW(e) wood pellet fuelled Biowatt, was demonstrated on several occasions at the following fairs and conferences: 1998 Midwest Renewable Energy Fair, Wisconsin; BioEnergy '98 Conference, Wisconsin; 1999 Midwest Renewable Energy Fair and Fourth Biomass Conference of the Americas, California, 1999.

Field testing plan

According to Lyn Bowman,[20] at the present stage, Biowatt/1Twin has not operated in anyone's home. However, as a field trial project, External Power schedules[21] to test the wood pellet fuelled 1Twin in 1,000 homes in North America and Europe during a one-year-period in 2002-2003. Plans for this project are being laid in co-operation with Dr. Giuliano Grassi, secretary-general of the European Biomass Industries Association (EUBIA). The field trial project is to be jointly funded by External Power, the U.S. DOE and by the European Union. Lyn Bowman envisions that the product will be installed in 25-50 homes in 24-40 communities with a local 'champion' in each community responsible for dealing with any problems that might occur. Furthermore, it is imagined that performance in each home will be monitored via the Internet.

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[18] kW(e) means kilowatt electric while kW(th) means kilowatt thermal.
[19] E-mail from Lyn Bowman (8 June 1999).
[20] E-mail from Lyn Bowman (1 Sep 1999).
[21] E-mail from Lyn Bowman (16 Dec. 1999).

Commercialisation plan

External Power expects to commercialise the 1Twin in 2003. The current plan is to launch natural gas fuelled and wood pellet fuelled models of the 1Twin, focusing on markets in North America, Europe and Japan. The next section is about the wood pellet fuelled 1Twin.

2.3 Description of the Wood Pellet Fuelled 1Twin

The wood pellet fuelled 1Twin, illustrated below, is a micro-cogeneration device, producing heat and electricity for single-family home use. To first classify the product, the wood pellet fuelled 1Twin may be categorised as a product for consumers, designed for use over an extended period of time (durable consumer-good). Furthermore, in regard to purchase, it is likely that potential buyers will shop around to compare various offers before the decision to purchase the wood pellet fuelled 1Twin (shopping product). In the following, benefits and technical features of the wood pellet fuelled 1Twin are described.

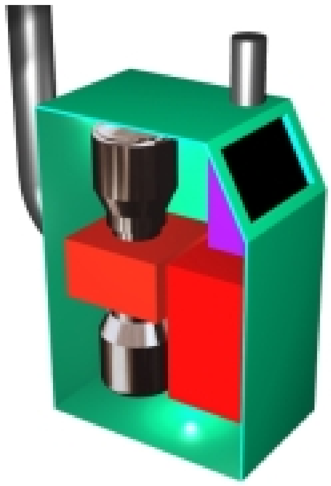

Fig.2.3 The 1Twin Micro-Cogen Unit (By courtesy of External Power, LLC).

2.3.1 Benefits of 1Twin

The wood pellet fuelled 1Twin may have many and varying benefits for different customers, and a few are suggested here:

- Heat and electricity in one
- Contribution to cleaner atmosphere
- Quiet operation
- Low maintenance

The core, or basic, benefit of External Power's wood pellet fuelled 1Twin is the satisfaction of home energy needs in regard to electricity supply, space heating and hot water supply. With an electric output of 3 kW, it has been estimated to suit the electricity and heating needs of a single-family dwelling. 1Twin is to be installed in the user's building, producing both electricity and heat at one time directly in the home. Although it thus allows the user potentially to become totally independent of the electricity grid, as we shall see later, it is considered most likely that Twin will be used in combination with the electricity grid in places where there is access to the grid, as is the case throughout most of Europe.

Electricity and heat is generated on the basis of combustion of wood pellets, which is a type of fuel categorised as biomass energy (see Chapter 3), belonging to the diverse group of renewable energy sources. As opposed to combustion of fossil fuels, combustion of wood pellets is CO_2-neutral as well as cleaner in terms of sulphur and nitrogen emissions, and the use of 1Twin may therefore be regarded as an environmentally friendly way of satisfying home energy needs.

An additional benefit is that operation of 1Twin is very silent and furthermore that the engine requires no maintenance due to engine construction.

2.3.2 Technical Features of the Wood Pellet Fuelled 1Twin

The main technical facts concerning the product are listed in the box below. The technical aspects of the wood pellet fuelled 1Twin (both Unit and Stand-Alone System) shall not be dealt with in detail, but in the following it is explained what the product consists of and what it can do.

Technical Facts about the Wood Pellet Fuelled 1Twin

Prime mover:	2 opposed free-piston Stirling engines
Fuel:	Wood pellets
Electric output:	Max. 3.1 kW
Thermal output:	Max. 27.9 kW
Fuel-to-electricity efficiency:	Forecast 15% (exact percentage is not known at present)
Fuel-to-heat efficiency:	Forecast 65-75% (exact percentage is not known at present)
Cogeneration modes:	Constant, electric or thermal load following.

The Micro-Cogen Unit

Electricity and heat is generated in the Micro-Cogen Unit, which is basically a box with the dimensions[22] 35 cm × 74 cm × 70 cm, containing the prime mover and a wood pellet burner.

The prime mover consists of a pair of opposed free-piston Stirling engines. The head of each of these is heated by an external heat source, causing the pistons inside the sealed cylinders to oscillate. Electricity is then generated directly from the moving pistons by a so-called linear alternator attached to the pistons. External Power can design the alternator so that the mode of electricity (voltage, frequency and current) generated from 1Twin is 240 V AC at 50 Hz, which is equivalent to what is used in residential sites in Europe[23], or 120 V AC at 60 Hz, which is what is used in e.g. the United States and in Canada. As

[22] E-mail from Lyn Bowman (8 June 1999). Note that the dimensions apply to Biowatt.

[23] In Europe, voltages vary from 220-240V. Source: *Electric power around the world* <http://kropla.com/electric2.htm> (30 Apr. 2001).

regards the principle of the Stirling engine, this will be discussed in a later section. Here it suffices to say that in a free-piston engine, the pistons are not mechanically linked to any rotating crankshaft or the like for the conversion of heat into mechanical energy.

The **lifetime** of the engine has been estimated to be 40,000-80,000 operation hours, equivalent to about 5-10 years. Exactly how long depends on the materials used in the final engine design: an upgrade in material means it may last up to 10 years.

The wood pellet burner is controlled automatically so that electric and heat output levels may be constant, or follow either electric or thermal loads. Wood pellets are combusted for production of heat, which is supplied to the Stirling engine for its operation. Heat, which is rejected to the water-based cooling system, is used for heating the house and for hot water supply. The burner's ceramic firebox is designed so that combustion takes place in two stages, thus ensuring high temperature combustion and minimal emission. Ash coming from the wood pellets is collected in a removable ash catcher, which is to be emptied from time to time.

The Stand-Alone System

The Stand-Alone System includes, besides the Unit, an inverter and 2 deep cycle batteries, which make it possible to store and use the stored electricity. An **inverter** is a device that converts direct current (DC) into alternating current (AC) or vice versa. It is necessary so that electricity stored in the batteries can be converted back into AC when it is to be used in the house.

Deep cycle batteries are extra heavy duty batteries which are intended for usage where they supply power for a long period of time and are designed to be discharged down to 50% or more without damage.[24] 1Twin can at any time generate a maximum of 3.1 kW(e). However, deep cycle batteries make it is possible to obtain more than this amount of electricity in order to manage potential extra electricity loads when electricity consumption exceeds the capacity of 1Twin. This may occur, for example, if an electric kettle, washing machine, tumble drier and vacuum cleaner are all in use at the same time. In off-peak periods the batteries will be recharging. According to Lyn Bowman,[25] batteries that can store around 2 kWh are possibly sufficient for household use.

The example below shows how electricity, generated constantly at the max. output of 3.1 kW, might be distributed during a 24-hour period, using batteries and inverter. In this example, the 1Twin Stand-Alone System can provide up to 8 kilowatts of electricity for a period of 1 hour to take surge loads from induction motors of washing machines and other household appliances.

Electric and thermal output of 1Twin

1Twin has a capacity of generating a maximum of approx. 3 kilowatts of electricity, and a maximum of approx. 28 kilowatts of heat. Electric and thermal output may be

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[24] *Deep cycle batteries* <http://www.windsun.com/Batteries/Deep_Cycle.htm> (30 Apr. 2001).
[25] E-mail from Lyn Bowman (1 Sep. 1999)

Example of 24-hour Distribution of Electricity from 1Twin Stand-Alone System

Electric output capacity: 74 kWh/day

Surge power:	8.1 kW	***Surge time:***	1.0 hour
Peak power:	5.6 kW	***Peak time:***	2.3 hours
Off-peak power:	2.6 kW	***Off-peak time:***	20.7 hours

Source: External Power, External Power Product Line, Document (no date)

electronically programmed so that output follows either electricity or heating loads. For example, assuming that one does not buy electricity from the grid, according to Lyn Bowman,[26] when little heat is needed in the summer, output levels are determined by the electricity loads, and any excess heat is discarded (e.g. by outdoor radiator). On the other hand, when more heat is needed in the winter, output is controlled by both heat and electricity loads. The burner is driven by a thermostat to produce additional heat for heating, increasing thermal output of the machine independently of electricity production.

Heat may be derived from two heat sources: the engine and exhaust from the burner. Heat from the engine warms water to a temperature of about 75° C, used for space heating and hot water supply. The temperature of heat from the exhaust from the burner is much higher, about 700° C. As this heat can be used to cook with, it is possible that a cooking function can be added in the future to use this heat, but at present no effort is being made to achieve this and there are no plans of making such a cooking device.

According to External Power,[27] at the present stage of development it is not yet possible to say exactly what the **fuel-to-electricity efficiency** of the wood pellet fuelled 1Twin will be when commercialised in 2003. In other words, at this point no reliable data exists on the fraction of the fuel's energy that the 1Twin machine can convert into electrical energy. However, External Power believes that, if successful, 15% will be a reasonable forecast. What the **overall efficiency** of the 1Twin will be is not clear either. According to the company, an overall efficiency of 80% is a reasonable forecast for the 1Twin that is first offered for sale in 2003. It is a possibility that External Power may offer an optional component to be added to the system that can increase the overall efficiency to 90%. Yet, it must be stressed that none of these figures are certain at the present stage. From this follows that it is also uncertain what fraction of the fuel's energy that can be converted into useful heat with the 1Twin. The forecasts of 15% fuel-to-electricity efficiency and an overall efficiency of 80-90% lets us know that the 1Twin may possibly have a **fuel-to-heat efficiency** of 65-75%, meaning that 10-20% of the fuel energy is **loss**, i.e. heat, which leaves the house in the exhaust gas. The efficiencies are shown in the figure below.

[26] E-mail from Lyn Bowman (29 June 1999).
[27] E-mail from Lyn Bowman (28 July 2000).

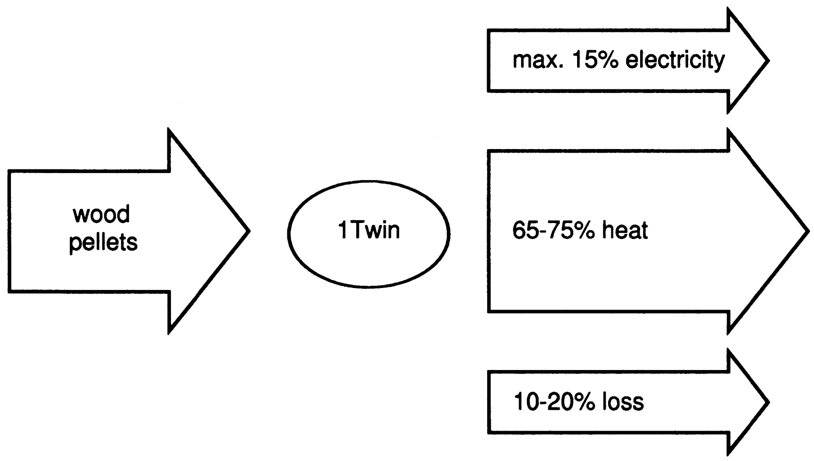

Fig. 2.4 External Power's forecast of fuel-to-electricity efficiency and fuel-to-heat efficiency and loss of the 1Twin when commercialised in 2003.

As for the machine's consumption of **wood pellets**, it will depend on the amount of electricity and heat produced, but 1Twin has a capacity of burning up to 4.5 kg wood pellets an hour. Wood pellets, discussed in Chapter 4, exist in several sizes, and moreover they can vary slightly from manufacturer to manufacturer. However, according to Lyn Bowman,[28] the wood pellet fuelled 1Twin handles all kinds of wood pellets, and the size is of no importance.

Grid-Connect or Grid-Independence?

The wood pellet fuelled 1Twin is designed to operate either completely independently of the electricity grid, or in conjunction with the electricity grid. The latter opens up for two possibilities, namely 1. to buy from the grid when extra electricity is required, and 2. to sell excess electricity to the grid. In Europe it seems likely that most users of 1Twin would use it in conjunction with the electricity grid in order to buy from the grid. But it seems unlikely that users will sell excess electricity to the electricity grid.

Auxiliaries for 1Twin

As the wood pellet fuelled 1Twin includes nothing for storage of wood pellets, nor for conveying the wood pellets to the fuel spout of the unit,[29] additional equipment will be needed for its operation. These include a storage solution for the wood pellets and automatic equipment to convey wood pellets to the machine.

A **wood pellet storage** solution is needed to match modern lifestyle as is would be inconvenient to have to refill the fuel hopper of the engine manually, e.g. every six hours of operation. Storage solutions include bins, silos or storage rooms, of which storage rooms are the most popular in Europe. Wood pellets are a solid fuel, and for conveyance of wood pellets from the point of storage to the burner, a feeder application is required. An **auger, screw feeder** or **conveyor screw**, which are devices shaped as a spiral, automatically handle conveyance of wood pellets to the burner.

[28] E-mail from Lyn Bowman (26 Oct. 1999).
[29] E-mail from Lyn Bowman (4 April 2000).

2.4 What is a Stirling Engine?

It was previously mentioned that a pair of Stirling engines are used for the generation of electricity in the wood pellet fuelled 1Twin, but what exactly is a Stirling engine? This shall be explained briefly in this section in order to provide a rough understanding among other things of its principle and characteristics. For a comprehensive description of this vast subject, the reader is referred to existing literature[30].

A Stirling engine is a certain type of heat engine, which is externally heated and operates on the heating, expansion, cooling and compression of a fixed amount of gaseous working fluid.[31] To be more precise, e.g. Walker et al.[32] describe the term Stirling engine as embracing all heat engines, which operate on a closed regenerative thermodynamic cycle. Although it was invented in the beginning of the 1800s, it was not until the 1950s that Rolf Meijer from Philips Laboratories in the Netherlands suggested the generic title 'Stirling engine' for this type of engine. The box below contains an explanation on how the Stirling engine works.

Principle: How do Stirling Engines Work?

There are numerous variations of the Stirling engine, having different configurations (mechanical arrangements). The principle[33], however, is basically the same: a gas (the working fluid) trapped inside a sealed cylinder is alternately heated and cooled by external sources. This causes an expansion and a compression, respectively, of the gas, which can be transformed into mechanical energy by the movement of pistons in the cylinder. In the original Stirling engine, the gas used was ordinary air, but later e.g. helium and hydrogen have also been used.

The cylinder is divided into a hot *expansion space* and a cold *compression space*. By means of piston movements, the gas is transferred back and forth between these two spaces. For example, in the original type of Stirling engine, the cylinder is closed at one end and sealed at the other by a movable piston (power piston). A displacer piston within the cylinder moves the working fluid between the hot and cold spaces. The displacer piston has a sloppy fit, which permits the working fluid to flow around it.

Between the hot and cold spaces there is a *regenerator*. Its function is to alternately absorb and release heat so that the hot working fluid is cooled down when it passes the regenerator on its way to the cold space, and is preheated on its way back to the hot space as it picks up the heat which was deposited. In this way, the amount of heat to be rejected and supplied can be minimized. The regenerator is made of finely divided metal (sponge-like metal threads, wires or strips).

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[30] For a short introduction, see for example the following article: G. Walker: *The Stirling engine* in Scientific American, Vol. 229 No. 2 (Aug. 1973), p. 80-87. The present section is based mainly on the following books giving a broad overview of Stirling engines:

Organ, *Thermodynamic and Gas dynamics of the Stirling Cycle Machine,* Cambridge University Press (1992).

Reader and Hopper, *Stirling Engines*, Cambridge University Press (1983).

Walker, *Stirling-cycle machines*, Clarendon Press, Oxford (1973).

Walker et al., *The Stirling Alternative: Power Systems,Rrefrigerants, and Heat Pumps,* Gordon &Breach, Yverdon (1994) .

West, *Principles and Applications of Stirling Engines,* Van Nostrand Reinhold, New York (1986).

[31] Seneft, *Ringbom Stirling engines*, Oxford University Press (1993), p. vii.

[32] Walker et al., *The Stirling alternative*, (1994), p. 1.

[33] West (1986), p. 1-6; Seneft (1993), p. 4-6; Walker (1973), p. Reader and Hopper (1983), p. 8-11; Walker et al. (1994), p. 46-46.

In order to give a simplified understanding of the principle of the Stirling engine, a cycle is illustrated and explained in the following. In this illustration, based on Walker et al.,[34] two opposed pistons are arranged in a cylinder with a regenerator in the middle. The two pistons are here referred to as expansion and compression pistons.

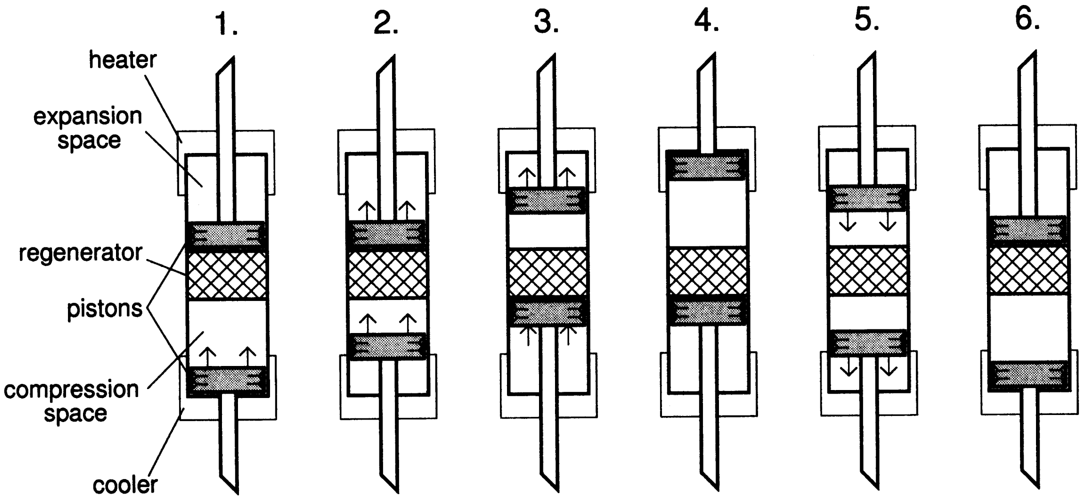

Fig. 2.5 The principle of the Stirling engine

(1) At this phase in the cycle, all the working fluid is in the compression space, while the expansion piston is at its inner dead point and the compression piston is at its outer dead point.
(2) Cooling decreases the pressure of the gas, and compression begins, making the compression piston start moving up towards the regenerator. Temperature is kept constant by the external cooling system (air or water) in order to compensate for the heating effect of the compression.
(3) Then both pistons move upward until the compression piston reaches its limit and stops at the regenerator and the expansion piston moves away from the regenerator. The working gas is transferred through the regenerator and is heated up in the process by heat deposited in the previous cycle.
(4) Heating increases pressure and makes the working fluid expand, moving the expansion piston up to its outer dead point. Temperature is kept constant by the external heat source in order to compensate for the cooling effect of the expansion. The working fluid is now in the expansion space.
(5) Pressure drops because the volume increases, and now both pistons move downwards, the expansion piston towards the regenerator and the compression piston towards its outer dead point. The working fluid is transferred through the regenerator, which absorbs heat and decreases the temperature of the working gas.
(6) The working gas is now again in the compression space. The pistons have reached their limits and the next cycle can begin (1).

Brief historical overview of the Stirling engine

Stirling engines have developed from the 19th century's heavy cast iron machines to today's efficient high-speed machines. The Stirling engine has its origins in a patent from 1816, granted for a hot-air engine with 'economiser' (regenerator). It was invented by a Scotsman, the Reverend Dr Robert Stirling (1790-1878), who was a minister of the Church of Scotland. Compared to the steam engine, which consumed mountains of coal and could

[34] Walker et al. (1994), *The Stirling alternative*, p. 43-46.

explode with scalding effects and fatalities, the Stirling engine was both more efficient and safe. The early Stirling engines were made of cast iron and used e.g. for pumping water and driving workshop machinery. Although the Stirling engine attained a measure of commercial success and was used throughout the 19th century, it never was a serious threat to the steam engine. The lack of suitable materials, which could withstand the heat they were exposed to,[35] meant that efficiency was low, and by 1914 production of Stirling engines had practically ceased world-wide. Both steam and hot-air engines were succeeded by a better and cheaper alternative, the internal combustion engine, which had been developed during the latter half of the 19th century. This was the end of the first era of the Stirling engine.

In 1937 the Stirling engine experienced a comeback at the laboratories of N.V. Philips Gloeilampenfabrieken of Einhoven, Netherlands, a manufacturer of radios and lamps. The objective was to develop a small, quiet electric generator to power radios and similar equipment. The reason was that the company began searching for markets outside Europe, including remote areas without electric supply such as locations in Africa and Asia. After examining various types of engines, the Philips engineers concluded that the hot-air engine offered the best prospects.[36] Development of the engine was a success, and after a number of years, the research team had greatly improved the Stirling engine, especially due to improvements of materials. The invention of the transistor in particular, however, eliminated the market for which it was intended. Since the engine had other potential applications, the Philips research team continued developing the Stirling engine, switching its efforts to larger engines. Interest in these was shown by Ford Motor Company and General Motors. In the following years, licencing agreements were made with among others General Motors of Detroit, Michigan, U.S.A. (1958-70), MAN-MWM of Stuttgart, Germany (1968-78), United Stirling of Malmö, Sweden (1968-83) and Ford Motor Company of Detroit (1972-97). Other research and development work on the Stirling engine has been undertaken e.g. by universities and industries mainly in the U.S.A., Japan and in Europe. Examples are Sunpower Inc. and Stirling Technology Company, both in U.S.A.

Characteristics and applications of Stirling engines

A characteristic of the Stirling engine is its quiet operation. As opposed to internal combustion engines in which pistons are put into motion by successive explosions, e.g. Otto engines[37] used in most of today's automobiles, there are no periodic explosions in Stirling engines. According to Walker et al.,[38] they literally sound like sewing machines. Another feature of the Stirling engine is its ability to operate on any heat source, including solar heat, due to the fact that heating is external. Furthermore, because heating is external, the combustion of fuels can be well controlled, and complete burning with little emission can be achieved. As the moving parts of the engine are not in contact with the fuel, wear is reduced, making long lifetime and low maintenance possible. What also characterises the

[35] Hargreaves, *The Philips Stirling engine*, Elsevier, Amsterdam (1991), p. 20.
[36] Op.cit, p. 29.
[37] *How car engines work* <http://www.howstuffworks.com/engine1.htm> (4 April 2001).

engine is that it requires expensive construction materials, for example superalloys (chrome-nickel steels), which increases manufacturing costs in comparison to internal combustion engines.

There are many applications for Stirling engines, which are either already used or potential. Of these may be mentioned:

- *Power systems:* underwater power systems (submarines, torpedo propulsion); marine engines (boats, ships); automotive engines (cars, buses, trucks, tractors); electric power generators; cogeneration systems; military ground power; remote power sources (navigation beacons, lighthouses); model engines (education, hobby); artificial hearts; water pumps; space power (spacecrafts).
- *Heat pumping:* refrigerators; cryocoolers, miniature cryocoolers; heat pumps.

Various mechanical arrangements

The elements of a Stirling engine can be arranged combined in multitudinous ways, some of which are identified by the name of the inventor or the original user[39]. The many designs of the Stirling engine may be categorised according to 3 levels: mode of operation, form of cylinder coupling and form of piston coupling.[40]

Firstly, the mode of operation mainly refers to whether the engine is single or double acting. In s*ingle acting* engines only one side of the piston is acted upon by pressure from the working fluid while in *double acting* engines both sides of the piston are acted upon.

Secondly, the form of cylinder coupling deals with how displacer and power pistons are arranged. *Alpha* engines have two separate cylinders for expansion and compression, each with a piston. *Beta* engines have a single cylinder with displacer and power piston in tandem. *Gamma* engines are a hybrid between alpha and beta, having two separate cylinders.

Lastly, piston coupling can be mainly divided into kinematic and free-piston engines. In kinematic engines, pistons are attached to drive mechanisms by solid mechanical linkages (e.g. crankshaft, swashplate, Scotch yoke, rhombic drive, etc.). In free-piston engines, pistons are not connected to any drive mechanism.

The Beale free-piston Stirling engine

The type of Stirling engine used in the wood pellet fuelled 1Twin is a *Beale free-piston Stirling engine*. It was invented in 1964 by Professor William Beale of the Department of Mechanical Engineering at the University of Ohio. He is the founder of Sunpower Inc., located in Athens, Ohio, U.S.A.

This type of engine is a single acting, Beta free-piston engine. According to Walker,[41] its cylinder is hermetically sealed and it can operate in any orientation, i.e. vertical, horizontal,

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[38] Walker et al., *The Stirling alternative* (1994), p.111.
[39] Walker, *Stirling-cycle machines* (1973), p. 51.
[40] Reader and Hopper, *Stirling engines* (1983), p. 161.
[41] Walker, *Stirling-cycle machines* (1973), p.121.

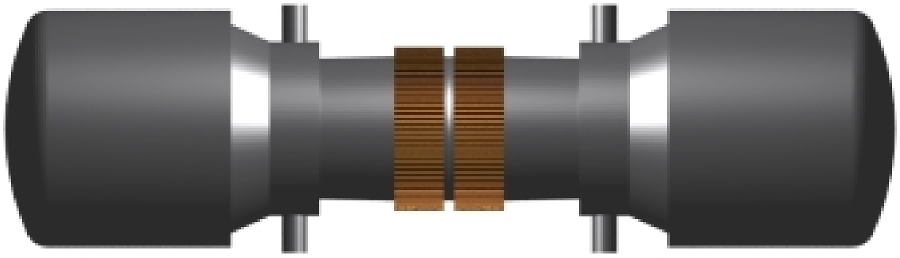

Fig. 2.6 Illustration of the 1Twin Stirling engine: two opposed Stirling engines (By courtesy of External Power LLC).

inclined or even upside down. There is no crankshaft connected to the pistons, but work is extracted from the oscillating piston by combining it with a linear alternator. The two opposed free-piston Stirling engines in the 1Twin are illustrated below. The two hot ends are joined together and heated by a single heat source in the middle.[42]

[42] External Power, *Twin-opposed engine pairs*, Document (no date). <ftp://209.239.142.78/Public_Information>

3 Energy Background Knowledge Relevant to 1Twin

The purpose of this chapter is to give background information concerning energy sources and generation of electricity and heat. Focus, however, is on subjects of particular relevance to the wood pellet fuelled 1Twin, placing the product in a broader energy context. Special emphasis is therefore on a discussion of biomass energy and micro-cogeneration.

3.1 Sources of Energy: General Overview

Energy sources fall into two categories: non-renewable energy sources, which comprise fossil energy sources and nuclear energy sources, and renewable energy sources, which is a large group of diverse energy sources. The most important energy sources are summarized in the table below.

Table 3.1 Various energy sources

Non-renewable energy sources	Renewable energy sources
1. Fossil energy sources:	• Hydro
• Coal	• Wind
• Crude oil (Petroleum)	• Wave
• Natural gas	• Solar
	• Tidal
2. Nuclear energy sources:	• Biomass
• Uranium-235	• Geothermal

Fossil energy sources

The main fossil fuels are coals, petroleum and natural gas. These solid, liquid and gaseous energy sources derive from decomposed plant material originating in the Carboniferous Period around 300 million years ago. A characteristic of fossil fuels is their high content of carbon, as high as 95% in the case of coal. *Coal* is found in several development stages (e.g. peat, lignite, bituminous (soft) and anthracite (hard) forms). *Petroleum* or *crude oil*, which is found beneath the surface of the earth or seabed, cannot be used as a fuel in its natural state. By heating the crude oil at a refinery, it is therefore processed into a number of useful fuels (e.g. gasoline, diesel fuel, kerosene, heating oil, paraffin, etc). *Natural gas* is mainly made up of methane. Hydrogen, which can be used as a fuel in fuel cells, does not exist freely in the nature but can be obtained from water or fossil fuels such as natural gas.

Nuclear energy sources

Nuclear energy[43] is obtained from the metal uranium, on the basis of nuclear fission. The nucleus of an atom is made up of protons and neutrons. *Uranium* occurs in several forms (isotopes), differing in the number of neutrons. Uranium, which is found in the earth's crust, is a mixture of two isotopes: uranium-238 (99.3%) and uranium-235 (0.7%). Uranium-235 can readily be split in two when it is hit by a neutron, and this

[43] *What is uranium* <http://www.uic.com.au/uran.htm> (6 Mar. 2001).

releases a tremendous amount of energy in the form of heat. In the process, 2-3 neutrons are thrown off, which can hit other atoms, starting a chain reaction.

Renewable energy sources
Renewable energy sources comprise many and diverse types of energy sources, but what they have in common is that they are constantly being replaced. *Hydropower* or hydroelectric power is obtained from flowing water in rivers and streams, usually by letting the water fall from reservoirs. *Wind power* makes use of air movements. *Waves and tidal energy* uses the flow of water in the sea. *Solar energy* is both light energy and heat energy from the sun. *Biomass energy* is energy from organic matter; this is explained in more detail in the next section. *Geothermal energy* is heat coming from the centre of the earth.

Each of the energy sources has different characteristics and offers certain advantages and disadvantages, for example in terms of pollution or availability. In regard to renewable energy, their suitability or availability often depends on geographical and climatic conditions. However, laws or political decisions may also promote or limit the use of certain fuels.

Fossil energy sources dominate world energy supply at present. According to the International Energy Agency,[44] fossil fuels account for about 80% of world's total energy supply (1997). Petroleum (crude oil) is especially dominating, representing about 36% of world energy supply.

From the beginning of the 1900s until 1973, economic activity was organised on the assumption of cheap and plentiful oil.[45] The OPEC oil price shocks of 1973-74 and 1978-80 provided an impetus for research and development in ways of reducing the consumption of conventional fuels. Modern attempts to use renewable energy sources therefore began in the 1970s. The main concern was whether there would be enough fossil fuels to meet needs at an affordable price.[46] In recent years, increasing concern about pollution and global warming are additional factors that have led to the search of energy sources that are more energy efficient and more beneficial to the environment in terms of reduced emission of carbon dioxide (CO_2), sulphur dioxide (SO_2) and nitrogen oxides (NO_x). This increased awareness of environmental problems has resulted in e.g. the United Nation conferences in Rio de Janeiro (1992) and in Kyoto (1997).

To give a quick overview of the energy sources used in Europe (according to TERES II, 1998)[47], the composition of energy sources in each of the European countries differs from country to county, but in the majority of countries there is a clear domination of fossil energy sources, particularly crude oil. Cyprus relies almost solely on crude oil. Bulgaria, Czech Republic, Estonia, and Poland rely mainly on coal, while Hungary, the Netherlands and Romania have larger shares of natural gas. Iceland is unique because nearly all its energy comes from hydro and geothermal energy sources. Norway has a very large share of hydropower, and in Austria and in Sweden a share of almost a quarter of the energy

[44] *Selected energy statistics* <http://www.iea.org/stats/files/glance.htm> (7 Mar. 2001).
[45] Begg, Fischer and Dornbusch, *Economics*, McGraw-Hill, London (1991), p. 2.
[46] *Introduction* <http://www.dti.gov.uk/renewable/intro.htm> (7 Mar. 2001).
[47] Data from *EuroREX country reports* <http://www.eurorex.com/country.asp> (8 Mar. 2001). EuroREX is based on data from the 2nd edition of the European Renewable Energy Study – TERES II, published in 1998 by the European Commission. The study was undertaken by Energy for Sustainable Development Ltd. (ESD), commissioned by the European Commission in 1995.

sources consists of biomass and hydro energy sources. In both France and Sweden, a large proportion of energy sources used are nuclear energy sources, but Belgium, Bulgaria, Czech Republic, Finland, Germany, Hungary, Lithuania, the Netherlands, Slovakia, Spain, Switzerland and United Kingdom are all countries where nuclear energy sources are used as well.

3.2 Biomass Energy

Biomass energy sources refers to all organic matter available on a renewable basis for conversion to energy. Energy such as electricity, heat and liquid fuels produced from biomass is commonly called *bioenergy*.[48]

The basis of all biomass is ultimately the process of photosynthesis[49]. Hereby plants capture energy from the sunlight to produce a carbohydrate, namely glucose ($C_6H_{12}O_6$), out of water (H_2O) and carbon dioxide (CO_2). During this process, energy from the sunlight is stored in the chemical bonds of the carbohydrates. Only plants, and certain microorganisms, can capture light energy directly but, through the food chain, this energy is passed on to animals as well.

When biomass is used as an energy source, generally plant material or waste is considered. Still, this covers a wide range of materials of which some examples are listed below. Wood pellets, which is one type of biomass, will be discussed in Chapter 4.

Examples of Biomass Energy Sources

Plant material

- *Wood and forestry residues:* trees, shrubs, sawdust, bark, chips, timber slash, mill scrap, etc.
- *Energy crops (i.e. grown especially for energy):* fast growing trees (poplar, willow, pine, eucalyptus), grasses (switchgrass, elephant grass, prairie bluestem, sorghum), starch crops (maize, wheat, barley, etc.), sugar crops (sugar cane, sugar beets), oilseed crops (soybean, sunflower, rapeseed, safflower, etc.)
- *Agricultural residues:* husks (rice, sunflower, coconut), straw (rice, wheat), shells (nuts, coconut), bagasse, corn fibre, coffee grounds, used vegetable oils, etc.
- *Aquatic plants:* algae, seaweed, water hyacinth, reed, rushes, etc.

Animal waste

- *Manure*: especially from cows, chicken and pigs

Industrial waste

- *By-products and residues of food processing*: e.g. vinasse, scraps from fruit and vegetables, etc.

Municipal waste

- Organic kitchen waste, paper, cardboard, yard clippings, sewage, waste water, landfills, etc.

[48] National BioEnergy Industries Association (1997), *U.S. Bioenergy Industries Directory*, p. 1.
[49] Mathews and van Holde, *Biochemistry*, Benjamin/Cummings, California (2nd ed.,1996), p. 588.

Biomass is a renewable resource because it can be replaced quickly e.g. by replantation. Furthermore, it is an abundant resource in the sense that it is available nearly everywhere on Earth. In some cases, however, problems may occur if the use is not properly managed: if trees, for example, are used extensively without being replanted, this may lead to deforestation and erosion.

When biomass is burned, various gasses – carbon dioxide (CO_2), nitrogen oxides (NO_x) and sulphur dioxide (SO_2) – are released to the atmosphere. From an environmental viewpoint, an advantage of using biomass for energy production is its very low content[50] of pollutants compared to fossil fuels. Even though the release of nitrogen oxide may still be of some environmental concern, biomass contains very little sulphur. Both sulphur dioxide and nitrogen oxides are a cause of acid rain[51]. But because biomass is burned at lower temperatures than fossil fuels, nitrogen oxide levels are lower. Another feature of biomass is that its use does not result in a net carbon dioxide increase since no carbon dioxide is added to the atmosphere (CO_2-neutral) as long as an equivalent amount of vegetation is replanted. Combustion of biomass reverses the process of photosynthesis so that carbon dioxide (and water) is returned to the atmosphere where it is 'recycled' by new plants.

3.2.1 Refining of Raw Biomass into Fuels

Biomass is used either in its original form or after it has been processed into useful fuels by various conversion methods. Fuels made of biomass can be solid, liquid or gaseous. Broadly, there are four techniques for preparing biomass so that it can be used as a fuel. These are briefly described in the following.

- **Unprocessed or slightly processed**

The most common way of using biomass as a fuel is to use it as it is or after a slight processing, such as cutting wood into smaller pieces that are easier to handle. Burning biomass in this way is known as *direct combustion*. All biomass with a moisture content of 55% or less can be used[52], but the most suitable fuels are wood, energy crops, agricultural residues in addition to solid municipal waste. In order to make fuels that are more compact, biomass is sometimes compressed into briquettes or pellets.[53] Oil extracted from oilseed crops, especially rapeseed, can be used as a replacement for diesel in cars or as heating oil.

- **Pyrolysis and gasification**

These processes, which convert solid biomass (usually wood) into liquid and gaseous fuels, are similar, as gasification is a variation of pyrolysis. Converting solid biomass into liquid and gaseous fuels can make fuel handling easier. In the pyrolytic process, biomass is heated or partially burned with no or limited oxygen supply, producing 3 different useful

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[50] Biomass contains by weight about 40% carbon, 53% oxygen, 7% hydrogen, 0.3-3.8% nitrogen and 0.1-0.9% sulphur. Source: *Biomass burning and the production of greenhouse gases* <http://asd-www.larc.nasa.gov/biomass_burn/biomass.html> (1 Mar. 2001).

[51] Sulphur dioxide is the main cause of acid rain (causing about 70% of acid rain), while mainly nitrogen oxides (NO_2 and NO_3) account for the rest. Source: *Acid rain* <http://www.soton.ac.uk/~engenvir/environment/air/acid.home.html> (1 Mar. 2001).

[52] National BioEnergy Industries Association (1997), *U.S. Bioenergy Industries Directory*, p. 3.

[53] *The Australian Renewable Energy Website* <http://acre.murdoch.edu.ay/biomass/biomass.html> (25 Feb. 2001).

combustible product: hydrocarbons rich gas, oil and charcoal. Gasification[54] is carried out with more air and at higher temperatures. Partial burning and partial cooking of the biomass produces a flammable gas consisting of hydrogen (H_2), carbon monoxide (CO) and methane (CH_4) together with non-flammable carbon dioxide and nitrogen. This gas mixture can be burned in the same way as natural gas, e.g. in gas-fired engines and for electricity generation. Methane can be further converted into a liquid form, methanol.

- **Anaerobic digestion**

This is a process based on bacterial decay. Biomass, such as animal manure, kitchen waste or wastewater, is put into an airtight container (a digester) together with bacteria and water. Bacteria feed on dead plants and animals, and in this process the organic material is broken down. The product is a gas known as *biogas*, which consists of mainly methane (CH_4) mixed with carbon monoxide and carbon dioxide. Biogas is nearly the same as natural gas, which also consists of methane. Again, methane can be converted to methanol. Biogas can be burned directly for cooking and heating, and used for electricity generation, combustion in gas engines, etc.

- **Fermentation**

This is the production of alcohol. By adding yeast to biomass containing sugar or starch such as sugar cane, sugar beets, and cereals, the biomass ferments. Sugar is broken down and converted into alcohol, also called ethanol (C_2H_5OH). This liquid fuel can be used for combustion in car engines, which has been done with success in Brazil. Wine, beer and liquor is produced in the same way.

Bioenergy accounts for about 15% of world energy use, while it represents about 35% of the energy used in developing countries; in these countries it is mainly burned for cooking and heating.[55] In industrialised countries, generally, the fraction is lower than world average, although it varies from country to country. In OECD Europe, biomass accounts for 3.5% of energy use (1998).[56] Several organisations deal with the issue of biomass; in Europe, wider use of biomass is promoted by AEBIOM.

The European Biomass Association (AEBIOM)

The European Biomass Association, officially Association Européenne pour la Biomasse (AEBIOM), was formed in 1990 with location in Belgium. It is a non-profit organisation which aims[57] to promote production and application of biomass throughout Europe. This is done, among other things, by developing and suggesting solutions that can remove obstacles to biomass development, by organising conferences and seminars, by the co-ordination of international activities, and by assisting in the establishment of national biomass associations. AEBIOM's members consist exclusively of national biomass associations all over Europe[58], both in Western, Central and Eastern Europe.

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[54] *Biomass energy* <http://www.soton.ac.uk/~engenvir/environment/alternative/biomass> (25 Feb. 2001).
[55] *Biomass energy fact sheet* <http://www.me3.org/projects/seed/biomass.html> (25 Feb 2001).
[56] Includes waste. Source: OECD/IEA (2000), *Energy balances of OECD countries 1997-1998*, p. II.35.
[57] *AEBIOM*<http://ecop.ucl.ac.be/aebiom> (26 Feb. 2001).
[58] AEBIOM's members currently list the national biomass associations of: Austria, Belgium, Bulgaria, Czech Republic, Denmark, Estonia, Finland, France, Greece, Italy, Ireland, the Netherlands, Norway, Poland, Slovakia, Slovenia, Spain, Sweden, Switzerland, and the United Kingdom. *AEBIOM*<http://ecop.ucl.ac.be/aebiom> (26 Feb. 2001).

The European Biomass Industries Association (EUBIA)

The European Biomass Industries Association (EUBIA) is located in Belgium. Inquiries were sent to Giuliano Grassi, secretary-general of the association, in order to obtain information about EUBIA but unfortunately no answer was received.

3.3 Ways of Generating Electricity and Heat

Electricity and heat can be produced separately or together (cogeneration). A wide range of energy sources and technologies are used to produce heat and power.

Electricity generation

Electricity can be produced via the movement of turbines or directly from sunlight. Typically, electricity is produced in a power plant, which often has a capacity of 2,500 MW or more. When turbines are used for electricity generation, the principle of electricity generation is the same whatever energy source is used. Mechanical movement is converted into electricity: steam or other forces are used to make a turbine spin, the shaft of which is connected to a generator. Inside the generator, a copper wire is hereby made to spin between magnets, creating an electric current in the wire.[59]

A thermal power plant is a plant that uses steam to drive the turbines. A fuel is used to boil the water creating steam. Examples of thermal power plants are coal-, oil-, or natural gas-fired power plants, nuclear power plants, biomass-fired power plants, and geothermal power plants. In this case, the steam will be needed to cool off, and this is usually done with water. In cogeneration plants, the water used for cooling is not wasted but used for heating, for example in the form of district heating.

In addition to steam, air or water movements can be used to drive turbines directly. Examples of such power plants are hydroelectric power plants, wind power plants ("wind farms"– a group of wind turbines interconnected to a common utility system), and tidal and wave power plants. Electricity can be produced without using turbines. Sunlight can be converted directly to electricity in photovoltaic applications.

Electricity does not have to be produced in a power plant. It can be produced on a smaller scale by small photovoltaic applications; or by electric generators, e.g. gas engines, diesel engines, and Stirling engines, which all convert mechanical movement into electricity. Farms sometimes have their own wind turbine for electricity supply.

Heat

Heat for heating of houses can be generated by combustion of various fuels such as oil, coal, natural gas, or biomass. In addition electricity or heat from the sun can be used for heating purposes. Heat can be generated directly in the rooms or spaces that are to be heated, for example in fireplaces or stoves. In central heating systems heat is generated

[59] *Electricity generation* <http://www.state.hi.us/dbedt/ert/electgen.html> (4 Mar. 2001).
Chapter 3:generators, turbines and power plants <http://www.energy.ca.gov/education/story/story-html/chapter03.html> (4 mar. 2001).

centrally, outside the space to be heated whereupon this heat is transferred to the space where it is needed by water or by air.

District heating plants generate and supply heat in the form of hot water and steam collectively, i.e. to multiple buildings. District heating plants include both combined heat and power (cogeneration) plants and heating plants. In cogeneration plants, it is the waste heat from electricity generation that is used for heat supply in district heating.

3.4 Cogeneration or Combined Heat and Power (CHP)

Cogeneration can be defined as the simultaneous generation of electrical energy and thermal energy from the same fuel source. Another well-used term for cogeneration is combined heat and power (CHP); and less frequently an older term, total energy system, is used.

A benefit of cogeneration is its higher overall fuel efficiency (up to 90% of the energy of the fuel is used) as opposed to a production of electricity alone, because heat is recovered and used which would otherwise be wasted. In this way, fuel consumption can be reduced. Also, if electricity is put to use at the point where it is generated, it can eliminate losses that occur during transportation of electricity through the cables of transmission and distribution systems.[60]

According to COGEN Europe,[61] in average about 10% of the electricity in EU members states is produced by cogeneration, but especially Austria, Denmark, Finland and the Netherlands have a high percentage of electricity generation based on cogeneration. In the Eastern and Central European countries, Czech Republic, Hungary and Poland, cogeneration is common and the heat is used for district heating.[62]

3.4.1 Micro-Cogeneration (or Micro-CHP)

Micro-cogeneration is one type of cogeneration. Although many books have been written about cogeneration, mainly about larger plants, little literature seems to exist specifically about *micro*-cogeneration, presumably because it is a more recent technology that has been made possible with the development of small internal combustion engines, Stirling engines, fuel cells, etc. Literature about micro-cogeneration is primarily in the form of articles, but unfortunately it was not possible for the author to get hold of other literature on micro-cogeneration than COGEN Europe's "An introduction to micro-cogeneration" (1999).

There are several categories of cogeneration based on electric output size: large-scale, small-scale and micro-cogeneration. Apparently there are yet no clear agreements[63] as to

[60] C. Butler, *Cogeneration,* McGraw-Hill, New York (1984), p. 108.
[61] COGEN Europe Members Directory, *Who's who in European cogeneration 1999-2000*, p. 7-8.
[62] *Cogeneration in Europe: overview by country* <http://www.cogen.org/whafra6.html> (31 May 1999).
[63] For example, the Technological Institute (Denmark), in conference proceedings on mini- and micro-cogeneration (16 May 2000), defines micro-cogeneration as below 5 kW(e) and mini-cogeneration as 5-60 kW(e), while COGEN Europe's definitions are different. The same differing definitions can be seen on web sites on the World Wide Web.

the size of electric output of these categories; however, small-scale cogeneration usually refers to systems below 1 MW(e). According to COGEN Europe,[64] micro-cogeneration is cogeneration below 20 kW(e). Furthermore, COGEN Europe divides micro-cogeneration into the following sub-divisions:

- **domestic** cogeneration with an electric output of 3 kW or less designed for single households, and
- **non-domestic** cogeneration, also referred to as mini-cogeneration, having an electric output of more than 3 kW (i.e. ~20 kW), which can be used in small hotels, apartment blocks, swimming pools, or the like.

By this definition, External Power's wood pellet fuelled 1Twin falls within the domestic micro-cogeneration category.

3.5 Cogeneration Associations

The cogeneration industry is organised in national, regional and international associations. Many of these associations are members of each other's associations and thus form a network. In short, they all work to promote the use of cogeneration and represent the interests of their members in the cogeneration industry. Below are the main organisations, which might give some indication of which countries are active within cogeneration.

The International Cogeneration Alliance (ICA),[65] located in Belgium, was created in 1998 in order to represent the cogeneration industry world-wide with members among national and regional cogeneration associations. Members include the Australian EcoGeneration Association, COGEN Europe, the Combined Heat and Power Association of the United Kingdom, and the United States Combined Heat and Power Association.

COGEN Europe,[66] located in Belgium and created in 1993, has members in most of Europe, which include both companies and national cogeneration associations[67]. However, COGEN Europe also has members outside Europe in Australia, Japan and the United States, and all in all there are about 190 members. COGEN Europe has set up four working groups, one of which is the "Micro-cogeneration Working Group". The purpose of this working group is among other things to assess the market possibilities of micro-cogeneration systems.[68]

The other important cogeneration associations that should be mentioned briefly are those located in Australia, New Zealand, United Kingdom and the U.S.A. **The Australian EcoGeneration Association (AEA)**[69] was formerly the Australian Cogeneration Association. **The Cogeneration Association of New Zealand**'s mission[70] is to stimulate recognition of the benefits of cogeneration and enhance the business prospects of its members. **The Combined Heat & Power Association (CHPA)** of the United Kingdom works[71] to promote

[64] COGEN Europe Briefing 8 (Jan. 1999), *An introduction to micro-cogeneration*, p. 3.
[65] ICA <http://www.localpower.org> (19 Oct. 2000).
[66] *COGEN Europe* <http://www.cogen.org> (19 Oct. 2000).
[67] COGEN Europe's European national cogeneration association members are from the following countries: Austria, Belgium, Denmark, Croatia, Estonia, France, Germany, Greece, Hungary, Italy, Luxembourg, the Netherlands, Poland, Portugal, Slovenia, Spain, Turkey, and United Kingdom.
[68] *Micro-cogeneration Working Group* <http://www.cogen.org/cogfra5.html> (18 Feb. 2001).
[69] *The Australian EcoGeneration Association* <http://www.ecogeneration.com.au> (17 Feb. 2001).
[70] *The Cogeneration Association of New Zealand* <http://www.cogen.org.nz> (18 Feb. 2001).
[71] *The Combined Heat & Power Association* <http://www.chpa.co.uk> (18 Feb. 2001).

the wider use of CHP. The **United Stated Combined Heat & Power Association (USCHPA)** advocates[72] that combined heat and power receive recognition by U.S. federal and local governments.

[72] *The United States Combined Heat & Power Association* <http://www.nemw.org/uschpa> (18 Feb. 2001).

4 Wood Pellets in Europe

Due to the limited company size, it is highly unlikely that External Power is going to be directly involved in fuel supply to owners of the wood pellet fuelled 1Twin. The purpose of this chapter is to identify potential European markets of the wood pellet fuelled 1Twin based on the criteria of wood pellet availability. A minimum requirement is that it is possible for the wood pellet fuelled 1Twin-user to obtain the necessary wood pellets, and therefore the wood pellet fuelled 1Twin cannot be offered to markets where wood pellets are not available.

In an international context, Canada and the United States have some of the most developed markets in terms of wood pellet availability and they are also the markets where wood pellet industries have existed for the longest time. Nevertheless, according to the Pellet Fuels Institute,[73] in 1996 Sweden's annual consumption of wood pellet fuel caught up with and surpassed the consumption in the United States.

In this chapter we present necessary background information about wood pellets in order to understand the wood pellet industry and markets. Apart from describing what wood pellets are, we describe how they are produced so that the requirements for the equipment of a wood pellet manufacturer can be understood. This will give us an idea of what is required for the establishment of new wood pellet factories and therefore how quickly we can expect wood pellet availability to expand. We also discuss general advantages and disadvantages of using wood pellets in order to understand what might motivate potential customers of the wood pellet fuelled 1Twin to use a product requiring this fuel.

Most importantly, we explore the present European market for wood pellets. To the author's knowledge, literature about wood pellets is scarce and no complete lists have yet been compiled showing countries in Europe with wood pellet availability. This chapter is based on three main reports: 1. *Industrial Network on Wood Pellets* (Malisius et al., 2000), 2. *Biomass Tank* (Grübl et al., 1998), and 3. *Systemstudier – Brenselsiden* (Skaugen et al., 1997). Furthermore it is based on documents on the World Wide Web from manufacturers and organisations and on personal inquiries.

4.1 What are Wood Pellets?

Wood pellets are made from waste wood from the wood industry such as sawdust, shavings and ground wood chips. This material has been compressed into small pellets, cylindrical in shape. Trees can be softwood (e.g. conifers, pines) or hardwood (e.g. oak). Hardwood has a higher content of dry matter per m^3 than softwood. Both the bark and the xylem of the trunk can be used for making wood pellets, although it is most common to use

[73] Pellet Fuels Institute: *And Then There Were Pellets* (Press release, date unavailable. See <http://www.pelletheat.org>).

the xylem. Below some facts concerning wood pellets are presented which are explained later.

Facts about Wood Pellet Fuel

Material:	Wood shavings, sawdust, wood chips, and other wood residues.
Dimensions:	Diameter typically 5-12 mm; length 5-40 mm.
Moisture contents:	Approx. 8%
Ash contents:	Approx. 0.5- 1%
Net calorific heating value:	Approx. 4.9 kWh/kg
Density:	Approx. 650 kg/m^3

Compared to other fuels in use today, wood pellets represent a relatively new type of fuel. According to a press release from the Pellet Fuels Institute,[74] wood pellets did not come into existence until the 1970s when they appeared for the first time in North America as an alternative fuel whose primary purpose was to help resolve the energy crisis. In the beginning they were used mainly by industrial and commercial sectors and by institutions for heating. When the first residential wood pellet stoves were sold to consumers in 1983, a residential wood pellet industry was created.[75] Today North America has over 70 wood pellet manufactures.[76]

In Europe wood pellet production began later than in North America. Various sources on wood pellets provide inconsistent versions of the history of wood pellets. According to the Pellet Fuels Institute,[77] Sweden started production of wood pellets in the 1990s, but Malisius et al. claim[78] that the first wood pellet plant started production already in 1982.

4.1.1 Manufacturing of Wood Pellets

Wood pellets are manufactured at wood pellet mills. The manufacturing process[79] is determined by the raw material but usually includes the following steps: reception of raw material, screening, grinding, drying, pelletising, cooling, sifting, and packaging.

Before sawdust, shavings or chips can be pelletised, it is important that the material is dry and homogeneous. Too big particles damage wood pellet quality, and usually the raw material is pulverised using e.g. a hammer grinder. Wet material is dried to a moisture level of about 8-10%. The material is then pressed through a pellet die whose holes determine the diameter of the wood pellets, and then the pellets are cut into the desired length. It is unnecessary to add binders to hold the material together as lignin is found

[74] Pellet Fuels Institute: *Pellet Fuel Can Help Reduce Global Warming* (Press release, date unavailable. See <http://www.pelletheat.org>).
[75] Pellet Fuels Institute: *And Then There Were Pellets* (Press release, date unavailable. See <http://www.pelletheat.org>).
[76] Pellet Fuels Institute: *Customer Satisfaction Fuels Pellet Heat Popularity* (Press release, date unavailable. See <http://www.pelletheat.org>).
[77] Grübl et al., *Biomass Tank*, (1998), p. 11.
[78] Malisius et al., *Industrial Network on Wood Pellets*, (2000), p. 9.
[79] Where nothing else is noted the section is based on Skaugen et al., *Systemstudier–Brenselsiden*, (1997), p. 14-17; Malisius et al., *Industrial Network on Wood Pellets*, (2000), p. 41-43; and Videncenter for Halm-og Flisfyring (1999) *Træ til energiformål*, p. 20.

naturally in wood and functions much the same way as glue[80]. Additional moisture is extracted from the material during the compression process.

As they leave the die, the wood pellets are very hot, around 90-95˚C. Cooling the wood pellets to a temperature of 25˚C hardens them. Remaining dust and fines is sifted away and the finished wood pellets are bagged or stored in silos. Wood pellets have to be handled so that they are protected against moisture and so that they do not fall apart.

Wood pellet quality is being improved by new developments in wood pellet manufacturing technology. In Norway, Cambi Bioenergi Vestmarka AS has developed a (still non-commercial) technology that makes wood pellets harder and more durable, less sensitive to moisture with fewer fines and a density of 850 kg/m^3. The new technology involves exposing sawdust to a steam-compression reactor; the pressure makes the material "explode" into wood fibres and releases lignin.

4.1.2 Some Quality Measures of Wood Pellets

Wood pellet quality from different manufactures can vary. Some important measures of quality are the size, the amount of fines, density, moisture contents, net calorific heating value, and ash contents.

These quality measures apply especially to wood pellets that are used in the residential sector. Whereas e.g. large heating plants do not require wood pellets of high quality, a small wood pellet burning device in the home, e.g. a wood pellet stove, does require consistent wood pellets without too many fines.

To ensure unproblematic operation of the wood pellet burning device, wood pellet *size* has to be consistent. Moreover, sawdust coming from pellet breakdown can be a problem. Wood pellets should therefore be without too many *fines* as these can cause technical problems if they build up in the fuel hopper and as they may reduce the burn quality.[81] Also, dust may be a problem if it is spread while loading wood pellets into the storage room. It is best that the wood pellets are of high *density* as low density wood pellets may create many fines. Also, wood pellets with low density can cause the fire to go out on very low burn settings.[82]

Other quality measures are moisture contents and net calorific heating value. The lower the *moisture contents* of the wood pellets is, the better they will burn. And the higher the *net calorific heating value* is, the more energy the wood pellets contain. Usually 1 kg of wood pellets contains around 5 kWh or about the same as 0.5 litre fuel oil.

Ash contents, meaning the amount of ash that is left when the wood pellets have been burned, indicates the quality of the material that the wood pellets are made of. Usually

[80] *Pellet Fuels Institute: What are pellets made of?* <http://www.pelletheat.org/fuel/46955.shtml> (13 Oct. 1999).
[81] *Pellet Fuels Institute: What are the common characteristics of pellets?* <http://www.pelletheat.org/fuel/59993.shtml> (13 Oct. 1999) and *Bear Mountain Forest Products Inc.* <http://www.bmfp.com> (10 Nov 2000).
[82] *Glossary* <http://www.pellet.org/glossary.html> (10 Nov. 2000).

wood pellets contain less than 1% ash. However, wood pellets made of bark contain more ash than other types of pellets because of the impurities contained in bark. For the consumer, lower ash contents means less ash removal and cleaning.

4.1.3 Dimensions of Wood Pellets

Wood pellets are produced in various sizes with diameters typically from about 5 mm to 12 mm. To the author's knowledge there is currently no international standards on the dimensions of wood pellets but in several countries voluntary national standards exist: in the United States, Canada, Austria, Germany, Sweden and the United Kingdom. The standards specify not only dimensions but also other quality measures.

The Pellet Fuels Institute with members among wood pellet manufacturers in North America has set some voluntary industry standards; here the standard for the diameter is ¼ inch (6.5 mm) or 5/16 inch (8.0 mm).[83] In Europe, standards have been set in Austria by Österreichisches Normungsinstitut, specified in ÖNORM M 7135. In Germany standards have been specified by Deutsches Institut für Normung e.V. with DIN 51731 concerning pressed wood and in Sweden by Standardiseringen i Sverige with SS 187129. In the United Kingdom, British BioGen, the Trade Association to the UK Bioenergy Industry, has proposed the adoption of a voluntary standard covering both pellets and pellet appliances: "British BioGen Code of Good Practice (COGP) for Biofuel Pellets and Pellet Burning Appliances".

According to British BioGen,[84] efforts are underway to develop a European Standard[85], *EN* (e.g. BS EN in the case of United Kingdom), for all biofuels, including wood pellets, and it is estimated that the process will take until 2005.

Lengths of wood pellets with uniform diameter can vary because wood pellets may break into smaller pieces. The length is typically 5-40 mm,[86] which is about the same as the standard of the Pellet Fuels Institute that operates with a maximum length of 1.5 inch (38 mm)[87].

4.1.4 Prices of Wood Pellets

In Europe, wood pellets can be bought in bags of different sizes or in bulk. A random check of various offers from European wood pellet manufacturers and suppliers shows that prices of wood pellets generally depend on the quantity purchased at a time. Not surprisingly, if the customer buys one bag of e.g. 15 kg, the kilo-price will be higher than if they are bought in bulk e.g. a tonne or more at a time. Wood pellet prices can also vary with the season and are usually cheapest in spring and summer.

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83 *Pellet Fuels Institute* <www.pelletheat.org/fuel/59993.shtml> (13 Oct. 1999).
84 *The British Biogen Code of Good practice* <http://www.britishbiogen.co.uk/bioenergy/pellets/cogp.htm> (4 Sep. 2000).
85 This is done by the European Committee for Standardization, CEN (Comité Europeen de Normalisation) with members in Europe, including the British Standards Institute. See for example the web site of CEN : <http://www.cenorm.be>.
86 Videncenter for Halm- og Flisfyring (1999), *Træ til energiformål*, p. 16.
87 *Pellet Fuels Institute: What are the common characteristics of pellets?* <http://www.pelletheat.org/fuel/59993.shtml> (13 Oct. 1999).

Prices of wood pellets can be found on web sites of manufacturers and supplier of wood pellets. Wood pellet manufacturers are listed in Appendix A. Malisius et al. have compiled a list[88] of wood pellet prices in European countries. In this list from September 1999, prices are measured in Euro per kWh, and they span from 0.020 to 0.056 EUR/kWh. Unfortunately, no mention is made of the sources of the list.

4.2 Organisations that Promote Wood Pellets

Organisations that promote wood pellets seem to be best organised in the United States and in Canada. In the United States we find the Pellet Fuels Institute (PFI) with members related to the wood pellet industry in both the United States and in Canada. In Canada we find BC Pellet Fuel Manufacturers Association (BCPFMA).

In Europe there are apparently only two similar trade organisations specifically for wood pellet manufacturers and suppliers. Sweden has Pelletsindustrins Riksförbund (PiR) or the National Association of Pellet Producers with 12 members.[89] And Austria has a trade organisation, Pelletsverband Austria (PVA), with members among wood pellet suppliers. More details about wood pellet organisations are offered in Appendix B.

In most countries the issue of wood pellets is rather handled under biomass organisations, such as national members of AEBIOM, the European Biomass Organisation. During the research it seemed that the degree of expertise about wood pellets varies, however, among national biomass organisations.

4.3 Reasons for Using Wood Pellets: Advantages and Disadvantages

Advantages or disadvantages concerning the use of wood pellets can be categorised according to two points of view: the societal viewpoint, e.g. environmental, and the viewpoint of the individual using the wood pellets.

Most of the arguments put forward by wood pellet manufacturers and by organisations are concerned with societal benefits. These arguments focus on the environmental benefits, such as wood pellets being a renewable energy source, being CO_2-neutral and reducing greenhouse gasses if they substitute fossil fuels. Grübl et al. mention[90] that there is no danger of pollution in case of an accident with wood pellets. In addition, the "environmental" arguments stress that wood pellets are by-products of scrap wood, which might otherwise have been disposed of and that consequently trees are not felled for the sole purpose of producing wood pellets.

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[88] See Malisius et al., *Industrial Network on Wood Pellets*, (2000), p. 64.
[89] *Pelletsindustrins Riksförbund* < http://www.pelletsindustrin.org/pir_uk.html> (28 Aug. 2000).
[90] Grübl et al., *Biomass Tank*, (1998), p. 58.

Another "societal" advantage which has been put forward is a macroeconomic benefit, namely that production of wood pellets contribute to the creation of jobs in the country.

Other arguments for using wood pellets are of the second type: that they are beneficial for the consumer. For example, these arguments claim that because of their homogeneity, wood pellets are well suited for automatic fuel supply to wood pellet-burning equipment. Furthermore, it is argued that wood pellets are safe and clean to touch and smell like wood.[91] Naturally, wood pellets are of benefit to the consumer if money is saved by using wood pellets rather than other types of fuels or energy sources.

In a press release,[92] the Pellet Fuels Institute lists a number of reasons why people in the United States and Canada choose to use wood pellets. Despite the fact that these reasons apply to the use of wood pellets as a fuel mainly for wood pellet stoves, they could give some idea of the general reasons for using wood pellets. The motivations that are listed by the Pellet Fuels Institute can be divided into the following main categories.

People use wood pellets for wood pellet stoves because:

1. They want to enjoy the atmosphere of a real wood fire but do not want the trouble that comes with cordwood, such as splitting cordwood, tending the fire, and removing ash. Furthermore, with wood pellets they get an instant and longer-burning fire. In addition, wood pellets do not take up as much space as cordwood and are therefore ideal also in condominiums and townhouses.
2. They are concerned about the environment.
3. They seek an economic fuel especially as relief to electricity, oil and propane.

Since one will probably not be able to enjoy the atmosphere of burning wood by using the wood pellet fuelled 1Twin, mainly the last two of the three reasons can be said to apply to a wood pellet fuelled 1Twin-user.

Not many disadvantages are mentioned. For the consumer, however, using wood pellets may create extra work compared to for example using natural gas. The reason is that wood pellets are a solid fuel that cannot be transported in pipes as natural gas. Wood pellets have to be ordered or picked up and they have to be stored.

4.4 A Survey of Wood Pellet Availability in European Countries

One might think that there is a connection between large forest areas and wood pellet availability in a country, but this is not always the case. For example, wood pellets are available in Denmark and here the share of forest area is only 10% of the total area. Yet, Belgium with a forest area of 20% of total area does not have wood pellets. However,

[91] Ibid.
[92] Pellet Fuels Institute: *Who's Heating With Wood Pellets Today?* (Press release, date unavailable. See <http://www.pelletheat.org>).

Sweden which is one of the European "leaders" in forest areas with 59% of the total land area covered by forests[93], does have Europe's largest production of wood pellets.

Unlike in the United States and in Canada where wood pellet manufacturers are organised e.g. in the Pellet Fuels Institute and where consequently information about availability of wood pellets is readily accessible, information about wood pellets in Europe is very dispersed.[94] The following contains information about the present wood pellet situation in individual European countries. For further reference, Appendix A contains a list of wood pellet manufacturers in Europe.

4.4.1 Austria

Austria has a well-developed wood pellet market. The report by Grübl et al. contains some information about the Austrian wood pellet market, and contacting Mr. Johannes Schmidl from Österreichischer Biomasse-Verband led to more detailed information.

According to Malisius et al.,[95] in 1994 a wood briquette company in Austria was the first to import wood pellets from Sweden and the Netherlands in order to test the market. In 1995 two companies started their own production of wood pellets.[96] In that year production amounted to 2,500 tonnes, and the next year, in 1996, the production increased by about 80% to 15,000 tonnes. In 1997 there were eight wood pellet manufacturers with a production of about 29,000 tonnes.[97]

The author is aware of 13 wood pellet manufacturers presently (Nov. 2000). According to Malisius et al., the current (1999) total production capacity lies around 118,000 tonnes/year, and total production is around 40,000 tonnes/year.[98]

4.4.2 Belgium

Mr. Yves Schenkel from the Belgian Biomass Association states[99] that Belgium has no market for biomass fuel pellets presently (Dec. 1999). However, a project is being carried out in which the European market for pellet fuels is assessed. Unfortunately, it was not possible to learn more about this project.

4.4.3 Bulgaria

The wood pellet industry and market in Bulgaria is in the pioneering stage with one wood pellet manufacturer, Axis Ltd., located in Sofia. In Bulgaria there is a large amount of wood residue available for wood pellet production and Axis Ltd. is taking advantage of the opportunities.

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[93] *Global Foresty Data* <www.forestworld.com/wow/country/countryframe.html> (31 Dec.1999).
[94] E-mail from Leslie Wheeler, Pellet Fuels Instituite (15 Nov. 1999).
[95] Malisius et al., *Industrial Network on Wood Pellets*, (2000), p. 29.
[96] Grübl et al.,*Biomass Tank*, (1998), p. 45.
[97] Op.cit., p. 46.
[98] Malisius et al., *Industrial Network on Wood Pellets*, (2000), p. 31.
[99] E-mail from Yves Schenkel, Belgian Biomass Assocaion (BELBIOM) (6 Dec. 1999).

According to Mr. Nikolay Dilkov,[100] the General Manager of Axis Ltd., the company expects soon to be ready to implement a project for introducing wood pellet heating in the country. In Bulgaria wood pellet heating has so far been unknown but Mr. Dilkov believes that it will be a new alternative to heating in the near future. The plan is to produce wood pellets and at the same time to import wood pellet stoves and furnaces. The company has already contacted manufacturers of wood pellet stoves and furnaces in Sweden, Canada and U.S.A., and as soon as the company can achieve a satisfactory level of wood pellet quality, it is going to launch its project.

4.4.4 Czech Republic

Existing literature does not indicate the availability of wood pellets in the Czech Republic. The Czech Biomass Association (CZ-BIOM) but unfortunately no answer was received.

4.4.5 Denmark

The Centre for Biomass Technology (Videncenter for Halm- og Flisfyring) has compiled a list[101] which shows that Denmark had ten wood pellet suppliers in 1996. All the companies supplied to private consumers. In addition, Mr. Henrik Houman Jacobsen[102] from the Centre for Biomass Technology informs that A/S Dansk Shell has started selling wood pellets.

In order to update and confirm the information on the list, an attempt was made to contact the companies. It turned out that at least three of the companies, Assens Træpille Industri A/S and Pindstrup Bioenergi A/S and Lerche-Henrichsen & Møller A/S, had stopped producing wood pellets.[103] Lerche-Henrichsen & Møller, however, was planning to start a wood pellet production of 1,000 tonnes/year again in 2001.

Among wood pellet manufacturers, there is a big variation in the size of wood pellet production. Hp briketter A/S and A/S SPANVALL are the largest manufacturers. Hp briketter A/S has a capacity of 110,000 tonnes/year[104] but an estimated production of 85,000-90,000 tonnes wood pellets in 2000[105]. Smaller companies produce around 1,000 tonnes/year.

Mr. Pieter Kofman from Danish Forest and Landscape Research Institute estimates[106] that the Danish total wood pellet production is of the size 120,000 tonnes/year and that the same amount is imported.

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[100] E-mail from Nikolay Dilkov, General Manager of Axis Ltd, Sofia, Bulgaria (28 Dec. 1999).
[101] Videnscenter for Halm- og Flisfyring, Vidensblad nr. 99, *Leverandører af halm og træpiller* (31 July 1996).
[102] Telephone communication with Henrik Houmann Jacobsen (13 Sep. 1999).
[103] Telephone communication with Assens Træpille Industri A/S, Pindstrup Bioenergi A/S and Lerche-Henrichsen (27 Jan. 2000).
[104] *Hp briketter A/S* <http://www.hpbriketter.dk> (6 April 2000).
[105] Telephone communication with Hans Poulsen, Hp briketter (27 Jan. 2000).
[106] E-mail from Pieter Kofman, Forskningscentret for Skov & Landskab (3 Feb. 2000).

According to web sites of various Danish wood pellet companies, it seems that wood pellets are available in the whole country at a price level of around DKK 800-900 per tonne excluding VAT and transport, and around DKK 1,000 per tonne including VAT.

4.4.6 Estonia

Energy consultant Ms. Meeli Hüüs, leader of the board of the Estonian Biofuels Association (EBA), informs[107] that Estonia has two large manufacturers of wood pellets: Hansa Graanul Ltd., located in the southern part of Estonia, and Flex Heat AS, located near the town Rakvere in Väike-Maaja.

Hansa Graanul Ltd. produces wood pellets primarily for export to Sweden. Hansa Graanul was founded in 1994 by the Swedish company Fastbränsle AB in collaboration with 3 Swedish and Estonian private persons.[108] According to Mr. Rainer Kuutma,[109] Member of Board at Hansa Graanul, the annual capacity lies around 25,000 tonnes. The price is DEM 125 per tonne (USD 65 per tonne) in bulk F.O.B. Pärnu Harbour South-West Estonia loaded on ship.

Flex Heat AS is a Danish wood pellet company, which started its operations in the autumn of 1999. The company’s production goes primarily to its own boilers (five 1.7 MW-boilers) and for export to Denmark. The company has an annual production of around 35,000 tonnes.

According to Ms. Hüüs, it is possible but complicated for Estonian customers to buy wood pellets as they have to place orders directly at the company. Wood pellets are very expensive for local people to use as a fuel in private houses. In Ms. Hüüs’ opinion, wood pellets will be useful in Estonia when technology that uses this fuel exists. At present, the state does not give support to such development, and furthermore environmental taxes on renewable energy are not favourable, and as from November 1999 a VAT was laid on all heat energy. Therefore she predicts that in the near future it is unlikely that biofuels, including wood pellets, are going to be further developed in Estonia.

4.4.7 Finland

Information about wood pellet production in Finland was obtained from Mr. Mikko Ahonen and Mr. Janne Nalkki from the Central Finland Energy Agency. Currently (2001)[110] there are 8 wood pellet manufacturers in Finland with a total production of around 155,000 tonnes/year. There has been a rapid development of new manufacturers since the first manufacturer, Finncambi Oy in western Finland, started production in 1998. In 1999, Ilonmantsin tehdas, Hehkupelletti Oy and Turengin tehdas started operation, and during 2000-2001, additional 4 manufactures started production.

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[107] E-mail from Meeli Hüüs, Estonian Biofuels Association (1 Dec. 1999)
[108] *High quality pellets from Estonia* <http://www.hansa.graanul.ee/history.htm> (6 March 2000)
[109] E-mails from Rainer Kuutma, Member of Board, Hansa Graanul Ltd. (7 March and 9 March 2000).
[110] *Wood pellet production in Finland 2000,,* OPET Finland (2001).

Although wood pellets are thus produced in Finland, very little is used in the country. 90% is exported mainly to Sweden and Denmark. The price of wood pellets is FIM 480-600/tonne (EUR 80-100/tonne) including 22% VAT. Because of long transportation distances and costs, distribution and use of wood pellets is concentrated relatively close to the wood pellet factories.

4.4.8 France

Mr. Fredric Douard from the European Institute of Wood Energy (l'ITEBE) informs[111] that wood pellet manufacturing began in France in 1982. Presently, there are three wood pellet manufacturers with an annual production of around 15,000 tonnes altogether, of which Cogra 48 is the largest manufacturer.

According to Mr. Douard, in the beginning of 2001, a “French Pellet Club” will be created within l'ITEBE.

4.4.9 Germany

According to Malisius et al.,[112] commercial wood pellet production in Germany began in the last two years in several locations. By combining lists of wood pellet manufacturers and suppliers in Germany found in Malisius et al.[113] and on the World Wide Web and by contacting the companies, it seems that there are 10 wood pellet manufacturers in the country. Malisius et al. estimate that 800,000-1,000,000 tonnes/year of raw material is available for wood pellet production, and can be re-distributed to this purpose as demand rises.

A German supplier of wood pellets, Biomassehof Allgäu-GmbH,[114] sells wood pellets in 15-kg bags costing DEM 6.40 a bag, while a pallet of 66 bags (990 kg) costs DEM 415 (equivalent to DEM 420 per tonne). Loose wood pellets are cheaper, costing DEM 319 per tonne, which is DEM 0.32 per kg.

The German Biomass Association, Deutcher Biomasse Verband (DBMV) was contacted in order to obtain details about the wood pellet market in Germany but unfortunately we received no answer.

4.4.10 Greece

According to Ms. Calliope Panoutsou from the Greek Biomass Association (HELLABIOM),[115] there is to her knowledge no wood pellet industry in Greece.

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[111] E-mail from Fredric Douard, l'ITEBE (22 Nov. 2000).
[112] Malisius et al., *Industrial Network on Wood Pellets*, (2000), p. 26.
[113] Op.cit., p. 84-85.
[114] *Preiseliste – Herbst 99* <http://www.holzbrennstoffe.de/preise_body.htm> (24 Sep. 1999).
[115] E-mail from Caliope Panoutsou, Greek Biomass Associaion (5 May 2000).

4.4.11 Hungary

As in Bulgaria, the Hungarian wood pellet market is in the pioneering stage with one recent start-up wood pellet company. The Hungarian wood pellet company, Kék Bolygó "Bioenergia" KFT is based in Nagycenk. The manager of Kék Bolygó, Mr. Gyula Asztalos, supplied information[116] about the company and about future plans. The company is the first and only in Hungary to produce wood pellets. Production starts in March 2000 with an annual capacity of 15,000 tonnes. The company plans to build and develop both production and distribution of wood pellets. The first customers to be targeted are big customers, e.g. thermal power plants and companies, but later also households will be targeted.

As wood pellets have not existed in Hungary previously, there has been no market for wood pellet burning appliances either. At around the beginning of 2000, Kék Bolygó began searching for wood pellet stoves/burners that the company could sell in Hungary. The company contacted manufacturers of wood pellet stoves/burners in Sweden to inquire about the possibilities of buying wood pellet appliances and representing wood pellet appliance manufacturers, respectively.

4.4.12 Ireland

Mr. Kevin Healion from the Irish Bioenergy Association states[117] that Ireland has neither production nor importation of wood pellets at present (Jan. 2000), but both options are being considered in order to promote wood pellets as fuel. A group of people are examining the potential of wood pellets in Ireland.

4.4.13 Italy

Mr. Fredric Douard from l'ITEBE is aware[118] of two wood pellet manufacturers in Italy, C&B Calor and La TiEsse.

4.4.14 Latvia

According to Mr. Martins Gedrovics[119] from the Latvian Development Agency's Department of Energy, Latvia has about 4 wood pellet manufacturers: CED, Latgranula, Latvall, and SBE Latvia. The total wood pellet production is approximately 40,000-50,000 tonnes/year of which about 91% is exported to Denmark and Sweden. Wood pellets are sold at the price of LVL 32.35/tonne in average from Liepaja harbour. The remaining 9% wood pellets are used in Latvia, mainly in the private sector.

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[116] E-mail from Gyula Asztalos, Manager of Kék Bolygó (5 Jan. 2000 and 3 Feb 2000).
[117] E-mail from Kevin Healion, Irish Bioenergy Association (13 Jan. 2000).
[118] E-mail from Fredric Douard, l'ITEBE (22 Nov. 2000).
[119] E-mail from Martins Gedrovics, Latvian Development Agency's Department of Energy (1 Nov. 2000).

Although a Latvian company by the name Delta Product LLC offers wood pellets in an advertisement on the World Wide Web[120], it was not possible to get further information about the company. The company was contacted but no reply was received.

4.4.15 Lithuania

It is unclear whether wood pellets are manufactured or available in Lithuania, as it was not possible to obtain any information whatsoever.

4.4.16 The Netherlands

According to Mr. Michel Arninkhof[121] from the Netherlands Bio-energy Association (NL-BEA), the Netherlands has 2 wood pellet manufacturers, Labee Group Moerdijk and Ekoblok BV. There seems to be a net export of wood pellets from the Netherlands, mainly to Austria and Scandinavia. Prices of wood pellets are not transparent.

4.4.17 Norway

According to Mr. Arnold Kyrre Martinsen[122] from the Norwegian Bioenergy Association (NoBio), Norway has 4 wood pellet factories with a total production of 10,000 tonnes annually: Cambi Bioenergi Vestmarka AS, Norsk Trepellets AS, Vaksdal Biobrensel AS, and Vi-Tre AS.

One more wood pellet manufacturer, Frya Bioenergi AS, is on the way. According to Mr. Roald Nilsen,[123] the company is currently (Nov. 2000) working on starting up a production.

About 6,500 tonnes of the production is consumed in Norway, while about 3,500 tonnes is exported, mainly to Sweden. Norway imports no wood pellets. The distribution system for wood pellets is still not very developed. Prices for private consumers vary depending on quantity: the kilo-price is NOK 1.50 for small bags, NOK 1.25 for big bags, and NOK 1.10 for wood pellets sold in bulk.

According to Malisius et al., wood pellet production on large scale has only started recently in Norway. Production capacity is expected to rise to 100,000 tonnes/year within the next two years, but much less is produced due to limited consumption.[124]

4.4.18 Poland

According to Ms. Magdalena Rogulska[125] from the Polish Biomass Association (POLBIOM), there is no market for wood pellets in Poland at the moment (May 2000). But

[120] *Wood pellets* <http://www.konsult.lv/pellets.htm> (6 March 2000).
[121] E-mail from Michel Arninkhof, Netherlands Bio-energy Association (2 May 2000).
[122] E-mail from Arnold Kyrre Martinsen, NoBio (16 March 2000).
[123] Telephone communication with Roald Nilsen, Frya Bioenergi AS (7 Nov. 2000).
[124] Malisius et al., *Industrial Network on Wood Pellets,* (2000), p. 14.
[125] E-mail from Magdalena Rogulska, POLBIOM (8 May 2000).

she knows of one company in Poland that manufactures wood pellets for the Danish market.

4.4.19 Portugal

In order to obtain information about the wood pellet market in Portugal a search was made for a national biomass association but apparently there is no biomass association in Portugal. However, a wood pellet price is mentioned in Malisius et al. and this may indicate that wood pellets are available in the country.

4.4.20 Slovakia

The literature does not mention the availability of wood pellets in Slovakia. The Slovak Association for Biomass (SK-BIOM) was contacted but unfortunately there was not reply.

4.4.21 Slovenia

Existing literature does not indicate that Slovenia has wood pellets. Unfortunately there was no answer from the Slovenian Biomass Association.

4.4.22 Spain

According to Mr. Fredric Douard from l'ITEBE[126], Spain has one wood pellet manufacturer, Ecoforest SA, with an annual production of about 9,000 tonnes.

4.4.23 Sweden

Wood pellet production in Sweden began in the mid-1980s, and today Sweden uses wood pellets more extensively than any other country in Europe. In 1990, around 10,000 tonnes wood pellets were produced, and in 1996 production rose to 500,000 tonnes.[127]

The author is aware of 16 wood pellet manufacturers in Sweden. Mr. Fredrik Lagergren[128] from the Swedish Bioenergy Association (SVEBIO) supplied more detailed information about the Swedish wood pellet market. According to Mr. Lagergren, the total consumption of wood pellets was about 550,000 tonnes in 1999 out of which 80,000 tonnes was consumed in the residential market. This was a 100% increase compared to the year before. 26,000 tonnes wood pellets were exported while about 40,000 tonnes were imported, mainly from Canada.

According to Mr. Lagergren, wood pellets are available in the whole country at a price level of SEK 0.15-0.30/kWh.

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[126] E-mail from Fredric Douard, l'ITEBE (22 Nov. 2000).
[127] Grübl et al., *Biomass Tank*, (1998), p. 131.
[128] E-mail from Fredrik Lagergren, Swedish Bioenergy Association (8 May 2000).

Documents on the World Wide Web show that prices vary slightly from supplier to supplier. SÅBI,[129] one of the larger manufacturers and suppliers of wood pellets, sells wood pellets in bulk for SEK 1,450-1,500/tonne (VAT included) when at least 3 tonnes is purchased at a time. Mockfjärds Biobränsle AB[130] sells wood pellets for the price of SEK 1,600/tonne and SEK 50 for a 25 kg-bag.

4.4.24 Switzerland

Switzerland currently (Nov. 2000) has one wood pellet manufacturer, Bürli Trocknungs-anlage, with a production of 1,000 tonne/year.[131]

The author talked to several wood pellet suppliers and other companies[132], and apparently the use of wood pellets is not yet widespread in Switzerland. The main reason is that devices using wood pellets, such as wood pellet stoves, are not widely in use. Most suppliers seem to get their wood pellets from Bürli Trocknungsanlage, but one imported from UMDASCH AG in Austria.

Bürli Trocknungsanlage sells wood pellets at a price of CHF 250/tonne, while Landwortschaftliche Genossenschaft sells them at a price of CHF 500/tonne.

4.4.25 United Kingdom

The United Kingdom's wood pellet market is developing. British BioGen (the Trade Association to the UK Bioenergy Industry) is working together with "Renewable Heat and Power Ltd and UK and EU partners on a project to 'Introducing Biofuel Pellets to the UK'."[133]

According to Mr. Desmond Godson,[134] Project Manager at British BioGen, there is in fact no wood pellet market in the United Kingdom, but work is being done to change the situation. Wood pellets are still not widely available. At the moment there is one working wood pellet fuel company and one other project is about to start. The existing wood pellet manufacturer's name is Envirofuel Ltd. Some of the companies that make wood pellets for cat litter are interested in supplying it as a fuel. Mr. Godson has no figures on the size of wood pellet production.

According to Giffard (1998),[135] clean softwood sawdust is made into pellets at six locations in the United Kingdom, but these are sold as cat litter and there is a possibility that these could be used as fuel as well.

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[129] *såbi prislista* <http://www.sabi.se/page/1/29.html> (10 Nov. 1999).
[130] *Mockfjärd Pellets* <www.dalnet.se/~bernth> (6 April 2000).
[131] Telephone communication with Bürli Trocknungsanlage (3 Nov. 2000).
[132] Telephone commmunication with Martin Vogel (8 Sep. 2000), Kohler, tel. +41 619119484 (8 Sep 2000), Diemo Handels AG (2 Nov. 2000), Hans Nebriker AGf (1 Nov. 2000), Interspan Tschopp (2 Nov. 2000), Landwortschafliche Genossenschaft (1 Nov. 2000), Savoldi Agrocenter (1 Nov. 2000) and Union Briekett-Verkauf AG (2 Nov. 2000).
[133] *Biofuel Pellets* <http://www.britishbiogen.co.uk/bioenergy/pellets/biofuelpellets.htm> (1 Sep. 2000).
[134] E-mail from Desmond Godson, Project Manager, British BioGen (2 May 2000).
[135] *10 Wood Pelletisation in the UK* <http://britishbiogen.co.uk/Bioenergy/Pellets/Swedish/p10.htm> (29 Nov. 1999).

In respect of the price of wood pellet fuel, according to Mr. Godson, two small-scale UK pelletisers are considering selling wood pellets at a bulk price of around GBP 70/tonne and bagged wood pellets will be sold at a higher price. In international commerce, wood pellets are sold at around GBP 65/tonne.[136]

4.5 What are the Future Tendencies?

From the survey it can be seen that both wood pellet industries and consumer markets (availability, distribution, etc.) in Europe are presently at different stages of development, which may be categorised as follows:

1. Wood pellet industry and consumer market is developed (Austria, Denmark, Sweden, Germany).
2. Wood pellet industry exists but production is mainly for export so availability is limited and distribution weak (Finland, Estonia, Latvia, the Netherlands, Norway, Poland).
3. Wood pellets are produced and in use but very limited (Switzerland).
4. Wood pellet industry and market is in the pioneering stage (Bulgaria, Hungary, United Kingdom).
5. The potential of introducing wood pellets is being explored (Ireland).
6. Wood pellets are not available at present (Belgium).

There is too little information about France Italy, Poland and Spain to place these in any category, and as for the rest of Europe, we have no information but the existing literature does not suggest that wood pellets are available at present.

Starting up a wood pellet production is not an easy task, particularly in countries where wood pellets have not previously existed. As we have seen, wood pellet production requires investments in pelletising facilities, and it also takes time before the right quality level can be reached. In other words, wood pellet production does not come into existence from one day to the next but may take many months of preparation. However, it also seems that once wood pellets exist in the country, production can be quickly expanded.

In general, due to signs that the market potential of wood pellets is being investigated in several countries, recent start-ups of wood pellet companies, etc., the author believes that European countries are going in the direction toward more development in the field of wood pellets. This means that wood pellet availability will increase and distribution will become more developed in the countries where wood pellets presently exist; and additional countries may begin producing or exploring the potential of starting up wood pellet production. We may also see a better organisation within the wood pellet industry in Europe. This development can for example be seen in the efforts in the European Committee for Standardization to create a European standard for wood pellets.

[136] E-mail from Desmond Godson, Project Manager, British BioGen (2 May 2000).

4.6 Where could the Wood Pellet Fuelled 1Twin Potentially be Launched?

It is difficult to predict exactly how the situation will be in 2003 when External Power is planning to launch the wood pellet fuelled 1Twin in Europe. There is an indication that the use of wood pellets is becoming more widespread. However, based entirely on the criteria of wood pellet availability, we believe that a reasonable strategy will be to concentrate on "core" markets, i.e. the presently well developed markets of Austria, Denmark, Germany and Sweden. In markets where wood pellets are already widely available, there seems to be a higher security of wood pellet supply to consumers and therefore we may predict a higher willingness to invest in a device, which uses wood pellets as fuel, such as the wood pellet fuelled 1Twin. However, it must be stressed that other factors examined in this report must be taken into consideration before it is possible to say where in Europe the wood pellet fuelled 1Twin could be launched.

In 2003, it is likely that some of the presently mainly wood pellet-exporting countries, Finland, Estonia, Latvia, the Netherlands, Norway and Poland should also be taken into consideration as potential markets as wood pellets exist in these countries, and it may not take long to develop a distribution network. It is equally important to have countries in Eastern and Central Europe, Bulgaria and Hungary, in mind as future potential markets.

5 Satisfying Household Energy Needs with 1Twin

The purpose of this chapter is to examine how the wood pellet fuelled 1Twin may be used for satisfying the energy needs of a household, and furthermore how much it would cost to use the wood pellet fuelled 1Twin in terms of the monetary cost of fuel required for the operation. These issues are especially significant from a buyer's point of view.

In this chapter, first the various energy needs of a household are described in order to give a basic understanding of these and of factors that influence the amount of energy consumed in the individual household. Next, it is discussed how micro-cogeneration may be used to cover household energy needs, with a focus on economically advantageous ways of doing this. This forms a basis for considering how the wood pellet fuelled 1Twin may be used to satisfy the energy needs of a household. *Three possible ways* of using the wood pellet fuelled 1Twin, depending on different household conditions, are identified. These three possible usages differ in the ways that 1Twin is used in combination with other ways of covering energy needs, such as natural gas cooking and electricity from the electricity grid.

Statistical data from Eurostat (1999) concerning average energy consumption in households in Europe is then presented. On the basis of this data and the previously identified 3 ways of using the wood pellet fuelled 1Twin, the *cost* of using the wood pellet fuelled 1Twin is estimated. Among other things, the amount of wood pellets required for the operation of the wood pellet fuelled 1Twin is estimated. At the end of this chapter a table presents estimated costs for covering average household energy consumption in selected European countries, comparing various combinations of energy sources.

5.1 Composition of Household Energy Consumption

Household energy consumption may be divided into the following four categories:

- **Space heating**
The rooms, or spaces, of the house can be heated centrally, using radiators to convey heat, or locally (e.g. stoves or fireplaces).

- **Hot-water supply**
This provides hot water for use in bathrooms, kitchen, scullery and other places in the house with hot water faucets.

- **Electricity for all uses except cooking**
This category includes electricity for lighting, refrigerator, freezer, dish washer, washing machine, clothes drier, TV, stereo equipment, personal computer, vacuum-cleaner, electric kettle, coffee machine, and all other electrical equipment and appliances. Some houses have electric space heating and hot-water supply but these are not included in this category.

- **Cooking**

Cooking can be done using various sources of energy. Electricity and natural gas are common sources of energy for cooking, but LPG, wood and coal are also used.

The amount of energy used for each of the four needs will differ from household to household as energy consumption is determined by a combination of various factors. A report from the European Commission mentions[137] household income level, the size of the dwelling, the number of residents in the dwelling in addition to climatic and cultural conditions as the major driving forces of household energy consumption. According to the report, income level plays an important role in determining household energy because households with a higher income level will be able to afford larger size dwellings and moreover, the household will be able to afford more energy consuming equipment, resulting in higher electricity consumption.

For the understanding of household energy consumption, it is important to keep in mind that, generally, use of energy in a household is not constant but varies throughout the day and the year. For example, during a period of 24 hours, more electricity is commonly consumed in the daytime than in the night. Electricity consumption normally starts rising in the morning when activity begins, e.g. lights are switched on, the kettle is put on, etc.[138] It may stay constant during the day, but will typically peak in the evening when people come home from work, switch on lights and begin preparing dinner. Energy used for space heating varies during the year largely because of temperature differences between summer and winter, and is mainly used in the cold season. Households also tend to use more electricity in the winter period compared to the summer period, one reason being the differences in light and dark hours.

For the different types of energy uses, a number of factors that affect the *annual* amount of energy consumption in a household are listed in the following. These factors overlap to some extent.

Space Heating and Hot Water Supply

The annual amount of energy used for space heating and hot water supply in a household will depend on several factors of which can be mentioned:

- size of house
- type of house (e.g. flat or detached house)
- number of residents in the household
- climate
- insulation and the age of the house
- desired temperature
- saving on heat
- amount of hot water used

[137] European Commission (1999), *Energy in Europe: European energy outlook to 2020*, p. 136.
[138] Statistik Dansk elforsyning 1997, p. 17.

Electricity and Cooking

Overall electricity use may depend on a number of factors, many of which are the same as for space heating and hot water supply. The number of residents makes a difference: e.g. according to the Danish Electricity Association,[139] an extra adult in the household may mean extra consumption of 1,000-2,000 kWh/year and a child 500-1,000 kWh/year. In many cases, meals are prepared by means of electricity, and this will also influence the amount of electricity used. However, cooking can also be done using other types of cooking equipment, e.g. natural gas cooking equipment. Statistics from Eurostat indicates[140] that the amount of energy used for cooking may largely depend on the number of residents although eating habits will clearly also have an influence, for example if the residents of the household frequently dine out.

Factors that may affect the extent of use of electricity and energy for cooking are:

- number of residents in the household
- extent and use of electrical equipment
- saving on electricity
- habits of the residents

5.2 How can Micro-Cogeneration Satisfy Energy Needs?

Micro-cogeneration can be used in several ways, depending on household conditions, to satisfy energy needs, but for the user it will be of interest that this may be done as economically as possible. For instance, it may seem uneconomical, in terms of wood pellet use, to produce all needed electricity with 1Twin, resulting in much wasted heat. As the examples will show, micro-cogeneration can be used together with the electricity grid, whereby there is no waste of useful heat from 1Twin.

Micro-cogeneration gives both heat and electricity. However, one must note that because of fundamental thermodynamical principles (the Second Law of Thermodynamics), it is not possible to convert heat energy (in our case released by the combustion of wood pellets) into 100% electrical energy. While it is possible to use the wood pellet fuelled 1Twin as a central heating furnace or boiler, generating heat only, it is not possible to generate electricity without generating heat simultaneously. The wasting of useful heat, which could be used for space heating and hot water supply, is equivalent to wasting wood pellets.

As an example, suppose that we have a remote household, which has no electricity grid connection and depends completely on the electricity and heat that can be generated on the premises. Let us assume that this household has a micro-cogeneration product that can convert 10% of the heat energy into electricity (i.e. a fuel-to-electricity efficiency[141] of 10%). In the summer, this household may need only negligible amounts of heat for hot water supply. Since it will not be possible to get electric energy alone, a fraction of almost 90%[142] of the initially available heat energy will be discarded, and hence wasted.

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[139] Danske Elværkers Forening (1998), *Bedre el-vaner*, p. 6-7. (Brochure)

[140] See *Energy consumption in households*, Eurostat (1999), p. 20 and 35.

[141] Note that "fuel-to-electricity efficiency" is a term that has been invented here in order to avoid confusion. In the literature it may be termed as "thermal efficiency".

[142] NB! This is not entirely correct. As micro-cogeneration always gives some heat waste in the exhaust gas, in this example the machine will in reality give less than 90% heat.

As regards the wood pellet fuelled 1Twin, according to External Power, it is not yet possible to say precisely what the fuel-to-electricity efficiency of the product will be when it reaches commercialisation as was already mentioned in Chapter 2. However, a 15% fuel-to-electricity efficiency is the optimistic forecast. The illustration below shows the maximum ratios of electricity, heat and loss that can be generated with the wood pellet fuelled 1Twin. Loss in this sense refers to the inevitable waste heat that leaves the house in the exhaust heat. Due to the electronic control mechanism of the machine, the level of electricity can be controlled, but the maximum output is 15% of the heat energy contained in the wood pellets. With a maximum fuel-to-electricity efficiency of 15%, the maximum fuel-to-heat efficiency is 65-75%, but in the following examples, it is assumed that the fuel-to-heat efficiency is 70%.

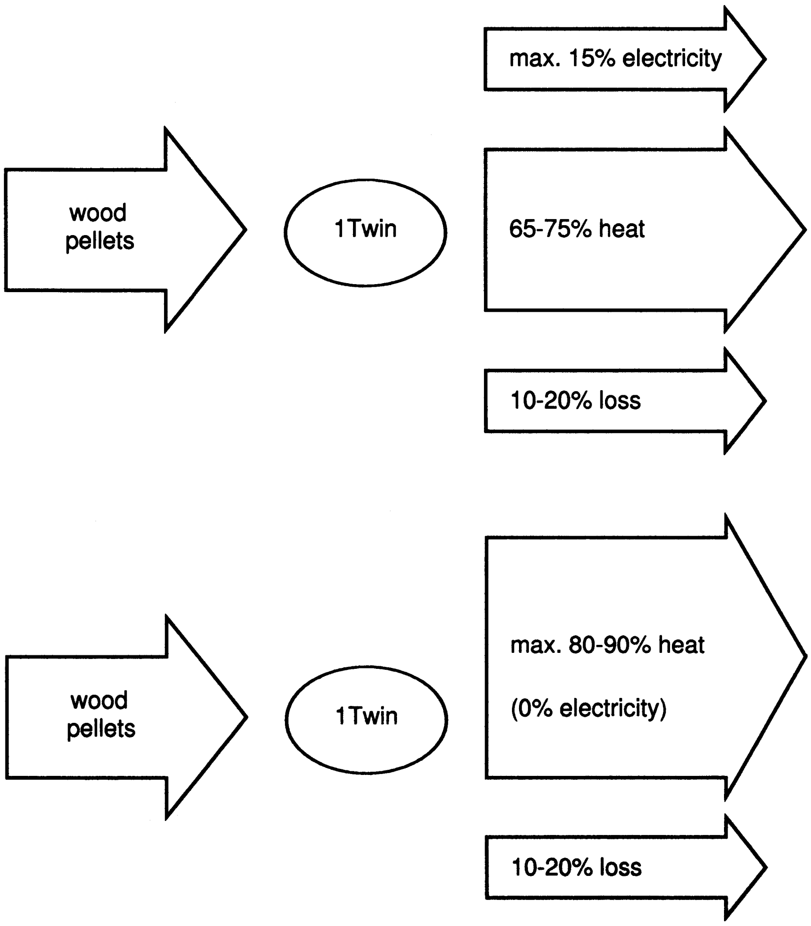

Fig 5.1 Ratios of max. fuel-to-electricity and fuel-to-heat efficiencies of the wood pellet fuelled 1Twin. When max. electricity is generated, 15% of the energy contained in the wood pellets can be converted into electricity, and 65-75% can be converted into useful heat. When no electricity is generated, a max. of 80-90% of the energy contained in wood pellets can be converted into useful heat.

Summer example: little heating requirement

To illustrate how the wood pellet fuelled 1Twin may work so that wood pellets are used as efficiently as possible, let us assume that a given household on a *summer day* has an energy need of 10 kWh heat and 10 kWh electricity. As heating requirements are low, it is economical that the machine works at the 15% maximum fuel-to-electricity efficiency, and while covering the heating needs, the households gets 1.8 kWh of electricity. But the household needs a total of 10 kWh electricity, and if an additional 7.2 kWh of electricity has to be produced, heat will be wasted. In order not to waste the useful surplus heat, instead the 7.2 kWh of electricity can be purchased from the grid. This will be economical when the price of electricity from the grid is cheaper than if it is to be generated by the wood pellet fuelled 1Twin. One must therefore keep in mind that in areas with access to the electricity grid, as in most places of Europe, the wood pellet fuelled 1Twin may be supplemented by the grid.

Winter example: high heating requirement

On a *winter day*, on the other hand, the energy needs of the same household may be 100 kWh heat and 12 kWh electricity. In this example, heating needs are high. If the machine were to run on the maximum fuel-to-electricity efficiency of 15% while covering the heating needs, then it could deliver 21 kWh electricity. But since only 12 kWh electricity is required, the machine will operate at a lower fuel-to-electricity efficiency of 9.1 %, and in this way there will be no waste. This illustrates the fact that adjustable fuel-to-electricity efficiency results in reduced heat loss. The two examples are illustrated below.

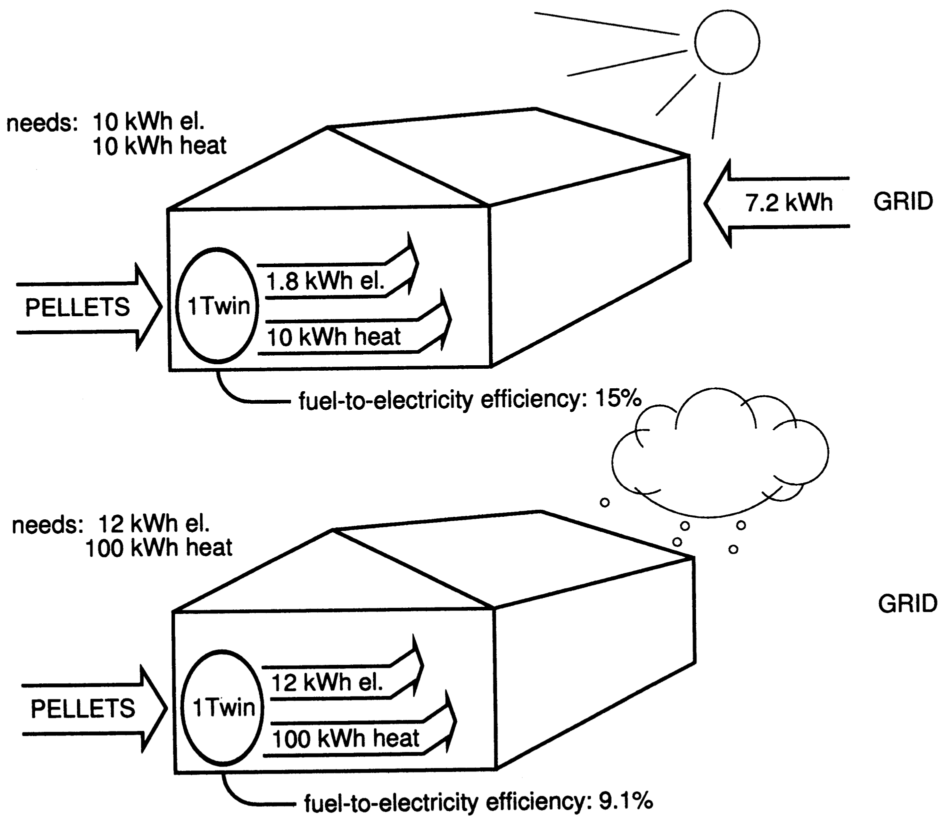

Fig. 5.2 Examples of how the 1Twin may be used. On a summer day, energy needs of the household may be 10 kWh electricity and 10 kWh heat. With max. fuel-to-electricity efficiency of 15%, 1Twin gives 1 kWh electricity and 10 kWh heat. The remaining 7.2 kWh electricity is purchased from the grid in order not to waste useful heat. On a winter day, energy needs may be 12 kWh electricity and 100 kWh heat. Operating at a fuel-to-electricity efficiency of 9.1%, both electricity and heating requirements are covered without waste of useful heat.

When considering how micro-cogeneration can be used to cover household energy needs, from the above mentioned examples, it can be seen that it is relevant to consider whether or not to buy from the electricity grid so that useful heat is not wasted by additional electricity generation. One might also consider whether, in cases where the customer uses non-electric cooking equipment such as natural gas, it is likely that the customer will switch to electric equipment and in this way use electricity generated from micro-cogeneration.

Measured in cost of fuel, is micro-cogeneration cheaper in operation than conventional ways of satisfying household energy needs? In the case of the wood pellet fuelled 1Twin, the answer depends on the price of electricity from the electricity grid, the price of wood pellets, and the prices of other energy sources used for heating such as natural gas, fuel oil, district heating, etc.

Electricity grid prices will determine whether or not it is economical to use the wood pellet fuelled 1Twin in combination with the electricity grid. If generation of 1 kWh of electricity, not taking useful heat into account, from 1Twin is cheaper than buying 1 kWh from the grid, it will pay to generate *all* electricity by using 1Twin, even when the heat is not needed. However, as is the case in the majority of the countries, if it is more expensive to generate 1 kWh of electricity from 1Twin than buying it from the grid, it will be wise to buy from the electricity grid when only electricity and not heat is required.

5.3 Usage of 1Twin for Three different Household Conditions

The question of how the wood pellet fuelled 1Twin can be used in a household is very complex. This is due to the different circumstances that exist in different households, e.g. in regard to existing cooking equipment and access to energy sources. Therefore, there are many possibilities of combining the wood pellet fuelled 1Twin with the grid and with energy sources for cooking other than electricity. In this section, three possible usages are identified, related to different household conditions.

First a note should be made. In Chapter 2 it was mentioned that it will be possible to sell electricity to the electricity grid if more electricity is generated than is used in the household. Although new laws are on the way that make it possible to export electricity to the grid, in the present situation the measures that have to be taken in order to do this may not be worth the trouble and investments. In order to be able to export electricity to the grid, it seems[143] that a meter has to be obtained and extra cables may need to be dug into the ground. If the wood pellet fuelled 1Twin operates on the maximum fuel-to-electricity efficiency of 15% in the winter period, especially in cold countries more electricity will be generated than required in the household. On the basis of statistics of average heating requirements in selected European countries[144], it is estimated that the excess electricity that potentially could be sold to the grid would be less than 1 kW in most cases. This is

[143] Telephone communication with Mr. Reimer, Marketing, Københavns Belysningsvæsen, Denmark (3 Aug. 2000).
[144] Based on: *Energy consumption in households*, Eurostat (1999), p. 35.

indeed a very small effect. Therefore, it seems to be wisest not to count on selling excess electricity to the grid. In the following usages, it is assumed that the user of 1Twin will not sell electricity to the grid.

First usage: "Grid-connected wood pellet fuelled 1Twin primarily for space heating and hot-water supply with the additional advantage of electricity"

Electricity: ***1Twin + Grid***	Space heating: ***1Twin***
Cooking: ***1Twin + Grid***	Hot water supply: ***1Twin***

Fig 5.3 First usage of the wood pellet fuelled 1Twin.

Most households in Europe are connected to the grid, and many already use electric cooking equipment. This usage involves covering all the space heating and hot water supply needs while generating the electricity that is possible on the basis of this heat but not more than is needed. Electricity from micro-cogeneration will therefore depend on the amount of heat that is used. When more electricity can be generated than is needed, the machine will operate at a lower fuel-to-electricity efficiency. When little heat is needed, the machine operates at the highest fuel-to-electricity efficiency. If additional electricity is still required, it is purchased from the grid. In this usage we assume that electricity is used for cooking.

Second usage: "We-already-have-gas-for-cooking"

Electricity: ***1Twin + Grid***	Space heating: ***1Twin***
Cooking: ***Existing equipment (e.g. gas cooker)***	Hot water supply: ***1Twin***

Fig 5.4 Second usage of the wood pellet fuelled 1Twin.

Many households already use other sources of energy than electricity for cooking, and in such cases the customer will be likely to continue using, e.g. the existing gas cooker, at least until it becomes too old or breaks down and has to be replaced. This usage is identical to the first usage, except for the fact that electricity is not used for cooking. This usage may be especially relevant in countries where the majority of households use non-electric cooking equipment,[145] such as in the Netherlands, Spain, Great Britain, and in many parts of Central and Eastern Europe, for example, Hungary, Latvia, Lithuania, Poland and Romania. There are other countries where the share of electricity consumption for cooking is almost the same as for example natural gas, and in these places it is also relevant to consider this solution.

[145] See *Energy consumption in households*, Eurostat (1990).

Third usage: “No electricity grid, and cooking with gas”

Electricity: ***1Twin***	Space heating: ***1Twin***
Cooking: ***Non-electric cooking equip-ment, e.g. gas***	Hot water supply: ***1Twin***

Fig 5.5 Third usage of the wood pellet fuelled 1Twin.

As the wood pellet fuelled 1Twin offers the possibility of being independent of the electricity grid, it is relevant to mention a 3rd usage where no electricity is obtained from the electricity grid. This solution may be especially relevant in areas without access to the grid, or in areas where the power grid sells electricity at a higher price than could be produced from wood pellets (here counting all the heat as waste).

If cooking is done with electricity, the wood pellet fuelled 1Twin can supply all energy needs in the household. However, generating electricity when the surplus useful heat is not needed is equivalent to unnecessarily ‘throwing away’ wood pellets, and therefore it may be assumed that cooking will likely be done using non-electric cooking equipment, e.g. cooking equipment using bottled gas such as LPG or wood, etc.

5.4 Statistical Data on Household Energy Consumption in Europe

Regarding statistics on household energy consumption in Europe, reliable figures for household energy consumption are difficult to find. It is often unclear what various sources include in “heating” figures, and furthermore one can easily end up having several and differing figures for energy consumption for space heating and hot-water supply because the sources use different variables, e.g. size of house, when it was built, etc. The data, which is used here, is from Eurostat (1999), the EU Statistics Institution, which was the most recent information available to the author.

The table below shows the energy distribution of average household energy consumption in selected European countries[146] in 1995. As the figures are average figures, they do not tell about variations in household energy consumption caused by the previously mentioned determinants of energy consumption, but nevertheless they give a rough indication about the pattern of energy consumption in each of these countries. Using average figures for our purpose means that it can be assumed that single-family dwellings in all probability consume a good deal more energy since the figures also include flats, which generally use less energy.

[146] The figures are based on *Energy consumption in households*, Eurostat (1999),which includes both a 1995 survey of the EU and Norway and a 1996 survey of Central and Eastern European countries. However, figures for Italy are not available in this Eurostat publication, and exact figures for annual energy consumption per household by type of use in Central and Eastern European countries are not listed either. For Central and Eastern Europe, the household energy consumption by end use is included as percentages (see p. 143 of the publication).

Table 5.1 Average annual energy consumption per household in kWh by type of use (1995)

	Austria	Belgium	Denmark	Finland	France	Germany	Greece
Space heat.	18,818	20,028	15,372	16,313	16,037	15,605	12,197
Hot water	2,635	2,946	3,692	3,471	2,191	2,492	395
Cooking	625	1,165	1,496	500	1,311	388	737
Electricity	2,105	1,356	2,041	3,858	1,922	1,837	2,132
Total	24,183	25,495	22,601	24,142	21,461	20,322	15,461

Cont'd	Ireland	Luxemb.	Netherl.	Norway	Portugal	Spain	Sweden	UK
Space heat.	16,959	34,086	12,661	12,400	2,698	4,245	14,970	11,103
Hot water	2,658	3,375	3,806	4,201	1,496	1,888	4,774	4,948
Cooking	6,159	956	638	694	3,669	1,046	556	1,526
Electricity	2,404	8,211	2,356	5,381	2,244	2,292	3,511	2,525
Total	28,180	46,628	19,461	22,676	10,107	9,471	23,811	20,102

Source: Eurostat (1999), *Energy consumption in households*, p. 35.

To give an overview of the household energy consumption in these countries, it can be mentioned that the average total consumption of energy per household in the European Union is about 19,600 kWh/year. Of the countries shown in the table, Portugal and Spain have much less consumption with total energy consumption constituting almost half of the EU average, but also Greece is below this average. In Portugal and in Spain the average energy consumption for space heating per household is considerably lower than in the various other countries, reflecting differences in climate.[147] Germany, the Netherlands and United Kingdom fall into a group of countries where the total household energy consumption is close to the EU average, while Austria, Belgium, Denmark, Finland, France, Ireland, Luxembourg and Norway are all above the average.

Average energy consumption for *space heating* per household varies from country to country. The amount used annually spans from about 2,700 kWh to 34,000 kWh annually with the lowest consumption in Portugal and the highest in Luxembourg. It is noticeable that Luxembourg has a very high consumption of energy for space heating compared to the Nordic countries. The explanation may lie partly in the fact that more than half of the dwellings have no insulation, while nearly all dwellings in Denmark, Finland, Norway and Sweden do have insulation.[148]

Energy used for *hot-water supply* lies in the range of about 2,000-4,000 kWh/year. Greece seemingly has an extremely low consumption of energy for hot-water supply, about 400 kWh/year, but the reason is that the figure unfortunately does not comprise solar heat, which is especially used in Greece.[149]

It can be seen from the table that energy used for *cooking* spans from around 400 kWh/year to around 6,000 kWh/year. Countries with the lowest amount of energy used for cooking

[147] *Energy consumption in households*, Eurostat (1999), p.12.
[148] See figures op.cit., p. 23.

per household are Germany, Finland and Sweden while countries with the highest consumption are Ireland and Portugal. The reason why Ireland and Portugal have a relatively higher consumption than the rest of the countries may have some connection to the fact that the size of households measured in number of persons are generally larger in these countries[150].

Use of *electricity* spans from approx. 1,300 kWh/year in Belgium to approx. 8,000 kWh/year in Luxembourg. The average amount of electricity consumed per household in the selected countries is about 3,000 kWh/year.

5.5 Calculations of Costs of using 1Twin

The main results of some calculations, based on Eurostat's average annual household energy consumption figures, are presented in this section. In the light of the previously identified three ways of using 1Twin, we wish to estimate how much heat is wasted in the case of the third usage, and how much electricity will be purchased from the electricity grid in the case of usage one and two. Furthermore, we wish to make an estimation of the amount of wood pellets required for the operation of 1Twin in all three cases. Finally, the costs of operating the wood pellet fuelled 1Twin in all three usages in terms of the cost of energy are compared with alternative ways of satisfying household energy needs in the selected countries in Europe.

Assumptions for Calculations

For the purpose of our calculations, some assumptions have been made. Firstly, it is assumed that there are no variations throughout the day, month and year in the consumption of electricity and in the consumption of energy for cooking and for hot water supply – i.e. these have been made constant. When using the wood pellet fuelled 1Twin, variations in electricity consumption during the day will be equalised by the battery so that it this will not be of concern.

Secondly, for simplicity it is assumed that space heating is used constantly for five months of the year (let us say November-March, or "winter" for simplicity), although it may in fact be used over a longer period of the year, as consumption is likely to increase slowly as the weather becomes colder and decrease as it becomes warmer. It is assumed that no space heating is used during the remaining seven months of the year (April-October, or "summer" for simplicity).

Thirdly, in Eurostat's statistics, all forms of cooking and heating of meals are included in the category of cooking, and energy used not only for cookers but also for toasters and microwave ovens are therefore included. This means that a combination of, for example, electricity and natural gas can be used for cooking. For simplicity, however, we assume that only one type of energy source is used for cooking.

Fourthly, because the fuel-to-heat efficiency lies in the range of 65-75% for simplicity we take the number 70%, and for loss, which lies in the range of 10-20%, we take 15%.

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[149] Op.cit., p. 13. This will mean that calculations for Greece cannot be regarded as being accurate.
[150] See op.cit., p. 20.

5.5.1 Wasted Useful Heat in the Third Usage

By using the wood pellet fuelled 1Twin in first and second usage, no heat will be wasted because micro-cogeneration is combined with purchase of electricity from the grid. However, as it can be seen in Table 5.2, if used in the third way, i.e. independently from the electricity grid, in all the represented countries, useful heat, ranging from approx. 2,000 kWh in Belgium to approx. 20,000 kWh in Luxembourg, has to be discarded in the 'summer' period. In the 'winter' period, however, no useful heat is wasted, except in Portugal where around 1,000 kWh of useful heat has to be discarded.

Table 5.2 Estimated amount of useful heat, in kWh, to be discarded for third usage (1995)

Country	Third usage	
	"winter"	"summer"
Austria	0	4,194
Belgium	0	1,972
Denmark	0	3,402
Finland	0	8,477
France	0	3,955
Germany	0	3,548
Greece	0	5,575
Ireland	0	4,995
Luxembourg	0	20,384
Netherlands	0	4,194
Norway	0	12,197
Portugal	1,041	5,235
Spain	0	5,139
Sweden	0	6,773
United Kingdom	0	3,988

Source: Own calculations based on average household energy consumption in Eurostat (1999).

5.5.2 Electricity Purchase from Grid in the First and Second Usage

In the possible usages one and two, electricity generation is led by heating requirements, and any additional required electricity is purchased from the electricity grid. Table 5.3 below shows the amount of electricity, which the average household will have to buy from the grid. In most of the countries, electricity needs are fully covered in the 'winter' period by the wood pellet fuelled 1Twin, but it will be necessary to buy between about 1,000 and 4,900 kWh of electricity from the grid in the 'summer' period. In countries with warmer climates, however, heating needs are so low that, at least if cooking is done with electricity (first usage), in both Portugal and in Spain it will be necessary to buy from the grid also in the 'winter' period.

Table 5.3 Estimate of amount of electricity, in kWh, to be obtained from the grid for first and second usage (1995)

Country	First usage (kWh)		Second usage (kWh)	
	winter	summer	winter	summer
Austria	0	1,263	0	899
Belgium	0	1,102	0	423
Denmark	0	1,602	0	729
Finland	0	2,108	0	1,816
France	0	1,612	0	848
Germany	0	986	0	760
Greece	0	1,624	0	1,195
Ireland	0	4,663	0	1,070
Luxembourg	0	4,925	0	4,368
Netherlands	0	1,271	0	899
Norway	0	3,018	0	2,614
Portugal	1,725	3,362	223	1,122
Spain	313	1,711	0	1,101
Sweden	0	1,776	0	1,451
United Kingdom	0	1,745	0	854

Source: Own calculations based on household energy consumption in Eurostat (1999).

It may be concluded that in warmer countries so little heat is needed that much electricity is bought from the grid, not only in the summer but also the winter. Therefore, it may not make sense to use micro-cogeneration in warmer countries unless it is cheaper than conventional ways of getting electricity and heat to satisfy household energy needs.

5.5.3 Wood Pellet Quantity needed for Operation of 1Twin

The amount of wood pellets that would be required *annually* for the operation of the wood pellet fuelled 1Twin to cover average household energy consumption in connection with the 3 usages is shown in Table 5.4 below.

Our estimates show that the amount of wood pellets required for the operation of 1Twin varies depending on the country and use of the wood pellet fuelled 1Twin. In most cases, there is not much difference in the energy consumption for first and second usage, but the second usage (cooking with gas) is the possibility that requires the least amount of wood pellets and the third usage requires the most. Countries with warmer climates require the least amount of wood pellets, while in the majority of countries an average household will need 4-7 tonnes of wood pellets annually, depending on how the wood pellet fuelled 1Twin will be used. It should be remembered that the figures are based on average energy consumption so the actual consumption will probably be a little higher in single-family dwellings.

Table 5.4 Annual estimated amount of wood pellets required for 1Twin in kg/year (1995)

Country	First usage	Second usage	Third usage
Portugal	1,198	1,198	2,991
Spain	1,753	1,724	3,192
Greece	3,256	3,184	4,777
Netherlands	4,280	4,217	5,416
United Kingdom	4,320	4,170	5,309
Germany	4,549	4,511	5,525
Norway	4,625	4,557	8,042
France	4,670	4,542	5,672
Denmark	4,941	4,794	5,766
Sweden	5,185	5,131	7,066
Austria	5,393	5,332	6,530
Ireland	5,534	4,930	6,357
Belgium	5,739	5,625	6,188
Finland	5,185	5,136	7,557
Luxembourg	9,813	9,719	15,542

Source: Own calculations based on average household energy consumption in Eurostat (1999).

The next table shows the estimated consumption of wood pellets per day. In the 'winter', more wood pellets will be consumed than in the 'summer'. In the 'winter', around 30 kg wood pellets are consumed per day in most countries, while in the summer it is only 2-3 kg a day. Although the wood pellet fuelled 1Twin has capacity of burning 4.5 kg of wood pellets per hour, in most cases the consumption per hour will be much less.

Table 5.5 Daily estimated amount wood pellets required for 1Twin in kg/day (1995)

Country	1st usage		2nd usage		3rd usage	
	winter	summer	winter	summer	winter	summer
Austria	32.6	2.1	32.2	2.1	32.2	7.7
Belgium	34.5	2.3	33.8	2.3	33.8	5.0
Denmark	28.4	2.9	27.5	2.9	27.5	7.5
Finland	30.3	2.7	30.0	2.7	30.0	14.1
France	28.3	1.7	27.5	1.7	27.5	7.0
Germany	27.2	2.0	26.9	2.0	26.9	6.7
Greece	21.0	0.3	20.5	0.3	20.5	7.8
Ireland	33.5	2.1	29.5	2.1	29.5	8.8
Luxembourg	60.8	2.6	60.2	2.6	60.2	30.0
Netherlands	24.0	3.0	23.6	3.0	23.6	8.6
Norway	25.8	3.3	25.4	3.3	25.4	19.6
Portugal	6.2	1.2	6.2	1.2	8.2	8.2
Spain	9.5	1.5	9.3	1.5	9.3	8.4
Sweden	28.9	3.7	28.5	3.7	28.5	12.8
United Kingdom	23.0	3.9	22.0	3.9	22.0	9.2

Source: Own calculations based on average household energy consumption in Eurostat (1999).

5.5.4 Price Comparisons: Three Usages of 1Twin and Four Other Options

In order to examine whether it may be cheaper to use the wood pellet fuelled 1Twin, the cost of operation, measured in the price of fuel, is compared with a number of other combinations of energy sources used to cover household energy consumption.

To begin with, 1999-prices of fuel oil, natural gas, electricity and wood pellets are listed below, all measured in Euro per megawatt-hour. These prices are used in the calculations of the options, which are selected for comparison.

Table 5.6 Prices of various energy sources in EUR/MWh in EU Member States and Norway (Sep. 1999)[151]

Country	Fuel oil	Natural gas	Electricity	Wood pellets
Austria	31	32	145	30
Belgium	23	31	195	—
Denmark	60	50	175	23
Finland	31	13	95	22
France	34	39	152	30
Germany	23	33	180	28
Greece	41	—	80	—
Ireland	28	33	115	21
Italy	75	55	75	56
Luxembourg	24	22	151	—
Netherlands	37	27	128	20
Norway	41	—	42	20
Portugal	—	—	138	41
Spain	30	40	149	41
Sweden	46	—	84	21
United Kingdom	23	25	125	21

Source: Malisius et al., Industrial Network on Wood Pellets, (2000), p. 64.

The cost of energy in connection with the three usages of the wood pellet fuelled 1Twin are compared with the following four other options, the estimated prices of which are presented in Table 5.7.

a) Fuel oil heating + electric cooking + electricity from the grid
b) Natural gas heating + electric cooking + electricity from the grid
c) Natural gas heating + natural gas cooking + electricity from the grid
d) Electric heating + electric cooking + electricity from the grid

[151] Note: the prices are used here although it lists the wood pellet price of among others Ireland, a country where wood pellets are not available according to the author's research. Thus there seems to be conflicting information on the availability of wood pellets and wood pellet prices can therefore not be confirmed by the author. Unfortunately, Malicius et al. do not list any sources of these prices.

Table 5.7 Comparison of estimated prices in EUR/year for various options for covering average household energy consumption in selected European countries

Country	a) Fuel oil heating/ electric cooking/ electricity from grid	b) Natural gas heating/electric cooking/ electricity from grid	c) Natural gas heating/natural gas cooking/ electricity from grid	d) Electric heating/ electric cooking/ electricity from grid	First usage: Wood pellet heating/ electric cooking/buy from grid	Second usage: Wood pellet heating/ natural gas cooking/buy from grid	Third usage: Wood pellet heating/gas cooking/ wood pellet electricity
Austria	1,061	1,082	1,012	3,507	871	830	857
Denmark	1,763	1,572	1,385	3,955	763	671	638
Finland	1,027	671	630	2,293	685	659	713
France	1,111	1,202	1,054	3,262	840	759	774
Germany	817	998	941	3,658	719	686	670
Ireland	1,534	1,632	1,127	3,241	1,030	766	771
Netherlands	992	828	763	2,491	527	491	478
Norway	936	—	—	952	520	—	—
Portugal	—	—	—	1,395	901	—	—
Spain	681	743	629	1,411	607	506	598
Sweden	1,250	—	—	2,000	612	—	—
United Kingd	876	908	755	2,513	604	517	512

Source: Own calculations based on prices from Malisius et al. (2000) and Household energy consumption, Eurostat (1999).

Note: Belgium, Greece and Luxembourg have been excluded, as there were no prices for wood pellets. Italy is excluded because no energy consumption figures were available.

According to these rough estimates based on 1999-prices from Malisius et al., it seems that in the majority of these cases (with the exception of Finland), it is cheapest to use the wood pellet fuelled 1Twin to cover household energy consumption. Interestingly, in Denmark, France, Germany and the United Kingdom, the third way of using the wood pellet fuelled 1Twin turns out to be the cheapest of the options. Apparently this can be explained by quite high electricity prices and low wood pellet prices so that it is cheaper to produce electricity oneself. In Finland, according to estimations, option *c)*, using natural gas for heating and cooking and electricity from the grid is a little cheaper than using the wood pellet fuelled 1Twin, which has to do with the low price of natural gas.

Although they may be helpful for initial guidelines of where it might be cheaper to use the wood pellet fuelled 1Twin, one must be cautious in interpreting the estimated prices above. Not only have 1999-prices been used for 1995-consumption figures but more importantly, as it must be strongly emphasised, fuel prices are *not static* which means that they may suddenly rise or fall. Rather, these estimated prices may be regarded as an example of how various alternatives for covering energy consumption may be calculated and compared.

5.6 Summary

This chapter has examined how the wood pellet fuelled 1Twin can be used to in order to satisfy household energy needs of space heating, hot-water supply, cooking and electricity. Also, on this basis, and taking into consideration the average household energy consumption, an analysis of the amount of wood pellets required in selected European countries has been made. An example of how the costs for the operation of the wood pellet fuelled 1Twin can be compared with used alternatives is shown. We have identified 3 possible ways of using the wood pellet fuelled 1Twin: (i) 1Twin in conjunction with the grid, (ii) 1Twin in conjunction with the grid and with gas cooking, and (iii) 1Twin independently of the grid and with gas cooking. The reason why it may be advantageous to use 1Twin in conjunction with the grid is that in this way, useful heat will not be wasted in cases of electricity generation without need of heat. Estimates show that, excluding warm countries such as Portugal and Spain where little heat is needed, generally average households would consume 4-7 tonnes of wood pellets annually, depending on the country and on the use of 1Twin (the three possible usages). Furthermore, in the winter it is estimated that around 30 kg/day is needed, while in the summer 2-3 kg/day is needed. The cost of operation in terms of fuel, compared with other ways of satisfying household energy needs will depend on the fuel prices, which may easily change.

6 Identifying Potential Competitors

In this short chapter, External Power's potential competitors in respect of the wood pellet fuelled 1Twin are identified and classified. When we speak about potential competitors, we mean companies providing products or services which may reduce the sale of the wood pellet fuelled 1Twin. All companies offering alternative products or services which essentially give the same customer benefits of electricity and heating are therefore regarded as potential competitors.

Exactly who can be considered potential competitors of the wood pellet fuelled 1Twin? First of all, there are the companies that make the same type of product as External Power's wood pellet fuelled 1Twin, namely micro-cogeneration products. Secondly, there are companies that make various types of heating equipment. Thirdly, there are various sources of electricity: the electricity grid and on-site electricity generating devices.

Naturally, some of the products mentioned need to be used in combination with other products in order to give both electricity and heating. The competitors can be classified according to different levels, which are described in the following section.

6.1 Classification of Competitors

External Power's competitors can be distinguished on the basis of degree of *product substitution*, using a modification of Philip Kotler's concepts of competition. We will classify the competitors according to three levels[152]: brand, industry, and form/market competition. The relation between the three levels is shown in the model below.

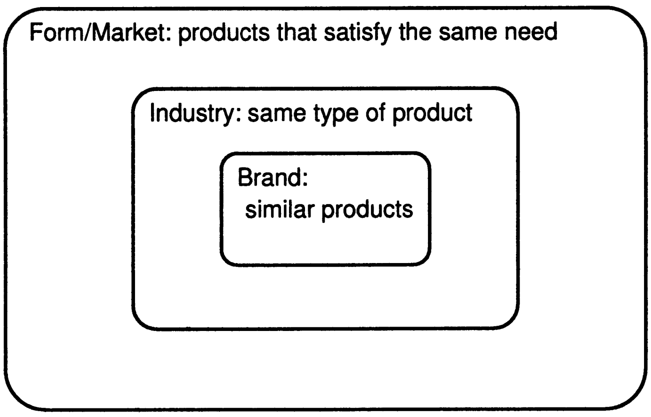

Fig. 6.1 Three levels of competition.

[152] P. Kotler, *Marketing Management: Analysis, Implementation, and Control*, Prentice-Hall, New Jersey (8th ed., 1994), p. 225. In his model, Kotler in fact mentions a fourth level, "generic competition", which is described as all companies that compete for the same consumer dollars. However, this level is extremely broad and is not considered relevant for the classification of External Power's competitors.

First level: brand competition

Seen from this narrowest level of competition, competitors consist of other companies that offer a similar product or service to the same customers at similar prices. In the case of the wood pellet fuelled 1Twin, we may define brand competitors as companies who manufacture and offer biomass Stirling engine micro-cogeneration products that are designed for single-family dwellings.

Second level: industry competition

From this broader viewpoint, industry competition consists of all companies making the same product or class of product. In this case, External Power's competitors in regard to the wood pellet fuelled 1Twin may be defined as companies that offer domestic micro-cogeneration products. Here we disregard the fuel that is used: it does not matter whether they are fuelled by natural gas, biomass, or other fuels, and we also disregard the type of engine that is used, whether it is a Stirling engine, internal combustion engine or another type of engine.

Third level: form/market competition

This is a market point of view in which competitors are seen as companies manufacturing products that satisfy the same customer needs. This comprises all the companies that offer products or services that satisfy household needs of heating and electricity. This means that the entire electricity industry, which is in the business of supplying electricity to households, among others, falls into this category along with companies that make equipment for on-site generation of merely electricity, such as generators based on diesel, and photovoltaic applications for household use. Also manufacturers of heating equipment, such as central and direct heating systems are included in this category. These may be based on for example electricity, oil, natural gas, coal, wood and other biomass, and solar energy.

6.2 Major Competitors to be Examined Further

In the following chapters (7, 8 and 9), selected competitors are examined further. The most important competitors have been selected based on the consideration that these may have the biggest impact on the sales potential of the wood pellet fuelled 1Twin. In *Chapter 7*, brand and industry competitors are analysed, while market competition is examined in *Chapters 8 and 9* describing the electricity industry in Europe and heating systems for household, respectively. Photovoltaic systems for household applications, for example, are not described, as they are presently very expensive to produce and have a low solar energy to electricity efficiency and do not seem to present widespread use in Europe in the nearest future. Leaving out certain competitors may create a weakness in the competitor analysis due to unexpected developments, i.e. in the future these competitors might develop against anticipations and gain foothold, thereby becoming a significant threat to the sales potential of the wood pellet fuelled 1Twin.

Brand and industry competition is examined because micro-cogeneration technology seems to be developing rapidly in the recent years, and some products have already been marketed while others are on the way to be launched. In other words, the industry is changing very quickly and it is important to monitor the development of competitors that make similar products. It is of interest to know how the situation might be in 2003. For instance, it is important to know how many companies are currently making micro-cogeneration products designed for residential application, how many are selling them and how many are planning to market such technology. It is also of interest to know whether there are any companies that make exactly the same product as External Power's wood pellet fuelled 1Twin, and how big differentiation there is between the products.

The electricity industry in Europe is not static, and especially at the present moment many things are happening in the industry due to the European Union's Electricity Directive, which introduces more competition in the industry. Today, the electricity industry is the principal and furthermore an extremely well-established source of electricity for households. Therefore, it is necessary to know about the changes that are going on as it may also influence the sales potential of the wood pellet fuelled 1Twin.

Heating systems for households are examined as the wood pellet fuelled 1Twin can be considered as a replacement for traditional or already well-established heating methods, especially district and central heating, which can be based on a number of energy sources. As homes may also rely on direct heating methods alone including wood-burning stoves, these are also examined in Chapter 9. Heating systems are commonly based on energy sources such as oil, natural gas and electricity.

7 Potential Brand and Industry Competitors

This chapter examines companies in the micro-cogeneration industry world-wide that are developing, testing, planning to launch, or have already launched micro-cogeneration products for the residential market. The purpose is to know what players exist in this field in order to estimate the potential competition coming from similar products in Europe in 2003 as this may profoundly affect the sales potential of the wood pellet fuelled 1Twin.

7.1 Overview of the Micro-Cogeneration Industry

Currently, there are not many companies in the micro-cogeneration industry. Globally, the author is aware of only around 15 companies that actually have micro-cogeneration systems, which are under development or have already been commercialised. These companies are located mainly in Europe, the United States, Japan and Australia, ranging from small research and development companies to large transnational companies. In fact, as far as the author is aware, only micro-cogeneration systems from the Swiss ecopower energy solutions AG, the German SenerTec Kraftwärme-Energiesysteme GmbH and the U.S. Polar Power Inc. are already commercially available, while other companies are very close to commercialising their products. It is difficult to predict what is going to happen in the micro-cogeneration industry as micro-cogeneration is a very recent technology, experiencing rapid development. In the opinion of Philip T. Hodge,[153] President of QRMC, micro-cogeneration is “certainly an interesting field, one that changes daily with technical advances, changing market conditions, and wildly erratic government regulations”.

The structure of the micro-cogeneration industry seems to be a differentiated oligopoly. The products are partially differentiated due to, for instance, electric and thermal output, and fuel and technologies used for the generation of electricity and heat. The micro-cogeneration products may also be designed to be operated in conjunction with the grid or independent of the grid. Additionally, there seems to be a gap in the estimated prices of these product, all of which creates different market niches that the companies can focus on, even though they essentially give the same benefit of heat and electricity for homes. Technologies used in micro-cogeneration products range from internal combustion engines, Stirling engines to protone exchange membrane (PEM) fuel cells. Currently, far the greatest majority of micro-cogeneration systems that are on the way are fuelled by natural gas (or LPG/propane).

7.2 Survey of Potential Industry Competitors and Products

We wish to know which companies exist in the micro-cogeneration industry and what products are available in the market or are on the way. In order to identify companies in the micro-cogeneration industry, initially searches were made on the World Wide Web;

[153] E-mail from Philip T. Hodge, President of QRMC (22 Oct. 2000).

furthermore, COGEN Europe was contacted, and some companies were mentioned in COGEN Europe's *Introduction to micro-cogeneration*[154]. Based on the searches, a preliminary list was compiled. Later, External Power, the U.S. DOE's CHP Initiative and various cogeneration associations (ICA, Australian EcoGeneration Association, USCHPA, UKCHPA, Cogeneration Association of New Zealand) were contacted with an inquiry as to whether they were aware of other companies in the domestic micro-cogeneration industry. With their help, additional companies were added to the list.

Although in some cases, certain information about micro-cogeneration products was unavailable, the information sought about each micro-cogeneration product was related to marketing issues:

- Name of micro-cogeneration product
- Electric and thermal output
- Fuel
- Type of engine
- Phase of the product (e.g. research, testing, commercialisation)
- Target customers
- Target countries
- Price of the product for consumer
- Distribution (channels) and installation at the customer

In the following, individual companies and products will be described. Information was gathered mainly from web sites and personal inquiries. The table below provides a quick overview of these companies and products.

Table 7.1: Overview of companies and micro-cogeneration products

Company	Location	Name of product	Electric & thermal output/ fuel/engine, etc.
Advantica Technologies Ltd. (formerly BG Technology Ltd.) http://www.advanticatech.com	Loughborough, Leicestershire, United Kingdom	MicroGen™ (being developed for a client)	0.5-1 kW(e)/20 kW(th) Natural gas fuelled. Free-piston Stirling engine.
Ballard Generation Systems (A subsidiary of Ballard Power Systems, Inc.) http://www.ballard.com	Burnaby, British Columbia, Canada	No name yet	1 kW(e) Natural gas fuelled. Ballard® fuel cell technology.
Bomin Solar Research GmbH http://www.bominsolar.com	Lörrach, Germany	HEATPULSE™ (former SUNPULSE+™)	1 kW(e)/15-20 kW(th) Natural gas fuelled or concentrated solar radiation powered. Non-resonant free-piston Stirling engine.
BHKW Betreiber GmbH http://www.bhkw-energie.de	Frankfurt am Main, Germany	Stirling Energie Modul (SEM)	1 kW(e)/ 6 kW(th) Natural gas burner

[154] COGEN Europe (1999), *An introduction to micro-cogeneration*, COGEN Europe Briefing.

		Bought from SIG Schweizerische Industrie-Gesellschaft (2000).	Stirling engine
ecopower energy solutions AG http://www.ecopower.ch	Biel/Bienne, Switzerland	ecopower micro-CHP Commercialised in 1999.	Natural gas fuelled: 2.0-4.7 kW(e)/6.0-12.5 kW(th) Propane gas fuelled: 2.2-4.7 kW(e)/6.6-13.8 kW(th) 1-cylinder Briggs & Stratton combustion engine.
ENATEC micro-cogen B.V. Joint venture company with 3 shareholders: NV Eneco, ATAG Verwarming BV and ECN. http://www.enatec.com	Lichtenvoorde, the Netherlands	No name yet.	Max. 1 kW(e)/ max. 24 kW(th) Natural gas-fired burner. Free-piston Stirling engine developed by Stirling Technology Company (U.S.A.), exclusively for ENATEC.
External Power LLC ftp://209.239.142.78/Public_Information/	Athens, Ohio, U.S.A.	Initially referred to as 1Twin Micro-Cogen Unit/Stand-Alone System	Max. 3 kW(e)/ Max. 27.9 kW(th) Natural gas fuelled or wood pellet fuelled. Beale free-piston Stirling engine. (Technology licensed from Sunpower Inc.)
Gastec N.V. http://www.gastec.com	Apeldoorn, the Netherlands	Develops micro-cogeneration systems in co-operation with clients.	Natural gas/propane.
Honda Motor Co., Ltd. http://www.honda.co.jp	Tokyo, Japan	No name yet.	1.8 kW(e)/4.8 kW(th) Natural gas fuelled Internal combustion engine (GF160V)
N.V. Nederlandse Gasunie http://www.gasunie.nl	Groningen, the Netherlands	No product but demonstrates and promotes micro-CHP products.	Demonstrates a 0.8 kW(e) WhisperGen in co-operation with WhisperTech Ltd. Fuel: Natural gas.
Plug Power Inc. http://www.plugpower.com	Latham, New York, U.S.A.	*HomeGen* 7000 To be distributed by GE MicroGen	7 kW(e) Natural gas or propane fuelled PEM fuel cell technology
Polar Power Inc. http://www.polarpowerinc.com	Carson, California, U.S.A.	Micro Cogeneration Unit	Max. 6 kW(e)/Max. 10 kW(th) Natural gas, propane, gasoline Kawasaki engine
Powerline GES Pty Ltd http://www.powerlinesystems.com.au	Sydney, Australia	General Energy System (“GES”)	4.5 kW(e)/10 kW(th) Natural gas or LPG. Engine unknown.
Quiet Revolution Motor Company, L.L.C.	Sallisaw, Oklahoma, U.S.A.	No product yet.	Researches Stirling engines

http://www.qrmc.com			
SenerTec Kraft-Wärme-Energiesysteme GmbH http://www.senertec.de	Schweinfurt, Germany	DACHS HKA	*Natural gas*: 5.5 kW(e)/ 12.5 kW(th) 5.0 kW(e)/ 12.3 kW(th) *LPG*: 5.5 kW(e)/12.5 kW(th) *Fuel oil*: 5.3 kW(e)/10.4 kW(th) *Biodiesel*: 5.3 kW(e)/ 10.4 kW(th) Sachs engine
Sigma Elektroteknisk A.S. http://www.sigma-el.com	Hølen, Norway	PCP™ (Personal Combustion Powerplant)	3 kW(e) and 9 kW(th) Single-cylinder (β type) kinematic Stirling engine Natural gas or propane
Stirling Engine Co., Ltd http://www.stirling-engine.com	Kawasaki City, Kanagawa Prefecture, Japan	ST-5 (licenced from Stirling Technolgy Inc.) Exclusive agent of External Power in Japan.	See Stirling Technology Inc. See External Power LLC.
Stirling Technology Company http://www.stirlingtech.com	Kennewick, Washington, U.S.A.	RemoteGen™ 3 models: RG-350 RG-1000 RG-3000	Fuels: Propane, natural gas, biomass, and liquid fuels. Three models: 0.35 kW(e) 1 kW(e) 3 kW(e) Free-piston Stirling engine
Stirling Technology, Inc. http://www.stirling-tech.com	Athens, Ohio, U.S.A.	ST-5 Has been licensed to Stirling Engine Co. Japan	Max. 3.5 kW (e)/Max. 25 kW(th) Fuel: all types of biomass. Stirling engine.
Whisper Tech Limited http://www.whispertech.co.nz	Christchurch, New Zealand	WhisperGen (AC and DC models)	0.75 kW(e)/ 6 kW(th) Gaseous and liquid fuels, e.g. natural gas, kerosene, LPG WhisperTech-designed double acting kinematic Stirling engine

7.2.1 Advantica Technologies (formerly BG Technology): *MicroGen™*

Advantica Technologies Ltd.[155] (formerly BG Technology Ltd.), is a subsidiary exclusively owned by Lattice Group. The company is located in Loughborough, Leicestershire, United Kingdom and has 850 employees (2001). Since Lattice Group demerged from BG Group in October 2000, BG Technology was renamed Advantica Technologies. Advantica's main activities are in the field of gas and pipeline markets, and the company is a provider of technology, software, training services and testing services for customers in gas, pipelines and associated industries worldwide.

As a contractor, Advantica is developing a micro-cogeneration package, MicroGen™ designed for the residential market. Advantica already offers MiniGen™, a mini-cogeneration package using micro-turbine technology, designed for businesses such as horticulture. Currently only little information is publicly available concerning MicroGen™. However, according to Mr. Ian Freeman of Advantica,[156] what can be revealed is that the product being developed for an unspecified client is natural gas fuelled and has a free-piston Stirling engine. Electric output will be in the range of 0.5-1.0 kW, while thermal output produced by the engine will be 3-3.5 kW, but a supplementary burner will make it produce up to 20 kW of heat in order to satisfy the needs of a household.

Prototypes of MicroGen™ have already been field tested, and in early summer 2001, it will be installed in Advantica's testing and demonstration house, located in Loughborough. It is planned that MicroGen™ will be launched in 2003 in markets in Europe. It is going to be sold at a price of around GBP 600-1000 above the price of boilers.

7.2.2 Ballard Generation Systems (BGS): *1-kW cogeneration fuel cell power plant*

Ballard Generation Systems (BGS), created in 1996 and located in Burnaby, British Columbia, Canada, is a designer, developer and manufacturer of stationary power generators for the below 1 MW capacity market. BGS is a subsidiary of Ballard Power Systems Inc, in partnership with GPU International Inc. (New Jersey, U.S.A), ALSTOM SA (France) and EBARA Corporation (Japan). Ballard Power Systems,[157] a Canadian manufacturer of Ballard® PEM fuel cells for use in transportation and stationary and portable electricity generators, develops and manufactures fuel cells for stationary applications exclusively for BGS.

In January 2000, the formation of a collaboration, for the development of a natural gas fuelled 1 kW micro-cogeneration fuel cell power plant for the Japanese residential market, between BGS, EBARA Corporation, Tokyo Gas and EBARA BALLARD (a company jointly owned by BGS and EBARA Corporation), was announced. This product is being designed[158] to satisfy space heating and hot water needs of a typical Japanese household while providing 1 kW of electricity. Furthermore, it is to be used in conjunction with the electricity grid, in order that consumers can get power from the grid when electricity needs exceed 1 kW. In February 2001, EBARA BALLARD unveiled a prototype of the product.[159]

Ballard Power System's annual report (2000) states[160] that BGS is expected to commercialise its first product, a 250 kW stationary fuel cell power generator, in 2002-

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[155] *Advantica* <http://www.advanticatech.com> (24 Apr. 2001).
[156] Telephone communication with Mr. Ian Freeman, Advantica (11 May 2001).
[157] *Ballard* <http://www.ballard.com> (24 Apr. 2001).
[158] Private communication with Ballard Power (14 Nov. 2000).
One-kilowatt cogeneration fuel cell power generator <http://www.ballard.com/1k_stationary.asp> (24 Apr. 2001).
[159] *Press release Feb 22, 2001: EBARA BALLARD unveils engineering prototype…* <http://biz.yahoo.com/bw/010222/_0117-3.html> (24 Apr. 2001).
[160] Ballard Power Systems Inc. 3rd Quarter Report 2000, p. 2-3.

2003, and this is to be followed by the 1 kW micro-cogeneration product for the Japanese market.

7.2.3 Bomin Solar Research GmbH (BSR): *HEATPULSE™ (former SUNPULSE+™)*

Bomin Solar Research GmbH (BSR) of Lörrach, Germany, a subsidiary exclusively owned by Power Pulse Holding AG based in Basel Switzerland (formerly Bomin Solar Holding AG), is a research and development company specialising in solar technology. BSR was founded in 1971 by Professor Hans Kleinwächter as a successor to the private research institute, KLERA, and is now headed by his son Jürgen Kleinwächter.[161]

BSR has developed HEATPULSE™, a free-piston Stirling engine designed for employment in stationary power systems such as water pumps, cogeneration and solar power stations.[162] The company's current focus is the development of micro-cogeneration products for residential customers and decentralised power stations. These micro-cogeneration products will supply 1 kW of electrical energy and about 15-20 kW of thermal energy and are either natural gas fuelled or concentrated solar radiation powered. The patented[163] HEATPULSE free-piston Stirling engine technology is characterised by high efficiency, low frequency, non-resonance, low to medium temperature and a novel feature called the 'Stirling valve'. One of the advantages of its construction is that manufacturing costs of the engine are significantly lower than that of high-temperature Stirling engines: due to its low frequency, inexpensive air or nitrogen can be used as working gas in the engine, and due to the fact that it operates at low (60-120ºC) to medium (120-500ºC) temperatures, less expensive materials can be used for its construction.

BSR expects[164] HEATPULSE micro-cogeneration systems to be commercialised in 2003. At the current stage (2000), a so-called demonstrator has been built, and a prototype is expected to be ready by 2002. Natural gas fuelled models will be developed mainly for the European market, while solar powered models are developed especially for what the company calls 'sunbelt' markets, mainly as use for decentralised power stations in Africa and Asia. Other target markets are U.S.A. and Japan. Estimated price is approx. USD 2,000-2,300 for a 1 kW micro-cogeneration product. Distribution and sale is likely to be undertaken through licensing partners.

Heatpulse AG, a wholly owned subsidiary of Power Pulse Holding AG, has been formed solely for the development and commercialisation of the gas-fuelled micro-cogeneration system based on HEATPULSE.[165]

7.2.4 BHKW Betreiber: *Stirling Energie Modul (SEM)*

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[161] *Company history* <http://bominsolar.com/history.php3> (24 Apr. 2001).
[162] BSR, *The Bomin Stirling Technology HEATPULSE*™, no date , p.7. (Document obtained from Bomin Solar Research, 3 May 2001).
[163] European patent P00861EP and patents in Australia, Brazil, Canada, Japan and U.S.A.
[164] Telephone communication with Bomin Solar Research (20 Apr. 2001 and 3 May 2001).
[165] Private communication with Dr. Claus Colsman-Freyberger (8 May 2001).

BHKW Betreiber GmbH,[166] located in Frankfurt am Main, Germany, was started in 1998 and has about 30 employees (2001). The company designs and markets energy and cogeneration systems for homes (single and multi-family) as well as business.

Around 2000, BHKW Betreiber bought the Stirling Energie Modul (SEM) from a large Swiss packaging group, SIG Schweizerishe Industrie-Gesellschaft,[167] based in Neuhausen am Rheinfall, Switzerland. Due to strategic changes, in 2000 SIG decided to concentrate on packaging technology and therefore, among others two divisions, SIG Arms (weapon) and SIG Positec (positioning/automation solutions for engines) were divested. With these changes, the prototype of SIG's free-piston Stirling engine-based micro-cogeneration system was sold to BHKW Betreiber. SIG had worked on developing the Stirling Energie Modul since 1994 together with partners.[168] According to Mr. Rene Andregg from SIG,[169] SIG already started field tests of SEM in spring 2000. SEM was intended for residential customers who are willing to pay EUR 2,000 more for SEM than for a conventional heating system, and the target price was EUR 5,000 for its first serial production. Due to financial support from the gas industry, SEM was designed to run with a natural gas burner.

The SEM, with a single-cylinder free-piston Stirling engine and a linear alternator, generates an electric output of 1 kW (230 V at 50 Hz) and a thermal output of 6 kW. The SEM free-piston Stirling engine's lifetime is estimated to more than 50,000 hours.[170] As for BHKW Betreiber's plans for SEM, only limited information is currently publicly available. Nevertheless, Dr. Hermann Sommer of BHKW Betreiber informs[171] that field tests of a gas-fuelled version of SEM are expected to be completed by spring 2002. Following this, BHKW Betreiber intends to introduce production of a small series to the market. Besides this, BHKW Betreiber is developing variants of SEM fuelled by fuel oil and renewable energy (biomass, pellets, etc.). It is not possible to say when these are going to be ready.

7.2.5 ecopower energy solutions: *ecopower micro-CHP*

Ecopower energy solutions AG,[172] located in Biel/Bienne, Switzerland, is a small development company with 15 employees (2001). The company is a joint venture capital company, founded in 1995 by Daniel Ryhiner. Ecopower's first product is the ecopower micro-CHP, a modulating power output micro-cogeneration system for homes and small businesses. According to Mr. Stefan Freudiger of ecopower,[173] ecopower micro-CHP was launched in autumn 1999 in Germany as the first European country, after 4 years of research and development and testing. Later it was introduced in Switzerland (2000), followed by Austria.

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166 *DIBA GmbH und BHKW Betreiber* <http://bhkw-energie.de> (3 May 2001).
167 *SIG* <http://www.sig-group.com> (24 Apr. 2000).
168 *SIG, Energie Stirling Modul: Die stromerzeugende Heizung* (brochure, no date), p. 2.
169 E-mail from Mr. Rene Anderegg, SIG Sweizerische Industrie-Gesellschaft, (6 June 2000).
170 *IG, Energie Stirling Modul: Die stromerzeugende Heizung* (brochure, no date), p. 2-5.
171 E-mail from Dr. Hermann Sommer, BHKW Betreiber GmH (9 May 2001).
172 *Mit Strom und Wärme der Zeit voraus!* <http://www.ecopower.ch> (24 Apr. 2001).
173 E-mail from Mr. Stefan Freudiger, ecopower energy solutions AG (5 June 2000).

Ecopower micro-CHP,[174] which runs on natural gas, propane gas or biogas (min. 60% methane), delivers an electric output of approx. 2.0-4.7 kW and a thermal output of 6.0-13.8 kW with slight variations depending on the fuel. Overall efficiency is more than 90% (fuel-to-electricity: max. 25%; fuel-to-heat: max. 65%). The engine is a single-cylinder gas engine (developed by Briggs & Stratton in U.S.A.). Its dimensions are L 137×W 76×H 108 cm. A feature of ecopower micro-CHP is its power modulation, developed and patented by ecopower and designed to ensure that it "is always producing the exact amount of energy instantly needed." Its mode of operation can be either heat controlled, typically used in homes, or electricity controlled, typically used in industry. Ecopower micro-CHP needs to be serviced every 4,000 hours or around once per year, and this includes change of oil, oil and air filter and various adjustments. The service-technician is supported by a maintenance program, facilitating diagnosis and adjustment procedures. Alternatively, the system may be equipped with a remote supervising kit.

Ecopower micro-CHP is especially targeted single- and multifamily houses but can also be used by small industry (e.g. small hotels, cheese dairies, butcheries, sports centres, etc.). The product has been approved according to the European Gas Appliances Directive and has been given the related CE-certificate[175] and can therefore be marketed in all of EU. As mentioned, it is already marketed in Germany, Switzerland and Austria, and other countries will follow. As for markets of the product, Mr. Freudiger informs that the first step is to market it in European countries with high electricity prices and high emissions for power generation.

In Germany it is marketed through VALENTIN Energie- und Umwelttechnik GmbH, Mainz,[176] which presently has 110 authorised partners in heating, sanitary and electrical engineering businesses. In Austria it is sold through Koller+Hofmann GmbH. According to Mr. Freudiger, the distributor sells the product to a local partner who will be responsible for servicing and initially operating the unit. The local partner sells it to an installer who will usually not be responsible for servicing the unit. Ecopower's brochure states[177] that the product is delivered ready for installation, and all connections are at the rear wall.

According to Mr. Freudiger, the price that the final consumer pays depends on distributor strategy and marketing conditions. In Switzerland ecopower micro-CHP is sold for a price of CHF 23,000 (this price includes a pump and additional sensors), and in Germany for DEM 21,500.

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[174] ecopower, *Care for the environment…for you too. Ecopower micro-CHP*, Brochure (no date, received June 2000), p. 2.
[175] PIN 0063AU3290
[176] *Über uns* <http://www.ecopower.de/frame.htm> (8 Sep. 2000).
[177] ecopower, *Care for the environment…for you too. Ecopower micro-CHP*, Brochure (no date, received June 2000), p. 4.

7.2.6 ENATEC: *micro-cogen unit*

ENATEC micro-cogen B.V.,[178] was established in 1997 as a development company with the objective of developing and demonstrating residential micro-cogeneration systems. The company is a joint venture between three Dutch shareholders: NV ENECO, ATAG Verwarming BV and ECN (Energie Onderzoek Centrum Nederland). ENECO is a gas and electricity utility company with 4,300 employees; ATAG Verwarming is a manufacturer of central heating systems, among others *Blauwe Engel II*; and ECN is a research institute in the field of sustainable energy with 600 employees.

ENATEC is currently (2001) developing a natural gas-fuelled micro-cogeneration system with an electric output of max. 1 kW (230 V at 50 Hz), and a modulating thermal output of 6-24 kW. Its overall efficiency is about 96%, according to an ECN paper (ECN-RX-00-004)[179]. The unit includes a free-piston Stirling engine with linear alternator developed exclusively for ENATEC by Stirling Technology Company of Washington, U.S.A. Moreover, it includes ATAG Vervarming's patented stainless steel heat exchanger, which is already used in Blauwe Engel II for transferring heat to water. Its natural gas burner is developed by ECN. The micro-cogeneration system is designed for houses that have a natural gas consumption of around 2,000 m^3/year or more for heating.

The system is designed to operate in conjunction with the electricity grid. It will be controlled by heating requirements for space heating and hot-water supply. In this way electricity is a by-product, which is to be either used in the house or supplied to the electricity grid by means of a so-called grid box, of which a prototype has been developed by Magnetics Enterprise BV. In other words it is to be used as a central heating boiler with the additional benefit of electricity. Installation is a 'plug and power' installation and no significant conversions are necessary in the home.

At the current phase, the product is still under development but a prototype generating 0.35 kW of electricity has been built and successfully demonstrated. According to Mr. Lucas Bekkering of ENATEC,[180] the micro-cogeneration system, which has no name yet, is to be marketed in Europe. ATAG Verwarming is responsible for distribution. ATAG estimates that the product will be commercialised on a large scale in 2004 but it is intended that the first units will be made available for early adopters already in 2003. As for the price of ENATEC's micro-cogeneration system, according to Mr. Bekkering, it is still too early to say.

7.2.7 Gastec

Gastec N.V. of Apeldoorn, the Netherlands, specialises[181] in gas technology and is a developer, manufacturer and provider of industrial products and services for supply and

[178] *ENATEC micro-cogen B.V.* <http://www.enatec.com> (7 May 2001).
[179] Publicatie ECN-Schoon Fossiel <http://www.ecn.nl/library/reports/2000/rx00004.html> (14 Sep. 2000).
E-mail from Mrs. Jonker-Hassing, ECN Library bidoc@ecn.nl (14 Sep. 2000): The paper is available from the ECN Library, P.O.Box 1, 1755 ZG Petten, the Nethelands at the cost of USD 35.
[180] Telephone communication with Mr. Lucas Bekkering, ENATEC (7 May 2001).
[181] Gastec <http://www.gastec.com> (12 Sep. 2000).

use of natural gas. Gastec, with branch offices in Bulgaria, Germany, Italy and United Kingdom, has around 400 employees (1999)[182].

Mr. Martin Hagen from Gastec informs[183] that Gastec's main expertise is the development of domestic and commercial systems ranging from 0.1-1,000 kW(e) that are natural gas or propane fuelled. Gastec works together with institutions and manufacturers in developing micro-cogeneration products, most often on a confidential basis. In this context, Mr. Hagen mentions a number of products, most of which are incorporated in systems that are currently undergoing field testing. One important product converts natural gas to hydrogen and is employed in fuel cell technology by the U.S. company Plug Power. Secondly, Gastec has developed cogeneration systems around existing conversion units, of which successful developments include a 1 kW(e) micro-cogeneration system based on an internal combustion engine and a 0.3 kW(e) micro-cogeneration system based on a linear Stirling engine. Gastec supports Honda Motor Co. Ltd. of Japan in making its micro-cogeneration system suitable for use in Europe.[184]

According to Mr. Hagen, most of the products are aimed at domestic and small to medium-sized commercial customers in the cooler regions in Europe, Japan and the United States. Prices are determined by the clients using Gastec's technologies but a price of EUR 100-2,000 per kW(e) is estimated to be acceptable for the clients. However, a small but important market now exists that is willing to pay EUR 2,000 per kW(e).

7.2.8 Honda Motor Co., Ltd.

Honda Motor Co., Ltd., a leading manufacturer of motorcycles and automobiles, was established in 1948 and has its head office in Tokyo, Japan. The company and its approximately 300 world-wide subsidiaries develop, manufacture and distribute a wide range of products, including motorcycles, automobiles, and power equipment such as small general purpose engines, generators, marine engines and mini-ploughs for agricultural use. Honda has more than 100 manufacturing facilities in 33 countries.

In a press release of March 1998,[185] Honda announced the development of a micro-cogeneration product for homes, using a novel gas engine "GF160V" described as the world's smallest, with an electric output of 1.8 kW and a thermal output of 4.8 kW. The system is fuelled by natural gas and has an overall efficiency of 80%. The dimensions of the unit are L 48 × W 52 × H 100 cm. The unit was exhibited at Honda Fun Lab at Twin Ring Motegi in Tochigi Prefecture, Japan. Honda's micro-cogeneration system is designed to operate in conjunction with the electricity grid. According to Honda,[186] the product has not yet been commercialised: basic development of the unit has been completed, and it is currently (2001) being tested. Further information was unavailable.

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[182] COGEN Europe Members Directory, *Who's who in European cogeneration 1999-2000* p. 54.
[183] E-mail from Mr. Martin Hagen, Gastec (19 July 2000).
[184] *Projects - Honda develops micro-CHP system for residential market* <http://www.gastec.com/projects/honda.asp> (24 Apr. 2001).
[185] *Honda develops new energy-efficient, home-use equipment* <http://www.world.honda.com/news/1998/p980312.html> (24 Apr. 2001).
[186] Telephone communication with Honda (Belgium) (15 May 2001).

7.2.9 Nederlandse Gasunie

N.V. Nederlandse Gasunie is a Dutch natural gas trading and transmission company, with headquarters in Groningen, the Netherlands. The company, which has over 1,600 employees, buys, transmits and sells natural gas in the Netherlands and in Western Europe.[187]

According to Mr. Bertus Postmus of Gasunie,[188] to support the natural gas market, Gasunie has a research department that improves gas applications with the aim of creating efficient, clean and reliable gas applications. Although Gasunie does not sell appliances in the market, the company often demonstrates new technologies in order to promote these. Micro-cogeneration for use in both domestic and commercial sectors is highly promoted by the company, and in this regard Gasunie Research laboratories operates a WhisperGen micro-cogeneration unit from WhisperTech Limited of New Zealand. The WhisperGen has a Stirling engine, is fuelled by natural gas and gives an electric output of 0.8 kW.[189]

7.2.10 Plug Power: *HomeGen 7000*

Plug Power Inc.,[190] based in Latham, New York, U.S.A., specialises in the design and development of on-site electricity generation systems using PEM fuel cells for stationary applications. The company was founded in 1997 as a joint venture between DTE Energy Company and Mechanical Technology Inc. with the purpose of developing and manufacturing PEM fuel cell systems for electric power generation in residential, small business and transportation applications. General Electric is also a shareholder in the company. Plug Power presently (2001) has over 500 employees. In February 2000, Plug Power acquired all Gastec's intellectual property relating to fuel processor development, and as part of the agreement, 15 of Gastec's employees became employees of Plug Power.[191] A subsidiary, Plug Power Holland, was established in Apeldoorn, the Netherlands and it now has grown to over 30 employees. Plug Power Holland is responsible for establishing a European production base and is to develop fuel-processing equipment for residential cogeneration and adapt fuel cell components for European applications. Plug Power has received support from US DOE. Its strategic alliances include Gastec (Netherlands); Vaillant (based in Germany), which is a leading manufacturer and supplier of heating appliance in Europe; Advanced Energy Systems Inc. (U.S.A.); Celanese (Germany), and Engelhard Corporation (U.S.A). Plug Power has been awarded 30 U.S. patents and 1 Dutch patent.

In the first half of 2002 Plug Power expects to launch some pre-commercial units of HomeGen 7000, a fuel cell micro-cogeneration unit for homes and small business, fuelled by natural gas or propane gas, giving an electric output of 7 kW. GE is developing a

187 *Gasunie* <http://www.gasunie.nl> (24 Apr. 2001).
188 E-mail from Mr. Berthus Postmus, Gasunie (16 June 2000).
189 *Micro-CHP knocking on the door* <http://www.gasunie.nl/eng/p_pg.htm> (13 Sep. 2000).
190 *Plug Power* <http://www.plugpower.com> (24 Apr. 2001).
191 Press release (9 Feb. 2000): *Plug Power to acquire Gastec…* <http://www.plugpower.com/news/pressreleases.cfm> (24 Apr. 2001).

product release strategy for these units. In 1998 a prototype was installed in a demonstration house in Latham, New York.

As for distribution of HomeGen 7000, in February 2000 Plug Power has entered an agreement with General Electric for distribution and service. GE Fuel Cell Systems, LLC, a joint venture between Plug Power and GE MicroGen, a subsidiary of GE Power Systems, was formed for the distribution, installation and servicing of HomeGen 7000. GE MicroGen will be handling the distribution efforts of the units in most of the world and is developing a global distribution network for the HomeGen 7000. GE MicroGen partner distributors will generally be electric utilities and natural gas companies. However, it has been agreed that DTE Energy Technologies will distribute the HomeGen in four states in U.S.A. So far, GE MicroGen has made agreements with partners in different parts of the world. In Europe, Vaillant is going to cover the markets of Austria, Germany, the Netherlands and Switzerland.

7.2.11 Polar Power: *Micro Cogeneration Unit*

Polar Power Inc.,[192] founded in 1979 and based in Carson, California, U.S.A., specialises in product design, development, system integration and engineering support services within the field of power generators and power supply for the telecommunication, military, aerospace and industrial markets. The company has about 15 employees (2001).

Polar Power offers a micro-cogeneration product, the Micro Cogeneration Unit, which includes a Kawaski engine and a Polar Power alternator. It is fuelled by natural gas, propane or gasoline, and available as DC or AC versions. The Micro Cogeneration Unit generates a maximum of 6 kW of electricity and up to 10 kW of heat for space heating, hot-water supply and air-conditioning. It is designed for both stationary and mobile applications, e.g. in homes, farms, offices, small business, military field posts, recreational vehicles, etc. According to Mr. Arthur Sams,[193] President and CEO of Polar Power, the Micro Cogeneration Unit is available only in the United States through utilities (currently it is sold to end-users by Arizona Public Service Company, a provider of electrical power statewide). In the first applications, the Micro Cogeneration Unit is designed to operate in independence of the electricity grid. Retail prices are about USD 9,500-9,900.

7.2.12 Powerline GES: *General Energy System ("GES")*

Powerline GES Pty Ltd.,[194] founded in 1995 in Sydney, Australia, focuses solely on the development, assembly and mass distribution of its micro-cogeneration unit for residential and small business applications, the General Energy System (GES). Powerline has established international branch offices in Bangkok, Boston and London.

The GES is designed to supply all electricity, heating and air-conditioning requirements of a typical residential dwelling in developed countries. Fuelled by natural gas or LPG, it

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[192] *Polar Power Inc* <http://www.polarpowerinc.com> (24 Apr. 2001).
[193] Telephone communication with Mr. Arthur Sams, Polar Power (11 May 2001).
[194] *Powerline GES - Providing greener energy solutions* <http://www.powerlinesystems.com.au> (24 Apr. 2001).

generates a maximum of 4.5 kW electric energy (110/220/240 VAC at 50/60 Hz output) and a maximum of 10 kW heat. Electric efficiency is 22-25%, and the overall efficiency exceeds 90%. Information about the engine is not publicly available for the time being, but the system is cooled by water and described as quiet, compact and efficient. Dimensions of the unit are H 100 × W 96 × D 62 cm. It is simple to install and it has low maintenance requirements.

The GES is designed to operate either in conjunction with the electricity grid or independently. The GES is aimed at several customer segments, including residential homes, remote and holiday homes and small business (offices, dairies, supermarkets, fitness centres, horticulture, schools etc.). In a community, several hundreds or thousands of GES units, which have the ability of communicating simultaneously, may be linked with each other, forming a 'micro-grid. Also, any number of units can be linked in order to meet larger power loads.

According to Powerline,[195] the GES is in its final stages of development, and is going to be produced at Powerline's manufacturing facilities in Thailand at the end of 2001. TXU Australia, a supplier and distributor of gas and electricity across Eastern Australia, has successfully tested the GES at various sites in Australia, and around 15 units are operating in Australia. Target markets are Australia, North America, and all of Europe. It will be sold to utilities for a price of about USD 3,000, and these will distribute it to final users. Powerline already has agreements with several electricity companies in the United Kingdom.

7.2.13 Quiet Revolution Motor Company (QRMC)

Quiet Revolution Motor Company, L.L.C. (QRMC)[196] located in Sallisaw, Oklahoma, U.S.A., was founded in 1999 by Darryl Phillips and Philip Hodge, with the purpose of developing and marketing Stirling engines and Stirling engine-related intellectual property. Darryl Philips already had over 20 years of experience in Stirling engines. QRMC initially concentrates on developing engines and intellectual property in the following fields of applications: research engines, aviation engines and non-aviation engines including sailboats and generators.

According to Mr. Philip Hodge,[197] President of QRMC, the company is still years away from having any commercial products. However, cogeneration is a planned future market, and Mr. Hodge believes it may be QRMC's biggest future market.

7.2.14 SenerTec Kraft-Wärme-Energiesysteme: *DACHS HKA*

SenerTec Kraft-Wärme-Energiesysteme GmbH[198] of Schweinfurt, Germany, was founded in 1996 with the objective to produce and market SenerTec cogeneration systems, and the company now has 65 employees (2001). The company's markets a micro-cogeneration

[195] Telephone communication with Powerline GES Pty Ltd. , Australia office, marketing department (9 May 2001).
[196] <http://www.qrmc/> (9 Oct. 2000).
[197] E-mail from Mr. Philip Hodge, President, Quiet Revolution Motor Company (22 Oct. 2000).

product called DACHS HKA. It is based on a certain sound-absorbent single-cylinder internal combustion engine, developed in 1979 by Fichtel & Sachs AG, a subcontractor to the automobile industry.

Mr. Heiko Hespelein of SenerTec informs[199] that DACHS HKA runs on natural gas, LPG, fuel oil and biodiesel. The electric output is about 5.0-5.5 kW while the thermal output is about 10-12 kW, depending on which fuel is used. It reaches an overall efficiency of 90%, and lifetime of the DACHS HKA is about 80,000 operation hours.[200] The product is designed for single and multi-family houses, hotels, public swimming pools, small business, etc. It can be installed to operate in conjunction with the electricity grid, or as a stand-alone unit without grid connection in remote areas, e.g. weekend houses or cottages in the mountains.

According to Mr. Hespelein, 3,500 units of SenerTec's DACHS HKA have been sold as of June 2000. The markets entered are the following: Germany, Austria, Switzerland, Italy, Belgium, the Netherlands, Luxembourg, Denmark, Poland and Mallorca. Moreover, it has been tested in France, Norway, Sweden and Japan. Further planned markets are United Kingdom, Ireland and Spain. The price in Germany is EUR 10,570 for a unit running on natural gas with an electric output of 5.5 kW.

The DACHS HKA is sold, installed and maintained by trained partners of SenerTec. Generally there is one partner in each region or country that builds up its own network of service partners. Services include counselling and assistance in general and technical questions, calculation of investment costs and profitability and a 24-hour emergency service.

7.2.15 Sigma Elektroteknisk: *PCP™*

Sigma Elektroteknisk A.S.,[201] of Hølen, Norway, founded in 1994, is a private Norwegian engineering company with around 13 employees (2000). In August 2000, the company was acquired by Ocean Power Corporation of the United States, becoming a wholly owned Ocean Power subsidiary. Sigma was set up specifically with the purpose of commercialising PCP™ (Personal Combustion Powerplant), a Stirling engine-based energy converter developed by Sigma, designed for application in micro-cogeneration systems for private homes. Sigma's Stirling engine technology was acquired from United Stirling of Malmö, Sweden.

The PCP™, which is fuelled by natural gas or propane, generates an electric output of 3 kW and a thermal output of 9 kW. The efficiency (natural gas to mechanical work) of the PCP is currently around 30% but is expected to be higher in the first commercial products. Lifetime is expected to be about more than 50,000 operation hours. The engine is a single-

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[198] *SenerTec Heiz-Kraft-Anlagen* <http://www.senertec.de> (24 Apr. 2001).
[199] E-mail from Mr. Heiko Hespelein (6 June 2000).
[200] SenerTec, *Heat and power from one unit* (Brochure).
[201] Sigma Elektroteknisk AS <http://www.sigma-el.com> (24 Apr. 2001).

cylinder (beta type) kinematic Stirling engine. PCP™ is designed to be heat led, generating electricity as a by-product and operating in conjunction with the grid.

Sigma will not develop or manufacture micro-cogeneration systems itself but the strategy is to manufacture and offer the PCP™ to OEM (original equipment manufacturer) partner companies that will integrate the component into micro-cogeneration products. PCP™ prototypes, which will be made available to OEMs for micro-cogeneration prototype package development, are planned to be ready by 2001. The PCM™ is then going to be launched in 2003, and PCM™-based micro-cogeneration systems are expected to be commercially available at the same time. The prime target markets are Germany, the Netherlands and United Kingdom. These are markets that have well-developed natural gas infrastructures where natural gas fuelled micro-cogeneration systems can replace natural gas boilers.

The first prototype of PCM™ was completed in 1998. For demonstration of the viability of PCP™, Sigma received support under the EU THERMIE programme.[202] In this connection, a consortium consisting of Sigma, Scottish Hydro Electric (UK), EA Technology (UK), NESA (Denmark), and TEM (Sweden) was formed with the objective of installing 5 PCP™-based micro-cogeneration units in European.

The price of the PCP™ when manufactured in large volumes (i.e. 100,000 units/year) is estimated to be about USD 1,100. For competitive reasons, the company could release no further details.[203]

7.2.16 Stirling Engine Co.

Stirling Engine Co., Ltd., a Japanese company based in Kawasaki City, Kanagawa Prefecture, Japan, was established in 1997 with the purpose of introducing biomass fuelled engines. The company’s main business is the manufacture and sale of ST-5 and related equipment under exclusive licence of Stirling Technology Inc. (Athens, Ohio, U.S.A.), covering the Asian region. In addition, Stirling Engine Co. is the exclusive agent of External Power in Japan, responsible for market development of biomass fuelled and natural gas fuelled 1Twin systems. Inquiries were sent to Stirling Engine Co. in order to obtain more information about the company’s plans, but unfortunately no reply was received.

7.2.17 Stirling Technology Company (STC): *RemoteGen™*

Stirling Technology Company (STC),[204] established in 1985 and located in Kennewick, Washington, U.S.A., is a U.S. designer and manufacturer of Stirling cycle machines, specialising in free-piston Stirling engines for various applications, e.g. power generation, cryogenic cooling computers, high temperature superconductors and lasers. In 1996, STC

[202] *Norwegians develop small Stirling engines* <http://www.eurorex.com/wyg/techno/NO0705.HTM> (3 Aug. 1999).
[203] E-mail from Mr. Simon Kolin, Sigma Elektroteknisk AS (14 June 2000).
[204] *Stirling Technology Company* <http://www.stirlingtech.com> (24 Apr. 2001).

commercialised BeCool™ Stirling cryocoolers for commercial applications. RemoteGen™ Stirling electrical generators are currently under development.

RemoteGen™ has several applications including residential micro-cogeneration. RemoteGen™ comes in three models (RG-350, RG-1000 and RG-3000), generating 0.35 kW, 1 kW and 3 kW of electricity, respectively. According to Mr. Dan Trolley, Marketing Coordinator at STC,[205] the most common fuels used for RemoteGen are propane and natural gas although RemoteGen can run on virtually any fuel that produces the needed heat.

Mr. Trolley informs that the models RG-350, RG-1000, and RG-3000 are presently (Aug. 2000) at different stages of development. The RG-350 is in limited production. The RG-1000 is undergoing initial testing, and field-testing is projected for autumn/winter of 2000. The RG-3000 will begin testing in early 2001.

According to Mr. Trolley, the RG-1000 and RG-3000 are intended for use in individual residences e.g. homes and apartments. STC is planning to supply the engine/generator to various partners who will integrate it into full products for individual use. As regards price, a final price is difficult to predict due to the unknown balance of system components. However, the partners of STC who are testing the units estimate that the RG-1000 based unit can be marketed for about USD 1,000 per unit with an annual production of 100,000 units. It is possible that the partners referred to are ENATEC.

7.2.18 Stirling Technology Inc. (STI): *ST-5*

Stirling Technology, Inc. (STI) of Athens, Ohio, U.S.A., incorporated in 1983,[206] researches, develops and manufactures energy recovery ventilators and Stirling engines. According to Ms. Chelsea Croston of STI,[207] however, the company's current main focus is on the manufacture of RecoupAerator® energy recovery ventilators designed to improve indoor air quality.

STI has developed the *ST-5*, a Stirling engine designed for stationary applications in residential and small-scale agricultural and industrial purposes. The ST-5 can be used in micro-cogeneration systems, generating a maximum of 3.5 kW of electricity and more than 25 kW of heat. The overall efficiency is 80%. The ST-5 has a multiple-fuel capacity, meaning that almost any combustible material is suitable for the ST-5, including wood, wood pellets, husks, peanut shells, weed, hay, cotton waste, and natural gas, enabling own production of fuel by the user. The ST-5 is especially intended for use in remote areas without access to the electricity grid. Moreover, it is intended for people who do not want to be dependent on the electricity grid.[208]

An ST-5 based micro-cogeneration system has been installed in the home of one of Stirling Technology's founders. According to Ms. Chelsea Croston, approximately 100 ST-5

[205] E-mail from Mr. Dan Trolley, Marketing Coordinator, STC (22 Aug. 2000).
[206] *The history behind Stirling Technology* <http://www.lychonia.com/history.html> (24 Apr. 2001).
[207] E-mail from Ms. Chelsea Croston, Stirling Technology, Inc. (28 June 2000).
[208] Total Energy Dependence <http://www.stirling-tech.com/striling/total.htm> (3 Sep. 1999).

engines were produced in India through a joint venture, but due to political reasons the joint-venture failed. Currently the technology is licensed for manufacture to Stirling Engine Co. Japan.

7.2.19 Whisper Tech Limited: *WhisperGen*

Whisper Tech Limited,[209] of Christchurch, New Zealand, is a research and development company specialising in Stirling engine-based micro-cogeneration cogeneration systems. It was established in 1995 with investment support from the Christchurch-based electricity network management company Orion New Zealand (former Southpower Limited) particularly for developing and commercialising WhisperGen, a 4-cylinder double acting Stirling engine. A feature of Whisper Tech's Stirling engine is its patented 'wobble yoke' linkage, which "has allowed the design of a compact, low vibration engine".

Whisper Tech has developed a WhisperGen micro-cogeneration system in two versions: a DC version (WhisperGen PPS16 DC System) and an AC version (WhisperGen AC System). Each of these generate an electric output of 0.75 kW and a thermal output of 6 kW. They are fuelled by most liquid or gaseous fuels, e.g. natural gas, LPG, kerosene and diesel. The products are targeted boat and homeowners.

The WhisperGen PPS16 DC System has been launched and is commercially available in Western Europe for marine applications. It has obtained a CE-certificate and is distributed by Whisper Tech's authorised agent in the Netherlands (Victron Energie BV) and according to Rangi de Abaffi of Whisper Tech,[210] WhisperGen DC systems are currently retailed for about NGL 20,000-25,000. The WhisperGen DC system supplies electricity at 12/24 V DC, and it is designed to charge batteries used mainly in yachts, houseboats and remote homes. In this application it is considered an electric generator with a by-product of heat.

The WhisperGen AC System is designed for single-household urban homes. It is currently natural gas or LPG-fuelled, supplying electricity at 230 V. It is cooled by water and the dimensions of the unit are W 45 × D 50 × H 80 cm. The WhisperGen AC system is designed to operate in conjunction with the electricity grid and to supply excess electricity to the electricity grid. It is intended for use in countries where central heating boilers are the norm, and it can be considered as a supplier of heat for space heating and hot water with the by-product of electricity. Apparently, the WhisperGen AC system is being field tested by parties in Denmark, Germany, the Netherlands, Korea, United Kingdom and the United States. Whisper Tech Limited plans to offer the first commercial product for sale in Europe in 2001.[211]

According to de Abaffi, at this stage the WhisperGen micro-cogeneration product are sold in Western Europe only, but is planned to be sold in the U.S.A. in the future. Whisper Tech

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[209] *Whisper Tech Limited* <http://www.whispertech.co.nz> (24 Apr. 2001).
[210] E-mail from Rangi de Abaffi, Whisper Tech Limited (7 July 2000).
[211] *Whisper Tech Limited Frequently Asked Questions* <http://www.whistertech.co.nz/whispfaq.htm> (15 Sep. 2000).

has developed a 3 kW(e) WhisperGen prototype, but de Abaffi informs that no further work is planned on this system for a number of years.

7.3 Discussion: 1Twin's Brand/Industry Competitors in Europe

Globally, no other company than External Power is apparently planning to launch wood pellet fuelled micro-cogeneration products anywhere in the world, so External Power does not seem to have any brand competitors. The closest one gets to brand competitors are Stirling Technology Company and Stirling Technology Inc., both located in the United States. Stirling Technology Company, which is co-operating with ENATEC, could convert its Stirling engine based micro-cogeneration product into biomass fuelled models as well, but seems to be concentrating on natural gas fuelled models. Stirling Technology Inc. has developed a biomass fuelled micro-cogeneration product based on a Stirling engine, but has licensed the technology exclusively to the Japanese Stirling Engine Co. covering the Asian region, and Stirling Technology Inc. themselves is currently focusing on a different product, namely a ventilation product. BHKW Betreiber in Germany is working on renewable energy fuelled Stirling engine micro-cogeneration products, but it is not possible to say when these may be commercialised.

Only two companies have so far launched micro-cogeneration products in the European market: the Swiss ecopower and the German SenerTec. Markets entered by ecopower are Switzerland, Austria and Germany. Markets in Europe covered by SenerTec are Germany, Austria, Belgium, Italy, Netherlands, Luxembourg, Denmark and Poland. Both companies have employed internal combustion engines in their micro-cogeneration products.

Most other potential competitors are planning to launch micro-cogeneration products almost within the same period as External Power: MicroGen™ being developed by Advantica in United Kingdom for an unknown client is planned to be launched in 2003 in Europe. HEATPULSE™, being developed by the German Bomin Solar Research is also expected to be commercialised in 2003 in Europe. ENATEC is planning to make its Stirling engine based micro-cogeneration product available to early adapters in 2003 followed by large-scale commercialisation in 2004. Equally, Sigma in Norway that its PCP™, as a component in original equipment manufacturers' micro-cogeneration products will be commercialised in 2003, primarily in Germany, Netherlands and the United Kingdom.

Some companies are apparently going to launch products earlier than 2003. WhisperGen of New Zealand seems already to be field testing a Stirling engine based micro-cogeneration in several European countries (Denmark, Germany, United Kingdom) and expects to commercialise the product in 2001. Plug Power expects to launch pre-commercial units of the fuel cell micro-cogeneration product HomeGen 7000, to be distributed by Vaillant in Austria, Germany and the Netherlands. Powerline of Australia is planning to produce its GES in Thailand in 2001 to be targeted Europe.

The survey of potential competitors therefore shows that when External Power launches its wood pellet fuelled 1Twin in 2003 as expected there are many other companies that will do the same. As most of these are fuelled by natural gas, it is possible that they may focus on different market segments. External Power is also going to commercialise a system fuelled by natural gas which will compete with these.

8 The Electricity Industry in Europe

This chapter explores the electricity industry in Europe in order to determine the potential nature of competition between this industry and the wood pellet fuelled 1Twin, which generates electricity directly in the home. In this connection, however, we shall remember that it seems most likely that the wood pellet fuelled 1Twin is going to be used in conjunction with the grid, considering that very few homes in Europe do not have access to the grid. This chapter focuses on the recent changes in the European electricity industry, mainly as a result of the implementation of EC Directive 96/92, and on how the industry looks today in terms of organisation, market structure, ownership and regulation. Additionally, the rules regarding auto-generation are examined, as this is of relevance to 1Twin.

Owing to its complexity and variety, the task of describing the European electricity industry is not an easy one. This chapter does not deal with the subject in detail, and for a more comprehensive understanding, the reader is referred to other literature and sources of information. Many books have been written concerning electricity industries in Europe, but owing to recent developments the current information is unfortunately partly outdated in many cases. Documents providing more up-to-date information are available on the World Wide Web.

8.1 General Characteristics of Electricity Industries

Although electricity industries can vary considerably from country to country, e.g. in respect of market structure and ownership (see the box below) and the use of energy sources for the generation of electricity in power plants, they do have certain similarities. They all comprise the main interdependent functions of generation, transmission, distribution and supply:

- **Generation**: Production of electricity in power plants. The electricity is dispatched into the network.
- **Transmission**: High voltage transportation of electricity through a network of power lines and substations. Voltages vary both within individual transmission systems and from country to country (common are e.g. 110, 132, 225, 220, and 400 kV lines).
- **Distribution**: Medium- and low-voltage transportation of electricity through a local network of overhead lines, underground cables and transformers operating at voltages down to e.g. 220 V, depending on the country. Distribution takes place from the transmission system or power plants to customers.
- **Supply**: The business of metering, billing, advertising, providing customer information, service, etc. to wholesale or retail customers in industrial, commercial or residential markets.

Transmission and distribution, which involve transportation of electricity from power plants to consumers, are considered natural monopolies with little scope for competition; it would be highly inefficient to have several parallel competing networks. There is typically one company operating the national transmission network and a number of regional companies operating the distribution networks. So-called *system operators* of transmission and distribution networks are responsible for technical operation and maintenance of the grid in order to ensure reliability and security of supply, including voltage and frequency stability.

A fundamental characteristic of electricity is that, unlike other commodities, it cannot be stored in large amounts except at very high cost batteries. This means that electricity must be used the moment it is generated and that demand and supply therefore has to be matched instantaneously at all times.

The fact that electricity is generally regarded by governments as a public necessity has resulted in highly regulated electricity industries. For example, they may be imposed certain public service obligations such as supplying electricity to geographically remote customers at reasonable prices.

Types of Market Structure and Ownership in Electricity Industries

Electricity industries are difficult to classify due to the variety of systems in different countries. Some market structures are more or less centralised with a dominant company controlling most industry functions. Other market structures are more or less decentralised, or fragmented, consisting of a plurality of companies. Companies may be vertically integrated, engaging in several functions of generation, transmission, distribution and supply. They may be horizontally integrated as well, engaging in non-electricity functions, e.g. gas supply. Nevertheless, it may be helpful to describe electricity industries along two dimensions: market structure and ownership.

There are many ways of viewing the market structure of electricity industries. For instance, Hunt and Shuttleworth suggest[212] that there are 4 basic, simplified electricity market structures, based on degree of competition and choice. While the first model has no competition, competition is systematically introduced in the next 3 models, first in generation, then wholesale and retail:

1. **Monopoly**
   A single vertically integrated utility is in charge of generation, transmission, distribution and supply. This model may apply to a whole country or to a single region or town. A variant of this model is the existence of separate distribution & retail companies, which can only purchase electricity from a single generation & transmission company. Until 1980, almost all countries had this type of market structure, but this is slowly changing although most countries still have this type of structure.

2. **Competition in generation**
   Competition in generation is encouraged by the permission of independent power producers. However, all generators have to sell to a single purchasing body, and generators will typically

[212] Hunt and Shuttleworth, *Competition and choice in electricity*, Wiley & Sons, Chichester (1996).

compete for supply contracts. The purchasing agency controls transmission and resells electricity to monopoly distribution & supply companies.

3. **Wholesale competition**
Monopoly distribution & supply companies may purchase electricity from any competing generator. There is open access to the transmission network, operated and maintained by a transmission system operator. A power exchange or spot market may be introduced.

4. **Retail competition**
All customers may choose their supplier; customers may buy electricity directly from competing generators or through a distribution & supply company or a supply company. Distribution is separated from retail activities, providing open access to both transmission and distribution networks.

Ownership may be roughly divided into public and private, although companies may also be of mixed public and private ownership. State-owned companies can be legally organised in several ways, from a government department to a wholly owned public limited company subject to private sector company law.[213]

Recent developments in many European countries, especially caused by EC Directive 96/92, are mainly restructuring, moving toward wholesale and retail competition, *not* change of ownership from public to private.

8.2 The EC Electricity Directive: Opening Up to Competition

An understanding of recent legislation within the European Union is particularly important for the understanding of the current developments in EU Member States and to some extent in candidate countries in Central and Eastern Europe. On 19th December 1996, the European Parliament and the Council of the European Union adopted Directive 96/92/EC[214] ("the EC Electricity Directive") with the aim of introducing competitive forces into the electricity industries of all 15 Member States. The intention of this directive, which has been effective as from 19th December 1999, is to lay a foundation for a common electricity market.

The EC Electricity Directive seeks to establish common rules for the generation, transmission and distribution of electricity (Article 1). Although a degree of freedom is given with regard to the method of introducing competition, Member States are required, as a minimum, to adopt national legislation in order to ensure that: (i) competition is introduced in the building of new generation plants; (ii) a transmission system operator is designated; (iii) distribution system operators are designated; (iv) accounts of integrated companies are unbundled; (v) non-discriminatory access to networks is given; and (vi) markets are gradually opened up to customer choice of supplier.

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[213] R. Vaitilingam (ed.), *A European market for electricity?*, Centre for Economic Policy, London (1999), p. 39.

[214] Dir. 96/92/EC concerning common rules for the internal market in electricity [1996] O.J. L27, 30.01.1997, p.20. For an interpretation see e.g. *Opening up to choice: the single electricity market,* European Commission (1999) or R. Vaitilingam (ed.), *A European market for electricity?*, (1999), p. 77-79.

In generation, Member States may choose between two procedures for the construction of new capacity: authorisation (Article 5) and tendering (Article 6). Under the *authorisation procedure*, construction of new plants is open to all companies provided that they comply with the criteria for grant of authorisation, related to e.g. safety, environmental protection, siting, energy source, etc. Under the *tendering procedure*, a designated authority estimates what new generating capacity is needed and solicits tenders, which is then allocated on a non-discriminatory basis.

In transmission, Member States must designate a transmission system operator (TSO), who is responsible for operating, maintaining and developing the transmission grid in addition to providing information to interconnected systems in order to ensure secure and efficient operation (Article 7). TSOs should dispatch generating plants in its area without discrimination in favour of plants owned by the same company as the TSO (Article 8). However, Member States may require TSOs to give priority to plants using renewable energy sources (Article 8.3). The directive requires that TSOs are independent from generation and distribution, at least in management terms (Article 8.6).

In distribution (Articles 10-12), the rules are similar to transmission. Distribution system operators must be designated. Member States may require distribution companies to supply customers in a given area at regulated tariffs.

The directive provides for unbundling of the accounts of integrated companies, i.e. separation of accounts for generation, transmission, distribution and non-electricity activities (Article 14).

Access to transmission and distribution networks to others than the owners (third party access) must be provided on a non-discriminatory and transparent basis. Member States may choose between three different arrangements (Articles 17-18): negotiated access, regulated access and the single buyer model. In any case, access may be denied on grounds of insufficient capacity. *Negotiated access* allows suppliers and eligible customers to negotiate with network operators for access. System operators are required to publish average prices over the previous year as a guide to potential users. Under *regulated access*, fixed tariffs, which are published, apply to all users of the network. Under the *single buyer procedure*, there is a single wholesale buyer of electricity. Member States that choose this procedure must designate a legal person to be the single buyer within the territory of the system operator. Supply contracts may still be concluded between producers and eligible customers.

Electricity markets are to be opened up gradually in 3 phases based on consumption levels (Article 19): 40 GWh by 19 February 1999, 20 GWh by 19 February 2000 and 9 GWh by 19 February 2003. An increasing share of wholesale and final customers, including suppliers, thereby gets the right to choose their supplier. The minimum required ratios of market opening correspond to about 26% in 1999, 28% in 2000, and 33% in 2003.

The procedures in building new power plants (authorisation and tendering) and providing network access (negotiated, regulated, single buyer) that Member States have chosen are described in the box below.

Opted Procedures for New Power Plants and Network Access

Procedures concerning building of new generation plant: All 15 EU Member States have opted for an authorisation procedure. Greece, Ireland and Portugal, however, have chosen to use both authorisation and tendering procedures, while France has chosen an authorisation procedure with complementary tendering.[215]

Procedures concerning access to networks: All Member States, except Germany and Greece have basically opted for regulated third party access. Germany and Greece have opted for negotiated third party access.

It should be noted that some Member States got derogation on the implementation of the directive: Greece got a two-year and Ireland got a one-year derogation. Belgium decided not to use its derogation.[216]

8.2.1 What does the Directive Say About Auto-Generation?

The Electricity Directive has only a few lines about auto-generation ("autoproducers"). It defines an auto-generator as "a natural or legal person generating electricity essentially for his own use" (Article 2.3). Furthermore, the directive states that it should be possible for autoproducers to obtain authorisation for the building of a plant (Article 6.6) and that necessary measure should be taken so that autoproducers can negotiate access to the network in order to supply own premises within the country or in another EU Member State (Article 20(i)).

Domestic micro-cogeneration belongs to the category of auto-generation. Nonetheless, at the time when the Electricity Directive was formulated, domestic micro-cogeneration products had barely been developed, not to mention commercialised. Large industrial auto-generators have existed for decades, but it is only within the recent few years that small-scale auto-generators, such as owners of micro-cogeneration devises have seriously started to appear. It seems that small-scale residential auto-generators have not been taken into consideration in the law, but that it may be necessary in the future.

Owning and operating a domestic micro-cogeneration device apparently does not present any problem. The problem arises if one is considering exporting surplus home-generated electricity into the grid. There is no doubt that it is possible, but permission has to be obtained and it may not always be permitted, although several electricity companies, e.g. Eastern Energy in United Kingdom[217], offer their customers to buy excess home-generated

[215] *Opening up to choice: the single electricity market*, European Commission (1999), p.6.
R. Vaitilingam (ed.), *A European market for electricity?*, (1999), p. 82-83.

[216] Op.cit., p. 81.

[217] *Committed to a greener future* <http://www.easternenergy.co.uk/about/sup_env.asp> (3 June 2001).

electricity, at the same time as customers buy what they need. This is the concept of net metering. An extra meter has to be installed in order to record the amount of electricity exported to the network. Extra cables might also be needed.[218] However, crucial is that the exported electricity fulfils the quality requirement in terms of voltage and frequency. Moreover, it is important that no safety threats are imposed on the staff working with the electric lines: a grid-connected micro-cogeneration devise works the same way as a power plant with the potential of maintaining voltage in lines that would otherwise the dead during blackout or line works.[219]

8.3 Overview of the European Electricity Industry

The electricity industry in Europe is complex, large and well-established. Geographically, its networks extend to nearly all households in Europe. Neither EU nor the International Energy Agency has information on the number of households in Europe without access to the electricity grid, but according to, for example, the Electricity Association in the United Kingdom,[220] "this figure for the United Kingdom is now so small that it is no longer collected by the government or the industry." Similarly, according to Sweden's largest electricity company, Vattenfall AB,[221] there are perhaps only about a hundred households in Sweden without access to the grid. The following provides a short description of the organisation of the European electricity industry and an brief overview of electricity industries in selected European countries.

8.3.1 European Organisation of Electricity Industries

Electricity systems of individual European countries generally do not operate in isolation of the electricity systems of neighbouring countries. Transmission systems are interconnected in order to allow trade and back-up power supply in cases of emergency, and larger areas of Europe operate in synchronously[222] interconnected systems. However, a synchronously interconnected system can be linked to another area via DC-connections.

Examples of such synchronously interconnected power systems are UCTE, Nordel and Baltic IPS (see Appendix C). UCTE comprises transmission system operators in Western and Central Europe, while Nordel comprises Scandinavia and Baltic IPS the Baltic countries. The purpose of these associations is mainly technical co-ordination of the interconnected transmission systems. Transmission systems of Ireland and United Kingdom are not synchronised with continental Europe although there is a DC-link between United Kingdom and France. Other regional organisations, such as ETSO, CDO, CENTREL and BALTREL play a role in non-technical, strategic co-operation between members.

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[218] Telephone communication with Københavns Belysningsvæsen, Denmark (3 Aug 2000).
[219] *Awake grid-connect dreamers* <http://www.ata.org.au/75guerrilla.htm> (2 June 2001).
[220] Private communication with the Electricity Association in the United Kingdom (18 Jan. 2001).
[221] Telephone communication with Vattenfall AB, Sweden (22 May 2001).
[222] *Synchronisation* is the act of bringing two sources of AC power into alignment so that there is no phase difference between the sine waves and they are at the same frequency. *Source:* <http://www.suttondesigns.com/glossary.sync.shtml> (24 May 2001).

8.3.2 Examples of Electricity Industries in Selected European Countries

In describing the electricity industries of the European countries, first of all, there is a great variation between the industries in terms of market structure, ownership and regulation. Since the Second World War, traditionally, electricity industries in Europe have been characterised by highly vertically integrated market structures with little competition in the potentially competitive segments, combined with state ownership.[223] This picture is gradually beginning to change. The box below provides a brief overview of some of the main companies in electricity industries in Europe in order to give an idea of how the electricity industries look today.

Roughly, in northern, western and parts of central Europe, most electricity markets are being liberalised, while electricity industries in eastern and parts of central Europe generally remain state-owned and government controlled with a monopoly company engaged in generation, transmission, distribution and supply. Even though many countries in Europe are reforming their electricity industries, the pace and type of reform differs significantly from country to country. For example, United Kingdom and some of the Scandinavian countries liberalised their markets before the EC Electricity Directive was adopted. Some are now liberalising faster than required by the Electricity Directive. Some countries, for example France, Greece, Ireland and Switzerland are slow in progress, while others, e.g. Germany, Italy and Austria are under gradual transformation.

In the United Kingdom, the 1989 Electricity Act laid the legislative framework for the first and most ambitions electricity industry restructuring and privatisation in Europe. In England and Wales, the national Central Electricity Generation Board was divided into three generating companies and a transmission company. Twelve Regional Electricity Companies were created as successors of the previous Area Board, and from 1999 all consumers were allowed to choose their suppliers. The industry also features the Electricity Pool for the trading of electricity. Norway, with the 1990 Norwegian Electricity followed immediately after with the second most ambitious restructuring of the electricity industry, and in 1992 and 1995 Sweden and Finland also began liberalising their markets. The reforms of these Nordic countries differed from United Kingdom's reform by being a restructuring without privatisation. In the Nordic countries, Nordpool was created for the trading of electricity. Other electricity pools now also exist in the Netherlands (Amsterdam Power Exchange–APX) and in Spain (Compañia Operadora del Mercado Español de Electricidad, S.A.–OMEL). Among Eastern and Central European countries, Hungary adopted the most ambitious restructuring and privatisation programme of its electricity industry. Also Poland and Czech Republic began a reforms, which were considered necessary to ensure foreign funds needed for upgrading power industries.

In respect of EU Member States as a whole, the changes are mainly caused by the Electricity Directive. The electricity directive naturally applies to all 15 EU Member

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[223] R. Vaitilingam (ed.), *A European market for electricity?*, (1999), p. 32.

States, but several EU candidate countries in Central and Eastern Europe have already started restructuring their electricity markets in order to comply with the directive. When these countries become members in the near future[224], they will have to incorporate the directive into national law.

Electricity industries are subject to a high degree of regulation and government intervention in most European countries. They are regulated in most cases by one or more government ministries or statutorily independent authorities.[225] Areas of regulation include the setting of price controls; the granting of public electricity supply licences; the planning of applications for power stations, transmission and distribution; and appeals bodies for disputes.

Brief Overview of Main Electricity Companies in European Countries

In the following a brief overview is provided of some companies in electricity industries of Europe.[226]

Albania: Korporata Elektroenergjetike Shqiptare (KESH) is a state-owned monopoly.

Austria: The biggest producer and transporter of electricity is Verbund Österreichishe Elektrizitätswirtschafts AG. It owns and operates the super-regional high-voltage grid (Verbund Austrian Power Grid) and also owns and operates 71 power stations, 75 hydro power stations and 5 thermal power plants.

Belgium: Generation is dominated by the private Electrabel and the public SPE (Societé Coopérative de Production d'Electricité). CPTE, the company for the co-ordination and transmission of electricity, is jointly owned by Electrabel and SPE, but the structure will be adjusted in view of the regulation of EC Electricity Directive concerning Transmission System Operators. Large industrial companies are supplied directly by electricity generators, while other customers are supplied by municipalities, which have a monopoly for the supply.

Bosnia and Herzegovina: The public electric company, Elektroprivreda Bosne i Hercegovine, is the largest provider of electricity, responsible for generation, transmission, distribution and export and import of electricity.

Bulgaria: The national electric company, Natsionalna Elektricheska Kompania J.S.C. (NEK), a joint stock company since 1991 with all shares held by the government, owns all nuclear and hydro power plants. Activities include generation, transmission, distribution and sale. NEK has 15 electricity supply branches.

Croatia: The public company, Hrvatska Elektropriveda dd. (HEP) is engaged in generation, transmission and distribution of electricity.

Czech Republic: Joint-stock company, Czech Power Company CEZ, a.s., operates 10 fossil fuel, 13 hydro, 1 nuclear power, 2 wind power and 1 solar power plant. In addition, CEZ owns and operates the transmission grid. Most of its production is sold to 8 regional distribution companies. The Transmission System Operator is CEPS, a.s., a joint-stock company owned by CEZ, which

[224] Hungary and Slovenia are estimated to be accepted as EU members in 2004, Czech Republic, Estonia and Poland at the *earliest* in 2004. As for the remaining candidates, Latvia, Lithuania and Slovakia are likely to obtain membership earliest 2006, and Bulgaria and Romania possibly in 2008-2009.

[225] R. Vaitilingam (ed.), *A European market for electricity?*, (1999), p. 45-50.

was formed in 1998 as CEZ detached its transmission system division in order to meet the requirements of the EC Electricity Directive.

Denmark: The Danish electricity industry is split into two systems. In eastern Denmark, Energi E2 A/S owns and operates 17 power plants, while the Transmission System Operator is Elkraft System a.m.b.a., established in 2000 and owned by the eastern grid companies. Large distribution and supply companies are NESA, SEAS and NVE. In western Denmark (Jylland/Fyn), Elsam A/S, owned by about 50 municipal or co-operative undertakings, is the main producer and supplier of electricity. Eltra, the Transmission System Operator, is owned by 48 distribution companies.

Estonia: Eesti Energia is a wholly state-owned vertically integrated public limited company, engaged in generation, transmission, distribution and supply.

Finland: The state-owned Fortum (merger between IVO and Neste) is the biggest electricity company. Fingrid Oyj owns and operates the transmission system. There are around 105 distribution companies.

France: Dominated by the state-owned Electricité de France (EDF), engaged in generation, transmission, and distribution. A Transmission System Operator, RTE, was set up to comply with the EC Electricity Directive.

Germany: Dominated by major generation and transmission Verbund companies, e.g. E.ON Energie (fusion between Bayernwerk AG and PreussenElektra AG), and VEAG Vereinigte Energiewerke AG.

Greece: Dimossia Epichirissi Electrismou (DSI) is the state-owned electricity company, engaged in generation, transmission and distribution.

Hungary: Magyar Villamos Művek Rt. (MVM), owned by ÁPV (the State Privatisation and Asset Holding Co), engages in generation and transmission. MVM owns 100% of its subsidiary transmission grid company, MAVIR Rt. There are 6 regional distribution and supply companies, Budapesti Elektromos Művek Rt (ELMU), Dédasz Rt., Démasz Rt., ÉDASZ Rt., ÉMÁSZ Rt. and TITÁSZ.

Iceland: The national electricity company, Landvirkjun, generates and sells electricity to local utilities.

Ireland: The state-owned Electricity Supply Board (ESB) engages in generation and supply.

Italy: The industry is dominated by ENEL, a joint stock company wholly owned by the State Treasury, which engages in generation, transmission, distribution and supply.

Latvia: LATVENERGO is responsible for generation, transmission, distribution and supply.

Lithuania: Joint Stock Company Lietuvos Energija is owned mainly by the state. Main activities include generation, transmission and distribution as well as export.

Luxembourg: The industry is dominated by CEGEDEL, a mixed-ownership company in charge of transmission, distribution and supply.

Former Yugoslav Republic of Macedonia: The electric company, Elektrostopanstvo na Makedonija (ESM) engages in generation, transmission and distribution.

Netherlands: 4 regional generation companies. TENNET is the transmission system operator.

[226] Note that much of the information has been based on documents from the World Wide Web and partly from books. It was not always possible for the author to find full information.

Norway: The state-owned Statkraft SF own 91 hydro power plants and is the largest generating company with about 30% of total capacity. 55% of generating capacity is owned by municipalities and counties while the rest is private. Statkraft owns 80% of the transmission grid, which is operated by Statnett SF (the Transmission System Operator). Statnett owns 50% of the Nordic power exchange, Nord Pool. Distribution and supply companies are mainly owned by generators.

Poland: Polskie Sieci Elektroenergetyczne PSE SA, a joint stock company wholly owned by the State Treasury, is the Transmission System Operator. The company also purchases electricity from generators and sells it to the 33 regional distribution companies.

Portugal: Electricidade de Portugal S.A. (EDP), held 70% by the state, is responsible for generation, transmission and distribution via one generation company, one transmission and 4 distribution companies.

Romania: Transelectrica SA is the transmission company.

Slovakia: Joint stock company Slovenské Electrárne, a.s. (SE a.s.), established 1994 with the National Property Fund of the Slovak Rebublic a founding shareholder, has activities in generation, transmission, export and import, distribution and supply. SE owns and operates 1 nuclear, 3 thermal and 34 hydroelectric power plants and also owns and operates the transmission system.

Slovenia: The state-owned Elektro-Slovenija, d.o.o (ELES) manages the entire electric power system, which includes 15 hydro, 3 coal, 2 oil and 1 nuclear power plant. ELES operates the transmission system, and incorporates 5 regional distribution companies.

Spain: Dominated by two companies, Endesa SA (mixed-ownership) and Iberdrola SA, which both carry out generation, transmission, distribution and supply. The publicly controlled Red Electrica de España (REE) is the Transmission System Operator and also the leading transmission company.

Sweden: Dominating generation companies include Vattenfall AB, which owns 2 nuclear, 70 hydro and 15 oil-fired thermal power plants accounting for 50% of the output, Sydkraft and Birka Energi. Svenska Kraftnät owns and operates the transmission system.

Switzerland: ATEL Aare Tessin AG is one of Switzerland's largest generators, with activities also in transmission and distribution. Transmission System Operator is ELTRANS, which is owned by 7 grid companies: ATEL, BKW, CKW, EGL, EOS, EWS and NOK.

United Kingdom: Is divided into 3 separate systems (England & Wales, Scotland and Norhern Ireland. There are 6 major generation utilities, including National Power, PowerGen and British Energy. National Grid Company is the transmission system operator in England and Wales. There are 12 regional distribution companies (RECs).

Price regulation

Currently, there is a wide differentiation of electricity prices between the different European countries.[227] Also, different prices usually apply to different types of consumers often according to voltage levels. For example, the French electricity company EDF maintains a blue tariff for households, agriculture and business, a yellow tariff for small industrial customers and a green tariff for large industrial customers. Rates for industrial customers generally vary according to time of use, but this does not often apply to residential customers. It is common that uniform tariffs exist for the whole country. Price levels are determined in various ways but are usually negotiated with or have to be

[227] R. Vaitilingam (ed.) *A European market for electricity?*, (1999), p. 43.

approved by a government authority, for example the Price Control Committee in Belgium, and the Department of Prices and Fair Trading in Portugal. Although the industry was privatised in the United Kingdom (England and Wales), Ofgem sets so-called price caps, a ceiling for prices to be charged, designed to give companies an incentive to reduce costs.

Overall, an increase in competition as a result of the EC Electricity Directive, is likely to lead to a downward pressure on electricity prices for consumers. This has been proven in markets, such as the United Kingdom and Norway, that have been liberalised for some time, and where the tendency of falling consumer prices can already be seen. Additionally, increased competition is likely to lead to improvement in customer service and reinforced reliability.[228]

8.4 Discussion: the Electricity Industry as a Competitor to 1Twin

The electricity industry in Europe may be considered a strong competitor to the wood pellet fuelled 1Twin. First of all, the industry is very large and well-established with networks that enable it to supply nearly all households. That is, there are only few households that do not already have access to electricity. Secondly, electricity can basically be regarded as a homogeneous product when power plants deliver electricity of the required quality with respect to voltage and frequency. Therefore, in terms of electricity, what the wood pellet fuelled 1Twin offers is not different from what is already delivered by the electricity companies. For this reason, price can be regarded as an important determinant of consumers' choices as to where to get the electricity.

Liberalisation of electricity industries in Europe, particularly as a result of the Electricity Directive, creates a downward pressure in electricity prices. This can be seen in the United Kingdom, which has both privatised and restructured its industry, and where electricity prices have fallen. Additionally, the increased competition in electricity industries with the opening up of markets, is likely to reinforce reliability and customer services. This may lead to a reduction in the sales potential of the wood pellet fuelled 1Twin. The Electricity Directive requires electricity industries of EU Member States to have opened up at least 33% of the market by 2003 but in many countries, the pace of liberalisation is going faster. Some EU candidate countries in Eastern Europe have started to comply with the Directive.

[228] *Opening up to choice: the single electricity market*, European Commission (1999), p. 4.

9 Traditional Heating Systems for Households

The purpose of this chapter is to examine what heating systems other than micro-cogeneration systems are available on the market and commonly in use in European households. Along with recent micro-cogeneration systems, the more widespread heating systems are options, which a potential customer may take into consideration when getting a new heating system or replacing an old one. This chapter describes the different types of traditional household heating systems that exist, both for space heating and hot-water supply. Furthermore, it is examined what types of heating equipment and fuels are used in European households. With this in mind, one can also consider the effort and changes that are required when converting to a heating system based on the wood pellet fuelled 1Twin.

9.1 Space Heating Systems

Heating is concerned with raising the temperature of an enclosed space with the primary purpose of ensuring the comfort of the residents. This can be done in various ways, which fall into three categories: central (or indirect) heating, local (or direct) heating, or district heating.[229] These shall be described in the following.

9.1.1 Central (or Indirect) Heating

In central heating systems, the generation of heat takes place outside the space or spaces to be heated and is therefore also described as an indirect method of heating. The generated heat is distributed to the rooms to be heated by means of water, air or steam.

A central heating system basically comprises the following three elements:

- **A heat-generating equipment** (furnace, boiler or water heater) in which an energy source is converted into heat.
- **A heat-transmitting medium** (e.g. air, water or steam) conveyed in pipes or ducts, for transferring the heat to the space to be heated.
- **Heat-emitting apparatuses** (e.g. radiators, convectors, baseboards, panels, embedded coils, or warm-air registers) located in the rooms to be heated for releasing the heat.

When heat has been generated, it is transferred to the medium which distributes it to various rooms via a system of pipes or ducts, depending on the type of medium. Through circulation, the heated medium is constantly removed and replaced by cooler supplies. The equipment in which heat is generated is called a *furnace* if the medium used for heat transmittance is air, and a *boiler* or a *water heater*[230] if the medium is water or steam. There are a many types of boilers and furnaces, using a variety of energy sources for the

[229] This chapter is based primarily on the following sources: *Heating, Ventilating and Air Conditioning* in *Encyclopædia Britannica*, 15th ed. 1974, p. 709-721 and *Encyclopædia Britannica. Heating* <http://www.britannica.com/eb/article/7/0,5716,40577+1+39743,00.html> (11 Mar. 2001).

generation of heat: fossil fuels (e.g. natural gas, fuel oil, liquid petroleum gas i.e. propane or butane, coal, coke, etc.), biomass fuels (e.g. wood, rapeseed oil, etc.), electricity, and solar heat.

The most commonly used energy sources in central heating systems are natural gas and fuel oil. Natural gas-fired and fuel oil-fired boilers and furnaces are easy to use as they are handled by automatic burners with thermostats, which activates the boiler or furnace as soon as the temperature in the room drops below a set point until the desired temperature is reached. Moreover, there is no ash residual to be removed. Natural gas requires no storage, whereas fuel oil is pumped into storage tanks.

Water and air are the most commonly used media in central heating systems. In most of Europe, water is the favoured medium for heat conveyance in central heating systems, while ducted warm air has never gained popularity in this part of the world. In North America, on the other hand, ducted warm-air heating is by far the most common central heating system in homes and offices, although hot-water heating is becoming more popular. Steam is rarely used anymore, except in industry.

Hot water is pumped and circulated through pipes, usually of steel or copper. Water as a medium has the advantages that it conveys heat at longer distances than for example air, that it is stable after countless cycles of heating and cooling, and that it is cheap. Disadvantages are its low boiling point at 100ºC and that freezing may cause pipes to expand and burst. *Warm air* is usually forced by a fan through a system of ducts to the rooms that are to be heated. Air as a medium is confined to shorter distances due to its low density and low specific heat. As hot water, *steam* is transported in steel or copper pipes. Because less heat is stored in steam than in hot water, it heats up and cools down faster than a hot-water heating system. A disadvantage of steam is its inflexibility of temperature, which cannot be varied in the same way as hot water.

The emitting apparatus, placed in the room that is to be heated, can be classified as either primarily *convective*, designed to heat the room by means of natural or forced air movement, or primarily *radiant*, emitting radiant heat at different temperature levels.

A radiator, for example, is primarily convective (‘radiator’ may be misleading), emitting about 80% by natural convection and 20% by natural radiation. Inside the radiator, made of steel or previously cast iron, hot water circulates through its hollow sections. It is usually placed at the floor along walls. The radiator heats air, making it rise to the ceiling, displacing cooler air and creating a current of air. A convector is similar to a radiator but has a smaller heating surface. It has fins that are attached to pipes through which hot water flows, and it is often installed along windows or walls. Radiant emitters are often embedded in the floor, ceiling or wall making them invisible in the room. They consist of

[230] The two terms are commonly used as synonyms even though a boiler correctly refers to a device that supplies steam and a water heater to a device that supplies hot water.

coils of hot-water pipes or warm-air ducts transferring heat to the entire floor, wall or ceiling at moderate temperatures.

Examples of various types of central heating equipment are presented below. As warm-air systems are rarely used in Europe, only hot-water (hydronic) systems are included. Usually these systems are installed by plumbing & heating companies that are specialised in or have been authorised to install the equipment.

Examples of Hot-Water Central Heating Equipment

Combustion based equipment (fossil fuels, biomass fuels)

- *Natural gas-fired boiler*
  Natural gas, delivered through underground pipelines, is combusted in the unit by a gas-fired burner.
- *Oil-fired boiler*
  An oil-fired burner mixes fuel oil with air and sprays it out a nozzle where the fuel is ignited by electrodes. A plumbing and heating company usually takes care of installation but often oil companies also sell and install this equipment.
- *Coal-fired boiler*
- *Wood pellet-fired boiler*

Non-combustion based equipment (electricity and solar heat)

- *Electric resistance boiler*
  Electric resistance coils become hot when an electric current is sent through them, heating up water in a boiler.
- *Electric heat pump*
  An electric heat pump[231] works opposite a refrigerator. The heat source is low-temperature heat present in the air, in the ground or in the ground water external to the house. The heat pump uses electricity employing a compressor to remove low-temperature heat from the air or ground and transfer it to water in a storage tank until the water has been heated to the predetermined temperature. Some heat pumps operate on gas or oil.
- *Solar heated boiler*
  A solar collector[232] converts solar radiation into heat, which is transferred to a medium and circulated in pipes and passed through a heat exchanger. The heat exchanger heats up water in a storage tank which can then be used throughout the day and night. The solar collector consists of a black metallic plate (absorber) in a flat box covered by glass. The solar collector is usually placed on roofs for practical reasons but can also be placed on walls or on the ground. Usually the system requires a back-up heat source for days when there is not sufficient solar radiation.

9.1.2 District heating

District heating is a development of central heating, supplying heat to multiple buildings, primarily in city areas. This is done by means of hot water or steam, which is produced at heating plants or cogeneration plants and distributed through a network of insulated underground pipes.

[231] <http://www.epelectric.com/apogee/res_html/rewhehp.htm> (heat pumps) (25 Mar. 2001).
[232] <http://www.ekowatt.cz/library/infolisty/sun_air_water.php3> (Solar heating) (25 Mar. 2001).

District heat can be used in two ways to heat a building. In some cases, hot water from the district heating company is used directly in the building. Usually, however, a heat exchanger is used to transfer heat from the district heat to the water circulating in a closed system within the building. Thus water from district heating is normally not in direct contact with the water in the house. A district heated system uses a heat exchanger to heat water in the central heating boiler. The heat exchanger consists of pipes with hot water or steam (supplied by district heating companies) that transfers heat from the hot fluid to the cold fluid.

9.1.3 Local (or Direct) Heating

Local, or direct, heating is the oldest way of heating. It refers to a method of heating by which heat is both generated and released in the room or space to be heated. A variety of direct heating appliances exist, including fireplaces, stoves and electric baseboard heaters. Most of these appliances can be used as the sole means of heating the home but are often used as supplements to a central heating system. As can be seen in the examples below, many different energy sources can be used, depending on the direct heating appliance: electricity, fossil fuels and biomass fuels, especially wood.

Examples of Direct Heating Appliances

- *Electric baseboard heaters* (electricity)
- *Stoves* (e.g. cordwood, wood pellets, wood briquettes, coal, coke, gas and electricity)
  Includes: Cast iron, steel and ceramic stoves
  Finnish masonry stoves
  Cooking stoves
- *Fireplaces* (cordwood, gas)
- *Ceramic/oil-filled radiator heaters* (electricity)
- *Portable space heaters* (electricity, kerosene, propane)
  Includes: Convection heaters (natural convection or fan forced-air convection)
  Radiant heaters

Electric baseboard heaters[233] are usually installed underneath windows and are controlled by thermostats in each room. Inside the cabinet, electric resistance wire elements, which produce heat, are encased in metal pipes surrounded by aluminium fins that aid heat transfer. Electric baseboard heaters work by convection, heating the air and making it rise. *Stoves* are available in numerous designs and forms, ranging from cast iron, steel, and ceramic to brick versions, and furthermore some metal stoves are covered by soapstone. Stoves are designed to give either convective or radiant heating. A flue is necessary to remove the smoke coming from combustion. A special stove is the so-called Finnish masonry stove. It is made of brick or stone, weighs about 3-4 tonnes and can retain heat for a long time because of its mass. It is sufficient to burn a fire for around 1-2 hours (or heat it

[233] *Consumer energy information: EREN fact sheets* <http://www.eren.doe.gov/erec/factsheets/elecheat.html> (28 Mar. 2001).

up by electricity if it is an electric version) after which the stove will release heat to the room for the next 24 hours. A cooking stove placed in the kitchen is naturally for cooking food but some homes, particularly older homes, still rely on this type of equipment as a source of heat.[234] *Fireplaces* are usually but not always built into the wall of the room. A chimney leads out the smoke.

9.1.4 Overview of Heating Systems used in European Households

According to Eurostat (1996),[235] it can be seen that the equipment and fuels used for heating in European households varies significantly from country to country (see Appendix D). Eurostat's report includes figures for 26 countries in Western, Central and Eastern Europe. To give an overview, there are very few households in Europe that have no heating system at all, around 1.5%, and these are concentrated in Portugal and Spain: 27% of households in Portugal and 10% in Spain have no heating system.

Households with central or district heating

The majority of all households in the 26 represented countries had some form of central or district heating, namely 63%. As mentioned previously, the systems used in Europe normally are hydronic systems, i.e. using water for heat conveyance. The share of households with central or district heating is especially high in the three Scandinavian countries Sweden, Denmark and Finland, as well as in Czech Republic, Lithuania and Slovenia (all 90% or more) but Sweden (100%) is the country with the highest percentage of households with central or district heating. Albania (0.1%), Portugal (3%), Norway (10%) and Bulgaria (19%) are countries with remarkably low percentages of households heated by central heating systems together with Romania and Spain (both 40%). It seems that these variations can be partly explained, according to Eurostat,[236] by the fact that central heating is more appropriate for continuous use in colder countries while cheaper equipment is used in warmer countries.

There is a big variation in the energy sources used in central heating systems when comparing individual countries. Overall, however, there is a clear domination of district heating (19%), natural gas (16%) and fuel oil (14%). The percentage of households using district heat-based central heating is particularly high in Denmark, Lithuania, Latvia, Finland and Sweden where around half of the households are heated in this way. As for natural gas, the Netherlands and United Kingdom have the highest ratios of households using this fuel in central heating equipment but it is also important in Germany and France. The use of fuel oil for central heating is especially noticeable in Greece, Luxembourg, Slovenia and Belgium.

Households with direct heating

[234] <http://www.heimer.com/information/heating_system.html> (28 Mar. 2001).
[235] *Energy consumption in households: European Union and Norway, 1995 survey, Central and eastern European countries, 1996 survey*, Eurostat (1999), p. 24-25 and 124-125.
[236] Op.cit., p. 12.

In Albania, Norway, Bulgaria, Portugal, Romania, Spain, Greece and Hungary around 40% or more of the households rely on direct heating only. Albania is a special case because here virtually all households are heated by direct heating only, mainly by wood-burning cooking stoves and electric stoves. Norway also has a high fraction (90%) of households using direct heating systems: this is mainly based on electricity but also on wood. Countries where about 1/3 of households rely on direct heating only are Austria, Belgium, Estonia and Poland.

Wood and electricity are the most commonly used energy sources in direct heating systems. However, wood is especially used in Romania, Bulgaria, Albania, Estonia and Latvia, while electricity is particularly used in Norway, Portugal and Albania. Other energy sources for direct heating may be dominating in individual countries. For example, natural gas is especially used in Hungary, the Netherlands and Belgium.

9.2 Hot-Water Supply Systems

Hot water used in the house normally is heated to a temperature of about 60ºC. Methods of supplying hot water can be categorised as either central or local systems. *Central* hot-water supply systems may be independent or connected to the central heating system. These include solar and district water heating systems.

Local hot-water supply systems[237] use electricity or gas as energy sources. The unit is fixed adjacent to the draw-off point, e.g. in the bathroom or in the kitchen. An electric heater uses a thermostatically controlled immersion element inserted into a storage cylinder. As for gas heaters, there are two types. The first is instantaneous, meaning that it is activated when hot water is needed and the incoming cold water is heated as it flows. The second is a thermostatically controlled gas heater that stores a larger quantity of hot water in a vessel for immediate use.

9.2.1 Overview of Hot-Water Supply Systems in European Households

According to Eurostat (1996), in the 26 represented European countries (see Appendix D), around 14% of all households have *no* water heating equipment, instead using cooking equipment for supply of hot water. In EU Member States the percentage of households without water heating equipment is generally very low (under 5% in individual countries) with the exception of Portugal (20%). In Denmark, Finland, the Netherlands, Norway and Sweden all households have water heating equipment. In Central and Eastern Europe, however, the percentage of households without water heating equipment is generally much higher, except in Czech Republic where all houses do have such equipment. Especially in Albania (72%), Romania (59%), Estonia (48%) and Latvia (44%) it is common not to have water heating equipment.

[237] Encyclopædia Britannica, p. 720.

Around 1/3 of all households in the represented 26 countries have a hot-water supply system which is connected to the central heating system. The percentage is especially high in Sweden (100%), Finland (93%), Denmark (91%), Ireland and United Kingdom (about 70%), but it is also common in Germany, Slovenia, the Netherlands and Austria (about 45-50%).

As for independent water heating systems (i.e. not connected to central heating), Eurostat has made no distinction between households with central and local water-heating systems. About 55% of all households have independent hot-water supply systems. The fraction is particularly high in Czech Republic (95%), Hungary and Norway (90%). However, the majority of households in Greece, Bulgaria, Poland, and Portugal (all about 80%), and Spain (75%), Lithuania (67%), France (63%), Slovenia (60%) as well as Austria, Estonia, Latvia and the Netherlands have independent hot-water supply systems. The favoured energy sources used in independent hot-water supply systems is electricity, especially in Norway. Natural gas is also very common, for example in the Netherlands, Poland, Belgium and Hungary. In Portugal 55% of households use LPG.

9.3 Discussion: Heating Systems as a Competitor to 1Twin

The wood pellet fuelled 1Twin can be regarded as a close substitute for existing central heating systems, such as oil-fired and natural-gas fired boilers, except for the fact that Twin offers electricity generation as well. Both central and district heating systems constitute strong competition for the wood pellet fuelled 1Twin because these systems already have a dominating market share of the heating market: they are already widely diffused and known. In comparison, micro-cogeneration is almost unknown among plumbing and heating companies who are usually responsible for giving advice to consumers and installing central heating systems. In countries where local heating systems is the established method of heating, local heating systems are close competitors to the wood pellet fuelled 1Twin.

The reason why the existing heating systems as an industry is a strong competitor, is that as a method of satisfying the need for space heating and hot-water, the wood pellet fuelled 1Twin essentially does not offer anything that existing central heating systems do not offer. Considering the high price of 1Twin, the fact that it also gives electricity may not prove to be an important bonus for people who are looking for a new heating system since the majority of households already have electricity supplied by the electricity companies.

In launching the wood pellet fuelled 1Twin in Europe, it should fit into the existing structure, i.e. it has to use water a medium since this is the preferred medium in central heating systems as opposed to other regions where hot air is the preferred medium. This will facilitate the replacement of existing hot-water central heating systems without it requires too many changes. Households with an electric heating system or without a central heating system will have to have pipes and radiators installed in the house if they are to convert to a system based on the wood pellet fuelled 1Twin. However, the same would apply if they wanted to convert to any other “ordinary” central heating system.

As we have seen, in some countries direct heating systems are more widely used than central heating systems. Such countries where direct heating systems are dominating include Albania, Norway, Bulgaria, Hungary, Greece, Portugal and Spain. In these countries the wood pellet fuelled 1Twin would have to compete with direct heating systems, requiring potential customers to make a change in system to central heating, making it more expensive. All other things being equal, it might be advantageous to focus on markets where central heating systems are widely in use in order that the wood pellet fuelled 1Twin can be used without too many changes. As we have seen, such countries include the Nordic countries Sweden, Denmark, and Finland in addition to Czech Republic and Slovenia. However, here one must also be aware that the share of households connected to district heating is great. Such household may have little incentive to change to other types of heating.

10 Laws and Policies in Europe regarding Atmospheric Pollution

Laws and policies in Europe seem to be in favour of energy-efficiency and a reduction in the emission of pollutants such as carbon dioxide, sulphur dioxide and nitrogen oxides mainly caused by the use of energy. Energy matters are thus intertwined with environmental matters. This chapter explores especially the branch of environmental laws and policies that deals directly or indirectly with atmospheric pollution, focusing on subjects of relevance to the wood pellet fuelled 1Twin. The chapter examines selected international laws, EC laws and current EU programmes, but does not examine national laws in Europe.

Laws dealing with manmade (anthropogenic) pollution of the atmosphere is a blending of complex scientific knowledge, much of which is subject to disagreements as it has not been fully tested or accepted, with conventional rules of law.[238] However, this chapter does not evaluate or raise questions regarding the assumptions that underlie the laws, the purpose being merely to examine if the laws and policies in themselves might have and effect on the sale of 1Twin.

10.1 International Environmental Law on Climate Change

International environmental law[239] did not emerge as a separate branch of international law until fairly recently. The 1972 United Nations Conference on the Human Environment in Stockholm is often considered the starting point of the development of international environmental law. It was attended by 113 states and adopted the **1972 Stockholm Declaration of the UN Conference on the Human Environment**. This document is not legally binding (soft law), but functions more as an inspirational document as implied in the preamble: "Having considered the need for a common outlook and for common principles to inspire and guide the peoples of the worlds in the preservation and enhancement of the human environment".

In 1983 the UN General Assembly formed the World Commission on Environment and Development, or the Brundtland Commission, which published a report on critical environmental and developmental issues. The report, entitled **"Our Common Future"** (1987), introduced the concept of sustainable development and recommends and calls on changes in a number of fields, including a more efficient use of energy resources and use of renewable energy sources. Subsequently, the UN General Assembly convened a second major conference, this time on both environment and development: the 1992 United

[238] R. Dolzer, *Atmospheric protection*, in R. Bernhardt (ed.), Encyclopedia of Public International Law, Vol I (1992), p. 290.
[239] Birnie and Boyle, *Basic document on international law and the environment,* (1995).
Kiss and Shelton, *Manual of European environmental law* (1997).
Handbook of environmental law UNEP (1998).

Nations Conference on the Environment and Development ("Earth Summit"), held in Rio Janeiro, attended by 176 states. Here the **1992 Rio Declaration of the UN Conference on Environment and Development** was adopted as a successor to the Stockholm Declaration together with a programme of action, Agenda 21, which designated the UN Environment Programme (UNEP) as the principal body within the UN in the field of environment. Like the Stockholm Declaration, the 1992 Rio Declaration is a non-binding document. It reaffirms the Stockholm Declaration, but as a whole goes beyond the Stockholm Declaration by introducing new principles, such as the precautionary principle (Principle 15): "[...] lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation."

The **United Nations Framework Convention on Climate Change,** adopted in New York in May 1992, and the subsequent **1997 Kyoto Protocol** to the Convention differ from the previously mentioned laws by being legally binding documents. The Convention ("UNFCCC") was opened for signature at the Earth Summit. By December 1993 it was ratified by 50 countries, and entered into force in March 1994. The UNFCCC addresses the issue of potential global climate change caused by the emission of so-called greenhouse gases. A few years earlier, in 1988, the World Meteorological Organization (WMO) and UNEP had jointly established the Intergovernmental Panel on Climate Change (IPCC) in order to assess scientific, technical and socio-economic information for the understanding of climate change.[240] The objective of the Convention is to stabilise greenhouse gas concentrations in the atmosphere "at a level that would prevent dangerous anthropogenic interference with the climate system" (Article 2). However, these levels are not quantified in the Convention. As in the Rio Declaration, the precautionary principle is applied (Article 3.3) in the UNFCCC, meaning that lack of scientific evidence may not be a reason for postponing measures taken to stabilise greenhouse gases.

All Parties of the Convention are committed, among other things, to report to the Conference of Parties on emissions of greenhouse gases, and to formulate or implement national or regional programmes for the reduction of these gases (Article 4.1). Countries listed in Annex I of the Convention ("Annex I Parties"), however, have a special obligation to adopt national policies and measures for the mitigation of mitigating climate change. Annex I Parties are industrialised countries, including the United States, Canada, Australia, Japan, Russia, EU Member States and countries in Eastern and Central Europe. The reason for making a differentiation in obligations between industrialised and developing countries is that industrialised historically countries have contributed the most to climate change, have a higher emission per capita and have greater financial resources.

181 governments and the European Community have ratified and become Parties to the Convention. The Conference of Parties (COP) is the supreme body to the Convention, and meets at annual sessions. At the first COP in Berlin, Germany, the Parties decided that the specific commitments for Annex I countries were not adequate. Then, at the third meeting

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240 *Intergovernmental Panel on Climate Change* <http://www.ipcc.ch> (6 June 2001).

of the COP, held in Kyoto, Japan in December 1997, the **Kyoto Protocol to the UN Framework Convention on Climate Change** was adopted.

In the Protocol six substances are agreed worldwide as being primarily responsible for climate change: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbon (HFC), perfluorocarbon (PFC) and sulphur hexafluoride (SF_6). Under Article 3 of the Protocol, the industrialised countries commit themselves to reducing the emissions of these six gases by at least 5% from 1990 levels in the period 2008-2012. It also states that each Annex I Party must have shown demonstrable progress in reducing emission levels by 2005. The European Community and its Member States, together with some of the EU candidate countries, have committed themselves to a reduction of 8% below 1990 levels. This is the greatest reduction commitment: in comparison, the United States is committed to reduce emission levels by 7%, Canada and Japan by 6%, and Russia by 0%. Australia on the other hand is allowed a level of 8% *above* 1990 levels.

Although the European Community and its Member States are committed to reducing emissions by 8%, a redistribution has taken place within the EU, the so-called *EU Bubble Agreement*. This redistribution means that Luxembourg, Denmark and Germany undertake the largest reductions of more than 20%, while Portugal, for example, may increase emissions by 27%:

Austria	-13.0%
Belgium	- 7.5%
Denmark	- 21.0%
Finland	0.0%
France	0.0%
Germany	- 21.0%
Greece	+ 25.0%
Ireland	+ 13.0%
Italy	- 6.5%
Luxembourg	- 28.0%
Netherlands	- 6.0%
Portugal	+ 27.0%
Spain	+ 15.0%
Sweden	+ 4.0%
United Kingdom	- 12.5%

As regards other countries in Europe included as Annex I Parties, the reduction commitments are distributed as follows according to Annex B of the Protocol:

Bulgaria	- 8.0%
Croatia	- 5.0%
Czech Republic	- 8.0%
Hungary	- 6.0%
Iceland	+10.0%
Latvia	- 8.0%
Lithuania	- 8.0%

Norway	+ 1.0%
Poland	- 6.0%
Romania	- 8.0%
Slovakia	- 8.0%

Each Annex I Party must, according to Article 2, promote sustainable development in achieving its quantified emission reductions by implementing or expanding national policies and measures, which e.g. enhance energy efficiency, protect and enhance so-called sinks, and promote the increased use of renewable energy sources and innovative environmentally sound technologies. Annex 1 Parties must also progressively reduce subsidies and the like for all greenhouse gas emitting sources.

Sinks are included in the calculation of emissions and count as a removal of emissions. The plantation of forests, for example, which can absorb CO_2, is regarded as a sink.

The Protocol provides for three mechanisms by which Annex I countries are allowed to fulfil their reduction commitments: (i) emission trading, (ii) joint implementation, and (iii) clean development mechanism. These mechanisms mean that emission reduction units may be bought from other Annex I countries and that measures taken to reduce emissions do not necessarily have to be implemented in the country committed to reduction but an implementation of greenhouse gas reducing projects in other countries can be accounted for by the country undertaking the project. In reality these mechanisms mean that some Annex I countries may not have to reduce emissions in their own country.

The Kyoto Protocol will enter into force when at least 55 Parties to the Convention have ratified it. In addition, Annex I Parties accounting for at least 55% of carbon dioxide emissions in 1990 in Annex I Parties must have ratified it. However, owing to disagreements between EU and the United States, it is hard to say when exactly this may happen. At COP6 held in 2000 in Hague, the Netherlands, the disagreements resulted in a breakdown in negotiations. It is decided that Part II of COP6 is to convene in Bonn, Germany in July 2001. In March 2001, United States' president, George W. Bush, declared that the United States would not ratify the Kyoto Protocol. The EU Member States are planning to ratify it in 2002 prior to the UN Conference on Sustainable Development. So far (2001), Romania is the only Annex I Party that has ratified the Protocol; this was done in March 2001.

10.2 EC Environmental Law on Atmospheric Pollution

Sources of EC environmental law are the EU Treaty and secondary legislation, mainly in the form of directives, including international law which the Community has adhered to. The EU treaty, concluded in Maastrict in 1991, amended in 1997 by the Treaty of Amsterdam and by the Treaty of Nice, signed in February 2001, provides a general framework, and the environment is mentioned only in general terms. A declaration in the

Treaty of Nice mentions[241] that the Parties are "determined to play a leading role in promoting environmental protection in the Union and in international efforts pursuing the same objective at global level". Objectives of Community environmental policy are set forth in environmental action programmes, usually adopted by Council resolution. Since 1973 six environmental action programmes have been adopted.

There is no overall Community strategy on atmospheric pollution.[242] Measures taken may vary from country to country. In this regard, some countries are considered "greener" than others: Germany, Denmark, the Netherlands, Austria (these are also some of the countries that have committed themselves to the largest reductions in the Kyoto Protocol). EC has regulations on specific air pollutants and sources of pollution, which are briefly described here:

- **Carbon dioxide**

In a directive[243] the Community has adhered to the previously mentioned 1992 UN Convention on Climate Change. CO_2 emissions in the Community are estimated to account for approximately 80% of all greenhouse gas emissions.[244] The Community adopted several measures for reducing CO_2 emissions. For example, energy efficiency was promoted by the SAVE programme, and Directive 93/76[245] aimed at improving energy efficiency in various areas. Moreover, in 1993, a Decision[246] was adopted for the monitoring of CO_2 emissions and other greenhouse gases in which Member States were asked to limit CO_2 emissions and report on these. An ALTENER programme for renewable energy was also suggested and adopted. Finally, the Commission's proposal of a carbon/energy tax on fossil fuels is being discussed without much progress; however, such taxes have already been implemented on the national level in some countries (e.g. Denmark, Finland, Netherlands, Norway and Sweden).

- **Sulphur dioxide and nitrogen oxide air quality standards**

The Community is a Party to the 1979 Geneva Convention on Long-Range Transboundary Air Pollution, establishing an international framework for the reduction of transboundary air pollution. Two of the five later Protocols to the Geneva Convention deal with reduction of emission of sulphur dioxide and nitrogen oxide.

Air-quality standards establish maximum allowable limits for substances in the air. In early 1980s, some directives were adopted that fix air quality standards for polluting substances, including sulphur dioxide and nitrogen oxide[247]. These were intended to protect human health and environment. However, apparently the effect of the directives was limited as

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[241] O.J. C 80/1, 10.03.2001, p. 78.
[242] L. Krämer, *EC environmental law*, (4th ed. 2000) p. 205.
[243] Dir. 94/96 concerning the conclusion of the United Nations Framework Convention on Climate Change, O.J. 1994 No. L 33/11
[244] L. Krämer, *EC environmental law*, (4th ed. 2000), p. 228.
[245] Dir. 93/76 to limit carbon dioxide emissions by improving energy efficiency [1993]O.J. L 237/28.
[246] Dec. 93/389 [1993] O.J. L167/31
[247] Dir. 80/779 on air quality limit values for sulphur dioxide and suspended particles [1980] O.J. l229/30.
Dir. 85/203 on air quality standards for nitrogen oxide [1985] O.J. L87/1

Member States could place measuring stations where they wished and furthermore had the possibility of designating zones where these standards were likely to be exceeded.[248]

- **Sources of pollution emissions**

Regulations on sources of pollution emission distinguish between mobile sources (e.g. motor vehicles, aeroplanes, etc.) and stationary sources (e.g. industrial installations, etc.). As for stationary sources, apparently EC laws do not deal with air pollution from residental installations but rather from industrial installations and large combustion plants. Laws on domestic heating installations, for example, can be found in national laws. In some countries, state subsidies are offered for domestic central heating systems using renewable energy sources.

10.3 Current EU Programmes

Under the various programmes, applications or proposals for projects may be submitted in response to calls that are published in the Official Journal of the European Communities.

Fifth Framework Programme for Research, Technological Development and Demonstration: *Energy, Environment and Sustainable Development* (1999-2002)[249] ("FP5") outlines the priorities, key actions and the budget for EU's research, technological and demonstration activities for a five-year period. The objective of the programme is to "contribute to sustainable development by focusing on key activities crucial for social well-being and economic competitiveness in Europe". FP5 has been divided into seven sub-programmes, each addressing specific areas. The four Thematic Programmes and three Horizontal Programmes under FP5 have received a total budget of EUR 13,700 million. The Forth Thematic Programme deals with energy and environment: EESD (Energy, Environment and Sustainable Development). EESD has been budgeted EUR 2,125 million, divided between two sub-programmes: 1. Environment and Sustainable Development, and 2. ENERGIE. ENERGIE replaces the previous combined JOULE-THERMIE programmes (1995-1998) concerning non-nuclear research, development and demonstration of energy technologies, aiming at promoting new energy efficient and environment-protecting technologies. Guided by the Kyoto Protocol, ENERGIE focuses on supporting projects that deal with cleaner energy systems, including renewable energies and energy-efficiency.

The Commission has proposed a new framework programme, covering the next five-year period 2002-2006. This programme breaks with the ambition and scope of FP5 and focuses on a better integration of research efforts.[250]

The Sixth Environmental Action Programme: *Environment 2010: Our Future, Our Choice* (2001-2010)[251] proposed by the Commission, outlines the European Community's

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[248] L. Krämer, *EC environmental law*, (4th ed., 2000), p. 206-209.
[249] *Fifth Framework Programme* <http://www.cordis.lu/fp5/src/over.htm> (4 June 2001).
[250] *The Commission's proposal for a new framework programme (2002-2006)* <http://europa.eu.int/comm/research/nfp.html> (9 June 2001).
[251] *Environment 2010: Our Future, Our Choice. 6th Environment Action Programme*, European Commission (2001).

objectives for sustainable development for a ten year period beginning 2001. It continues some of the objectives from the previous Environmental Action Programme: "Towards Sustainability" (1992-2000) but goes further. The programme addresses four areas of priority where action is needed: the tackling of climate change; the protecting of nature and wildlife; environmental and health issues; and the preservation of natural resources and waste management. In regard to climate change, the EU aims to take a lead in reducing greenhouse gases. The objective is to stabilise concentrations of greenhouse gases in the atmosphere causing climate change. While the short term goal is to reduce emissions by 8% from 1990 by 2008-2012 levels according to the Kyoto Protocol, a longer term goal is to reduce emissions by 20-40% from 1990 levels by 2020. These goals are to be achieved firstly by implementing the Kyoto Protocol, secondly by setting objectives for cutting greenhouse gases in the main economic sectors, thirdly by establishing a greenhouse gas trading scheme within the EU by 2005, and finally by supporting renewable energy sources.

SAVE II (1996-2002) SAVE II (Specific Actions for Vigorous Energy Efficiency)[252] is a Community-wide programme aimed at promoting energy efficiency particularly in transport and industry but also in commerce and residential sectors. The programme plays an important role in reducing emissions of CO2 in response to the Kyoto Protocol. It deals only with non-technological aspects, such as policy measures, information, studies and pilot actions. It is a continuation of the SAVE programme (1991-1996). SAVE II was adopted by the Council in 1996[253] with a budget of EUR 45 million for the five-year period 1996-2000. However, a decision was made to prolong SAVE II until 2002 as a component of the Energy Framework Programme (1998-2002), which outlines EU energy policy for a five-year period. Legal entities within EU can apply for funding from the SAVE II programme for carrying out projects that improve energy efficiency, such as studies and measures that supplement Community schemes and monitor progress. Apart from buildings, transport, industry, and CHP, the SAVE II programme focuses on equipment used in the residential sector, including central heating boilers.

ALTENER II (1998-2002) is a non-technological EU programme[254] with the objective of studying and promoting renewable energy sources. It is managed by the Directorate-General for Energy and Transport and replaces the previous programme, ALTENER (1993-1997). ALTENER II is to contribute in achieving the Community's strategy and action plan for renewable energy outlined in the Commission's White Paper from 1997 on renewable sources of energy. The White Paper sets out a strategy to increase the share of renewable energy consumption from 6% to 12% by 2010. This is not only to reduce CO_2 emissions but also to reduce dependency on imported energy and ensure security of supply. The programme has a budget of EUR 77 million. One of the important functions of

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[252] Directorate-General for Energy (no date): *For an energy-efficient millennium SAVE 2000.*

[253] Council Decision 96/737/EC of 16 Dec. 1996 concerning a multiannual programme for the promotion of energy efficiency in the Community – SAVE (O.J. L 335, 24/12/1996, p.0050)

[254] Decision 646/2000/EC of the European Parliament and the Council of 28 Feb. 2000 adopting a multiannual programme for the promotion of renewable energy sources in the Community (Alterner) (1998 to 2002).

ALTENER II is to spread generated knowledge on renewable energy e.g. by supporting education and training, and thereby support market development and use of renewable energy sources. Furthermore, harmonisation of products and equipment is encouraged and both private and public investments are supported in order to increase production and use of renewable energy sources. ALTENER II co-operates with countries in Central and Eastern Europe.

INDEBIF (An Integrated European Market for Densified Biomass Fuels),[255] an ALTENER-project, focuses on improving knowledge about the European densified biomass fuels, such as wood briquettes and wood pellets, and establishing a network for these.

OPET (2000-) The OPET Programme (Organisations for the Promoting of Energy Technologies) comprises a network of both private and public bodies whose purpose is to inform and promote the benefits of new energy technologies. New energy technologies include technologies in the field renewable energy, solid fuels, energy efficiency, etc. OPET is an initiative of the European Commission. A new OPET programme started in 2000 managed by the Directorate-General for Energy and Transport with support from the Fifth Frameworks Programmes' sub-programme ENERIGIE under the 4th Thematic Programme.

10.4 What Impact may the Laws/Policies have on Sale of 1Twin?

On the basis of the previous description of international laws, EC laws and EU programmes, it is clear that these are in favour of CO_2 reductions and energy efficiency. The wood pellet fuelled 1Twin complies with both of these tendencies by using wood pellets, which are CO_2-neutral, and a Stirling engine, which allows efficient use of the fuel. In the Kyoto Protocol, the EU Member States together with most countries in Eastern and Central Europe have agreed to a reduction of CO_2 emissions of 8% from 1990 levels in 2008-12. The fact that this is the largest reduction commitment compared to the other industrialised countries generally shows a strong commitment in Europe to reducing CO_2 emission levels. Even though U.S.A. has said (2001) that they will not ratify the Kyoto Protocol, it has not changed EU's attitude towards reducing CO_2. At EU-level, there are many programmes, such as the Sixth Environmental Action Programme, SAVE II, ALTENER II, OPET and ENERGIE, that are dealing with the promotion of energy efficiency, renewable energy and renewable energy technologies in Europe.

All in all, the laws and policies examined here therefore show that at both international and EU-level there is support for energy efficient and CO_2 reducing technologies. However, owning to a redistribution of reduction levels internally within the EU Member States, individual countries such as Denmark, Germany and Austria have especially taken the lead

[255] *INDEBIF* <http://www.sh.slu.se/indebif> (9 June 2001).

in this by committing themselves to much larger reductions. But the laws examined here do not specifically indicate whether it will have a positive impact on the sales potential of the wood pellet fuelled 1Twin. This will depend on the consumers. Consumers may, however, have an incentive to buy the wood pellet fuelled 1Twin if they receive a state subsidy. It may therefore be a good idea to take a closer look at countries, which may have programmes and subsidies for renewable energy technologies.

11 Concerns about Customer Workload associated to Use of Wood Pellets

This chapter examines the possible labour associated with the use of wood pellets, which are necessary for the operation of the wood pellet fuelled 1Twin, because this may have an adverse effect on the sales potential of the product, e.g. if potential consumers regard the work that needs to be done as troublesome and do not want to be bothered with it. At issue in this chapter is specifically the possible workload which may be imposed on the customer in obtaining and storing wood pellets as well as removing and disposing of the ash. As we shall see, in Europe it is most likely that wood pellets are delivered directly at the consumer's house and pumped into a storage room or silo, making obtaining and storing of wood pellets comparable to the use of fuel oil in a central heating system.

11.1 Wood Pellet Supply to Private Consumers

This section concerns how the user of the wood pellet fuelled 1Twin may obtain wood pellets. In Europe it is generally becoming widespread that wood pellets are delivered directly to the consumer's house by a wood pellet supplier. Some wood pellet suppliers handle everything from manufacturing of wood pellets to distribution at the final consumer, while others are merely sales companies that distribute and sell wood pellets bought from manufacturers or through agents who import them. In North America, [256] wood pellets are mainly available in 18 kg-bags at e.g. stove and fireplace dealers, home centres, and feed and garden supply stores. Also in Europe it is possible to buy bagged wood pellets in certain stores.

Wood pellets are distributed in various ways depending on the region and on the particular distributor. Nevertheless, three common distribution forms[257] can be identified in which the private consumer can obtain wood pellets: in bulk, in small bags and in big bags. Some suppliers offer other special delivery forms. Most often wood pellets are delivered at the home, but in many cases the consumers additionally have the option of picking up the wood pellets themselves, either directly at the wood pellet mill or at a retailer.

11.1.1 Bulk Delivery

Loose wood pellets, also called bulk delivery, are delivered directly at the home by pump-tank cars, also called biomass tanks.[258] This form of delivery is similar to delivery of fuel oil by a fuel oil tank. Because wood pellets are a solid fuel, however, loose wood pellets are *blown* into the customer's wood pellet storage room or silo by means of a hose as it can

[256] Pellet Fuels Institute: *And Then There Were Pellets* (Press release, date unavailable. See <http://www.pelletheat.com>).
[257] See for example Malisius et al. *Industrial Network on Wood Pellets*, (2000), p. 57.
[258] Grübl et al. *Biomass Tank*, (1998), p. 5 and 100.

be seen from the illustration below. According to Malisius et al.,[259] delivery of loose wood pellets is becoming the main form of wood pellet distribution in Europe.

Fig. 11.1 Example of wood pellet delivery by pump-tank car (By courtesy of Glechner GesmbH Ko KG).

Pump-tank cars are known from grain transports. According to Grübl et al.,[260] the size of the pump-tank car can differ from supplier to supplier, and the tank of one vehicle can contain a maximum of 10-24 tonnes wood pellets. The hose used for blowing wood pellets into the customer's storage room has an output of about 500 kg per minute. The length of the hose may vary from between 10-50 metres.[261]

There seem to be a few weaknesses with this form of delivery; although these are not of direct concern to the customer but rather to the supplier they shall be mentioned briefly. According to Grübl et al.,[262] there may be difficulties with the weighing system and therefore the billing to the customer. Although one solution to these problems is to weigh the tanker on a weigh bridge before and after filling the customer's storage room, this may be time-consuming and customers do not have direct control over the amount that has been filled into their storage. Another solution is an on-board weighing system[263] where the amount of wood pellets that have been unloaded to the customer is measured immediately.

11.1.2 Small Bags

Reports about wood pellets[264] do not entirely agree on the amount of wood pellets in a small bag, most likely because not all European distributors and manufactures are covered in the surveys that the reports are based on. Amounts ranging from 15 to 35 kg are stated, but bags with a content of up to 40 kg wood pellets are advertised on web sites of wood pellet dealers in Europe.

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[259] Malisius et al., *Industrial Network on Wood Pellets*, (2000), p. 57.
[260] Grübl et al. *Biomass Tank*, (1998), p. 51.
[261] Op. cit., p. 52.
[262] Op. cit., p. 104-106.
[263] Malisius et al., *Industrial Network on Wood Pellets*, (2000), p. 58.
[264] Malisius et al., *Industrial Network on Wood Pellets*, (2000), Skaugen et al., *Systemsudier–Brenselsiden,* (1997) and Grübl et al., *Biomass Tank* (1998).

Small bags are made of plastic or paper, and according to Malisius et al. they can be bought in household good stores, at filling stations and in agricultural supply stores. When delivered to the home, the bags are usually delivered on pallets of about 1 tonne.

Wood pellets in small bags have the advantage that the amount of fines is low and that they are protected against humidity. Small bags are also easier to handle than big bags, which cannot be lifted without equipment. A disadvantage of small bags is the higher price than wood pellets in bulk, especially if a large quantity is needed.

11.1.3 Big Bags

Again, reports do not agree on the amount of wood pellets in a big bags. According to Skaugen et al., a big bag contains 300-800 kg, while Malisius et al. and Grübl et al. state the amount of 1.0 to 1.5 m^3 contents, or about 650-1,000 kg. Wood pellets in big bags are packed in the materials fabric or foil. In order to transport the bag after it has been delivered to the customer, equipment such as a pallet truck is needed.

11.1.4 Other special delivery forms

There are other delivery forms than the three previously mentioned forms. SBE BrikettEnergi in Sweden,[265] for example, offers the possibility of delivering wood pellets in an "SBE Container", containing 10 tonnes of wood pellets. The container is used as a storage tank, which can be opened at the bottom in order to allow it to be connected with an auger or screw feeder. Upon delivery of a new supply of wood pellet in a container, the empty container is returned to the company.

11.1.5 Discussion: Preferable Forms of Wood Pellet Delivery for 1Twin-Users

When determining which form or forms of wood pellet delivery that may be most convenient for users of the wood pellet fuelled 1Twin, first of all the *amount* that is needed should be taken into consideration. The average amount of wood pellets required for the operation of the wood pellet fuelled 1Twin was estimated in Chapter 5. This amount will differ from country to country so that in the warmer European countries (Portugal and Spain) about 1-3 tonnes of wood pellets would be needed annually while in the other European countries examined about 4-7 tonnes of wood pellets would be needed annually in an average. However, it should again be remembered that wood pellet consumption in single-family houses can be expected to be slightly higher. Nevertheless, these figures may be regarded as rough estimations of wood pellet consumption. In Chapter 5 it was also estimated that the average household in selected European countries will use approximately 28-30 kg per day in the winter period and 2-3 kg per day in the summer period. The different are discussed here in relation to the wood pellet fuelled 1Twin.

[265] *SBE BrikettEnergi* <http://www.brikettenergi.se/trad2.htm> (12 June 2001).

If the user of the wood pellet fuelled 1Twin chooses to buy wood pellets in small bags, a bag or less per day will be sufficient to cover the daily needs. The use of small bags will require daily or frequent emptying of bags into a bin or the like from where the wood pellets will be fed to the unit by an auger. The author believes that customers will probably regard this work as extra trouble. In comparison, an oil boiler or an electrical heating system will not require this frequent labour. Therefore, the use of small bags are not considered an ideal solution for the customer unless there is no alternative. Rather, small bags are relevant in connection with wood pellet stoves which do not require much refilling, and which are not in use all the time.

Since few homeowners will have the equipment to move big bags, the solution of using big bags is not relevant either. It is unlikely that the customer will invest in a pallet truck or the like for the sake of lifting big bags. Perhaps only customers who live on a farm will have the necessary tools to handle big bags.

Bulk delivery, on the other hand, being similar to fuel oil delivery is most likely to be the delivery form that is most suitable for a wood pellet fuelled 1Twin-user and modern lifestyle. More wood pellets are needed in the winter period than in the summer period, but in most countries bulk delivery will mean that the biomass tank will only have to come once a year to fill up the customer's wood pellet storage. Also it may pay for the consumer to order the wood pellets in summer when wood pellets are often cheaper than in winter.

A special delivery form such as SBE BrikettEnergi's container, seems particularly advantageous since the customer will not have to think about a storage solution.

11.2 Storage of Wood Pellets in the Customer's House

The customer will need a storage solution for the wood pellets as well as an auger or another device for feeding the wood pellets to the machine. As mentioned, bulk delivery seems to be the most convenient form of delivery for users of the wood pellet fuelled 1Twin. Considering the three most common ways of obtaining wood pellets (in small bags, big bags or in bulk), each present different storage possibilities. If wood pellets are bought in small bags, these do not require any specific storage solutions other than available space, as small bags can be easily stacked. However, a storage bin or the like would then be needed into which wood pellets can be emptied manually. Big bags can be stored the way they are since they are already packed but they seem to be inconvenient to handle. Loose wood pellets require a special storage solution. Wood pellets have to be protected against humidity, and therefore reports about wood pellets recommend[266] storing loose wood pellets in a silo or in a storage bunker.

[266] See for example Malisius et al., *Industrial Network on Wood Pellets*, (2000), p. 58

11.2.1 Silo

Because of the homogeneity of wood pellets, a silo from which the wood pellets can slide out from the bottom is ideal for storage.[267] According to Malisius et al.,[268] silos are generally the best way of storing wood pellets due to the fact that in this way, wood pellets are protected against moisture; furthermore they will continuously slide towards the conveyer system, and little dust is produced. Silos are easy to fill by a pump-tank car.

Owing to aesthetic considerations and building regulations,[269] a silo of the type used on farms may generally not be suitable for consumers living in detached houses in urban areas. However, a Swedish manufacturer of silos, MAFA i Ängelholm AB,[270] offers wood pellet silos especially designed for small buildings and private houses (see the photo below). The company also offers feed screws for wood pellets. The silo can be placed outside the house or for example be built into a carport with an auger leading the wood pellets to the place where they are combusted. The silos are galvanised and are offered in a wide range of sizes with different heights and lengths, depending on the consumer's space and needs. From the company, a silo that can contain around 6 tonnes of wood pellets with a height of 2 meters, costs around SEK 18,000. The company has several dealers in the Nordic countries and in Germany.[271]

Fig. 11.2 Silo for wood pellets for private homes, model MAFA SUCCÉ.

11.2.2 Storage Room/Bunker

According to Malisius et al.,[272] a storage room/bunker is the most common type of wood pellet storage solution in single-family houses, usually placed in the basement near the boiler. A wood pellet storage room/bunker[273] is a room into which wood pellets can be

[267] Skaugen et al. *Systemstudier – Brenselsiden*, (1997), p. 18.
[268] Malisius et al., *Industrial Network on Wood Pellets*, (2000), p. 58.
[269] Op.cit, pp. 58-59.
[270] *MAFA* <http://www.mafa.se> (12 June 2001).
[271] Telephone communication with MAFA (12 June 2001).
[272] Malisius et al., *Industrial Network on Wood Pellets*, (2000), p. 59.
[273] Grübl et al., *Biomass Tank*, (1998), p. 107-117 and Malisius et al., *Industrial Network on Wood Pellets*, (2000), p. 58-59.

pumped directly by the pump-tank car. The storage room will have a door with a window or a hatch so that the wood pellets can be seen and the quantity controlled.

According to SBE BrikettEnergi,[274] consumers may either build a storage room themselves – guidelines are available – or have them built professionally.

When designing the storage room, several aspects have to be taken into consideration. Technical details are not included here, but the important aspects are the room's dimensions, its sealing, protection against humidity and connections to pump-tank car. Other requirements of the storage room depend on fire-protection regulations, which will not be examined here.[275]

The storage room's *dimensions* depend on fuel consumption. In other words, it is important that the dimensions of the storage room allow that it can contain the amount of wood pellets that are going to be used during the year. For this purpose, Grübl et al. recommend[276] that the storage room can contain about one and a half times the annual requirement. Furthermore, since wood pellets are not a liquid fuel, they form a 'mountain' during filling of the storage room, and it is neither possible to fill nor empty the storage room completely. To avoid this problem, the floor of the storage room can be made so that it inclines 45°, and the room should be rectangular and narrow with a width of up to 2 metres. It can be assumed that the storage room can be 2/3 full. As the density of wood pellets is 650 kg/m^3, this will mean that they take up roughly 6-11 m^3 if the annual requirement of wood pellets for the wood pellet fuelled 1Twin is about 4-7 tonnes. However, with the above mentioned considerations concerning the dimensions, the size of the storage room will have to be around 13-25 m^3 if it is to contain wood pellets for the whole year.

A second important aspect is *sealing* the room[277] in order to prevent dust from coming out of the storage room. Due to dust coming from the wood pellets, the storage room should be sealed tightly. The walls of the room should therefore be made from plaster and the door and window should be sealed.

The storage room has to be dry in order to protect the loose wood pellets against humidity. In order to withstand humidity, the outside walls have to be insulated with at least 5 cm boards of thermoplastic material. If the wall is not insulated, condensed water will form on the wall and cause the wood pellets near the outside wall to become damp.[278]

In order that the hose of the pump-tank car can be connected to the storage room during filling, *couplings* are needed on the outside wall. Two couplings are needed: one is used to attach the hose from the pump-tank car to the storage room during filling, and the other is used for attaching a hose so that air can escape through the opening.

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[274] Telephone communication with SBE BrikettEnergi (12 June 2001).
[275] Grübl et al., *Biomass Tank*, (1998), p. 111 and Malisius et al. *Industrial Network on Wood Pellets*, (2000), p. 58.
[276] Grübl et al. *Biomass Tank*, (1998), p. 107-108.
[277] Op.cit., pp. 102 and 114.
[278] Op.cit., p. 115.

Concerning the location of the storage room, it should be possible for the pump-tank car to be within 10-50 metres reach of the couplings connected to the storage room since the hose of the pump-tank car is between 10 and 50 metres long depending on the supplier.

11.2.3 Discussion: Preferable Storage Solutions for 1Twin-users

It is likely that the user of the wood pellet fuelled 1Twin will store the wood pellets in a wood pellet storage room/bunker as this is apparently the most common storage solution in single-family houses. Space must therefore be available in the house with room for a 13 m^3, or larger, storage room, depending on how often the user expects to refill it. It is very important that the requirements of the storage room are fulfilled to ensure that the size of the storage room is adequate for storage of the necessary amount of wood pellets and that the room is kept dry and insulated to secure the quality of the wood pellets. Couplings also have to comply with the hoses of the pump-tank car used by the wood pellet supplier. An auger is also needed. The users can either build the room/bunker themselves or have it built professionally. Another, and easier solution, is to acquire a silo such as MAFA's wood pellet silo. What the user chooses will depend on the user's preferences and housing conditions.

11.3 Ash Removal and Disposal

The combustion of wood pellets produces very little ash, as its ash content is about 0.5-1%. A daily consumption of 28-30 kg wood pellets in the winter period means that 150-300 g of ash is collected daily in the ash catcher, amounting to about 1.5 kg per week. In the summer period, with a daily consumption of 2-3 kg wood pellets, the ash output is much less: about 20-30 g per day, or roughly 150-200 g per week. A user of the wood pellet fuelled 1Twin will therefore presumably have to empty the ash catcher once a week in the winter period, and less often in the summer period. Lyn Bowman states[279] that ash has to be removed at about weekly intervals.

Ash can be disposed of e.g. in the user's garden by spreading it on the lawn. It is good nourishment.[280] Users might also discard it together with ordinary waste.

The fact that ash has to be emptied regularly creates extra work for the user compared to e.g. natural gas heating. Whether or not the user perceives it as extra work depends entirely on the user's preferences.

11.4 Summary

In this chapter the workload that is connected with obtaining and storing the wood pellets and removing the ash collected in the ash catcher has been examined. Due to the fact that

[279] E-mail from Lyn Bowman (1 Sep. 1999).
[280] Telephone communication with Svensk BrikettEnergi (11 June 2001).

we may count on a consumption of 4-7 tonnes (or more) wood pellets annually for the operation of the wood pellet fuelled 1Twin, it is most convenient for the user of the wood pellet fuelled 1Twin to obtain wood pellets in bulk by a pump-tank car. This is also the main distribution form in Europe. Storage of loose wood pellets requires a silo or a storage room that keeps the wood pellets protected from humidity. Protection against humidity is extremely important. Storage room/bunkers are commonly in use in which wood pellets are pumped directly into a storage room through couplings in the outside wall. A wood pellet silo, however, seems to be more convenient for the user as it can be placed outside or inside the house.

The solution of using storage rooms/bunkers or silos, means that the customer will not have to worry about having to refill a wood pellet bin, for example daily or with intervals of days if the wood pellets are obtained in small bags. Wood pellet delivery will be similar to delivery of fuel oil, the storage room or silo being refilled every half-year or every year. Ash removal creates extra work as it has to be removed at weekly intervals, but wood pellets contain less then 1% ash and it can be disposed of in the garden. Whether this is perceived as extra work depends on the consumer.

12 Discussion: Potential Target Users

As previously mentioned, 1Twin is intended for "most single family homes equipped with all of the modern conveniences". However, the single-family home market is a very broad group with many differing characteristics, and it is certain that the wood pellet fuelled 1Twin will not be equally suitable for all single-family homes. Anyway, how is a "single-family home" defined? To take some examples, are small houses inhabited by two families included in this definition, and what about a manor house or a summer house?

The selection of a target market strategy will form the basis for marketing decisions concerning, for example, product, price, distribution, and promotion decisions. Specifically which consumers in Europe External Power may decide to target will depend on various factors and information, some of which has already been covered in the previous chapters. However, a more comprehensive study of potential consumers and decision-making processes will be necessary to get a better picture of potential consumers in connection with deciding on target markets. Such a study might involve interviews with potential customer groups. This short chapter will not provide a consumer analysis, but in the following, a brief outline is given of issues that might be taken into consideration when identifying target market(s) for the wood pellet fuelled 1Twin. It should be stressed that the ideas and suggestions outlined here are unverified hypotheses that would need further investigation.

12.1 Market Segmentation

A market segmentation is the act of dividing the market into distinct subsets of customers that behave the same way or have the same needs. Based merely on a guess, feasible target market segments for the wood pellet fuelled 1Twin can be imagined to be particularly farmers living in farms as well as people living in detached single-family houses in suburbs. Market segmentation is commonly based on different variables that the company chooses. Some variables that may be relevant for identifying target markets for the wood pellet fuelled 1Twin are outlined here: type of dwelling, location, lifestyle, income level and attitude.

- **Type of dwelling**

The residential sector has numerous types of dwellings which may fall into categories such as flats, detached houses, semi-detached houses, bungalows, villas, terraced houses, townhouses, farms, summer residences, week-end cottages, etc. Certain countries may be characterised by certain types of houses, but in Europe it is likely that the types of houses that exist are quite similar. Statistics Denmark, for example, classifies[281] houses as follows (the figures refer to the share of houses of the total households in Denmark):

[281] Danmarks Statistik (1999), Statistical ten-year review 1999, p. 88-89.

1. Farmhouses (5.6%)
2. Detached single-family houses (41.2%)
3. Other single-family houses, e.g. terraced houses and semi-detached houses (12.7%)
4. Blocks and flats (38.7%)
5. Student hostels (1.2%)
6. Other dwellings (0.6%)

Most households have access to the electricity grid, implying that the wood pellet fuelled 1Twin is likely to be used in conjunction with the grid (first and second possibility identified in Chapter 5). A target market consisting of houses without access to the grid but with access to wood pellets is therefore likely to be a very small niche market.

Energy sources used for heating vary from area to area. It should be taken into consideration that people living in houses located in areas with access to district heating or natural gas might be disregarded as a potential consumers. Instead, the *natural gas* fuelled 1Twin might be targeted areas with natural gas.

Consumers in target markets must have sufficient space for storage of wood pellets, either inside or outside the house. Also, it may be ideal for people with a garden that is not too tiny due to ash disposal. Ownership of the house may also play a significant role in the decision to buy the wood pellet fuelled 1Twin.

Some indications of the market size in selected European countries could be based on the number of dwellings (see below). One has to remember that the replacement intervals for central heating systems may be around 10-15 years, meaning that potential consumers will only consider buying a new central heating system every 10-15 years, determining the annual demand. In this connection it is also relevant to consider if and how the wood pellet fuelled 1Twin can be targeted both the market of existing houses and the market of new houses being built.

Table 12.1 Size of population and number of dwellings in selected countries in Europe (1995-96)

Country	Population	Total dwellings
Austria	7,796,000	3,570,000
Denmark	5,146,000	2,437,000
Estonia	1,572,000	607,000
Finland	4,998,000	2,224,000
France	56,652,000	27,713,000
Germany	79,753,000	36,938,000
Hungary	10,300,000	3,822,000
The Netherlands	15,070,000	6,530,000
Norway	4,248,000	1,995,000
Sweden	8,587,000	4,888,000
United Kingdom	56,467,000	23,833,000

Source: Eurostat (1999), Energy consumption in households, p. 19 and 115

- **Location (e.g. urban, rural)**

The location of the dwelling might be an important variable, not only because the type of houses that can be found in cities, suburbs and rural locations may vary, but also because wood pellets might not always be practical to use in the city. It may also be worth examining exactly how many houses are located in remote areas without access to the electricity grid.

- **Lifestyle**

The wood pellet fuelled 1Twin must match the lifestyle of the user. As we have seen, the use of wood pellets will have some affect on the potential consumer's routines. There will be some work to do in connection with its operation, which differs from alternative or "easier" ways of obtaining electricity and heat. In this regard, farmers might be an ideal potential market segment. Generally, one may imagine that farmers seldom go on vacation, their work is in the place where they live, they are used to handling grain and fodder and will not mind handling wood pellets as well, and they are used to silos.

On the other hand, the wood pellet fuelled 1Twin is not suitable for busy yuppies, for example, who do not spend much time at home and do not want to spend their free time on disposing of ash or ordering wood pellets. Furthermore, it is probably not suitable for elder people relying on home-helpers. These were some examples of different lifestyles. Often it is the case that the type of house people have chosen to live in is linked to their lifestyle.

- **Income level**

At least at the wood pellet fuelled 1Twin's introductory stage, initial investment costs for potential consumers are high when purchasing and installing the product. The Micro-Cogen System has been estimated to be priced at USD 11,886 F.O.B. factory. Thus, if this is the wholesale price to a dealer, the retail price can be expected to be higher for the consumer, and will be higher after taxes have been included. Costs of installation also have to be included. On top of this, the costs for silo/storage room and auger have to be added. The question is whether potential consumers can afford and are willing to pay the amount of money that is required. The existence of a state subsidy or the like for biomass fuelled heating installations may provide some incentive to potential customers. It is possible that a farmer who can afford to invest in a tractor can also afford the wood pellet fuelled 1Twin.

- **Attitude**

It may be relevant to investigate the reasons why potential consumers would consider buying the wood pellet fuelled 1Twin. In this connection, it may be imagined that potential consumers with certain attitudes are important to take into consideration. Some possible special groups of consumers might include:

1. People who are conscious of the environment and want to actively contribute to a cleaner atmosphere.

2. The group of “consumer pioneers” called innovators and early adopters in Everett Roger’s categorisation of adopters,[282] who are interested in new products even if the cost is high, might be important to be aware of in the launching of 1Twin.
3. Stirling engine ‘enthusiasts’. There may be very few people who have heard of the Stirling engine but Stirling engine ‘clubs’ do exist.
4. People who consider using wood pellets for heating. In Chapter 4, reasons for using wood pellets stoves were discussed, and some of the motives may also apply to potential consumers of the wood pellet fuelled 1Twin.

12.2 Final Consumer’s Decision Process

As micro-cogeneration is still very new, many people are not yet aware of the existence of micro-cogeneration products and of the possibility of purchasing such products. Understanding how potential consumers make decisions in purchasing products to satisfy needs of electricity and heat in their home is important in the company’s decision about how to reach potential target consumers. For example, it is relevant to analyse why and when people would buy the wood pellet fuelled 1Twin (e.g. as replacement for central heating boiler when the old one it is about breaking down).

According to Kotler,[283] consumers pass through five stages in the decision process: need recognition, information search, evaluation of alternatives, purchase, and post-purchase behaviour. However, in low-involvement purchases, the consumer may skip or reverse some stages.

Because the wood pellet fuelled 1Twin is a durable consumer good, which a potential buyer will compare with other products or alternatives to satisfy the specific needs, there will be a high involvement in the purchase decision process. Generally, it is unlikely that the potential consumer will have full information about the full range of choices, and here promotion may be regarded as essential to create awareness. It is also of importance to know what factors influence potential consumers’ choice of how to satisfy electricity and heating needs (e.g. price, convenience, environmental considerations, etc.).

A Swedish wood pellet manufacturer, Skellefteå Kraft has described[284] the steps that a consumer may take when considering changing the existing heating system:

- The existing heating system may have become old and worn out and it is time to replace it. It may also be perceived as being too expensive in operation, impractical or not environmentally friendly.
- Inquiries are made among friends and relatives. Brochures are collected and economic and technical aspects are discussed.
- Sooner or later an expert is consulted. Various products are examined and questions such as costs, workload, etc. are discussed. Finally a purchase decision is made.

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[282] P. Kotler, *Marketing Mangement: Analysis, Implementation, and Control*, McGraw-Hill, New Jersey (1994), p. 346-348.
[283] Op.cit, p. 193.
[284] *Så här kan en installation gå till* <http://www.skekraft.se/produkter/pellets/install/> (6 April 2000).

According to another source,[285] there are many homeowners who wait until their heating system fails before shopping for a replacement. In order quickly to regain their heat supply, it means that they may often hurry to buy a replacement without taking to time to shop around and compare different systems.

12.3 Summary

The selection of target users for the wood pellet fuelled 1Twin will require an analysis of potential consumers. As a basis for deciding on potential target users, possible variables that could be used for segmenting the broad group of single-family homes are suggested: type of house, location, lifestyle, income level and attitudes of potential buyers. It is also important to examine the process that potential consumers may undergo in the purchase of the wood pellet fuelled 1Twin. More information about consumers is needed, but an initial guess may be that rural areas and especially farmers living in farmhouses are one of the suitable target users when the wood pellet fuelled 1Twin is launched.

[285] <http://www.doityourself.com/plumbing/hotwaterbuying.htm> (25 Mar. 2001).

13 Evaluating the European Sales Potential of 1Twin

In the previous chapters, various aspects of the European marketing environment which may influence the European sales potential of the wood pellet fuelled 1Twin in 2003 have been analysed. It is now time to gather these pieces in order to present the big picture. Yet, it must be stressed that the issues which have been examined do not provide a definite answer as to the European sales potential, but may be helpful in gaining an understanding of some of the elements that influence the sales potential. The purpose of the investigation was to provide an enhanced basis for marketing decisions concerning the launch of the wood pellet fuelled 1Twin. In the following paragraphs the results of this report are summed up.

Based on the availability of wood pellets in Europe, where in Europe could the wood pellet fuelled 1Twin be launched?

Wood pellets are being manufactured in many countries throughout Europe, but Sweden, Austria, Germany and Denmark are a group of countries where wood pellet markets are especially well developed. It might therefore be a reasonable strategy to concentrate a launch of the wood pellet fuelled 1Twin in these countries. Finland, Estonia, Latvia, the Netherlands, Norway and Poland are markets where wood pellets are produced mainly for export markets, such as Sweden and Denmark. In other countries, wood pellet production is still limited or starting up. All in all, wood pellet markets in Europe seem to be developing quickly in the recent years, and in 2003 it is likely that wood pellets are going to be even more widespread than they are currently.

How can the wood pellet fuelled 1Twin be used to satisfy household energy needs in Europe?

Being a micro-cogeneration product, the wood pellet fuelled 1Twin can supply both electricity and heat to a household. Three possible ways of using the wood pellet fuelled 1Twin to satisfy household energy needs of space heating, hot-water supply, electricity and cooking were compared:

1. 1Twin is used in conjunction with the electricity grid. Generation of electricity and heat is lead by heating requirements. and consumers buy the additionally required electricity from the grid.
2. A variant of the first possibility, 1Twin is still used in conjunction with the electricity grid but instead natural gas for cooking. In this way, households which are already using natural gas for cooking can continue to do so.
3. 1Twin is used independently of the electricity grid, but gas (e.g. bottled LPG) is used for cooking. By using gas for cooking, the waste of useful heat is minimised.

For satisfying average households energy needs in Europe, estimated 4-7 tonnes of wood pellets is required annually. The third possibility of course requires the highest amount of wood pellets. In the winter, typically in Europe around 30 kg is needed per day while 2-3 kg per day is needed in the summer. Prices of operating the wood pellet fuelled 1Twin in terms of fuel use compared to other ways of satisfying household energy needs depends on energy prices which are not static.

What is the potential competition of the wood pellet fuelled 1Twin?

Potential competitors comprise three levels: brand, industry and market/form competitors, of which selected potential competitors have been analysed. Although there are around 15 companies which have either launched micro-cogeneration products or are planning to do this in the near future, the wood pellet fuelled 1Twin seems to have no close competitors making the same product at the time of writing. However, two companies already sell internal combustion based micro-cogeneration products in Europe. Moreover, Advantica Technologies of United Kingdom, ENATEC in the Netherlands, Sigma Elektroteknisk in Norway, Bomin Solar Research in Germany and Powerline GES in Australia are all planning to launch natural gas/LPG fuelled micro-cogeneration products in Europe around 2003 at the same time as External Power.

As for form/market competitors comprising companies that offer products which satisfy the same needs as the wood pellet fuelled 1Twin, both the traditional heating system industry and the electricity industry are strong competition. They represent the established ways of obtaining heat and electricity. In contrast, most people are not yet aware of the existence of micro-cogeneration. Most households are already using traditional heating systems and most households are also already connected to the electricity grid. The wood pellet fuelled 1Twin may compete as a replacement for old central heating systems. These are especially dominating in countries such as the Nordic countries. A new EC law, the Electricity Directive of 1996, requires EU Member States to liberalise their electricity markets. This means a downward pressure on electricity prices which may result in reduced incentive to switch to alternative ways of obtaining electricity.

Which laws and policies may affect the sale of the wood pellet fuelled 1Twin?

International laws and EC laws and EU programmes dealing with atmospheric pollution were analysed. It is confirmed that these are in favour of energy efficiency and reductions of CO_2 emissions. This may benefit the sale of the wood pellet fuelled 1Twin as it is both energy efficient and CO_2-neutral. The 1997 Kyoto Protocol commits industrialised countries to reduce CO_2 emissions by 2008-12, and actions to reach this goal are already taken. However, some countries, such as Austria, Germany and Luxembourg have committed themselves to the largest reductions of CO_2. It is important to examine further what measures are taken at the national level in order to comply with the Kyoto Protocol, e.g. subsidies for CO_2 neutral heating installations, which might provide increased incentives for consumers to buy the wood pellet fuelled 1Twin.

What is the customer's workload in connection with use of the wood pellet fuelled 1Twin?

Potential customer workload in connection with use of wood pellets required for the wood pellet fuelled 1Twin was examined, focusing on how to obtain and store wood pellets and dispose ash. Wood pellets are usually delivered directly to the home in bulk and stored in a silo or a storage room. An auger automatically feeds the wood pellet fuelled 1Twin. Ash has to be disposed of at weekly intervals, and whether this is regarded as extra workload depends entirely on the customer.

To which groups of consumers might the wood pellet fuelled 1Twin be targeted?

We close this report by touching upon this important and crucial question, being a subject for investigation on its own. Potential consumers that the wood pellet fuelled 1Twin might be targeted, could be divided into groups based on some of the following suggested variables: type of dwelling, location, lifestyle, income level and attitude. It is also important to examine the decision process that consumers might undergo when buying the wood pellet fuelled 1Twin. Based on a guess, it is suggested that farmers might be a potential target group.

A List of Wood Pellet Manufacturers in Europe

The following is intended to be a list of all wood pellet manufactures in Europe that are known to the author. As wood pellet suppliers can come into existence and disappear in shorter time than manufacturers, this list is not intended to include companies that merely supply wood pellets.

This list was made by gathering various lists of wood pellet manufacturers and suppliers, notably the lists found on the web site of C.A.R.M.E.N. e.V. (the Coordinating Office for Renewable Raw Materials, a German organisation) and the ones found in Malisius et al. (2000). In other cases, lists have been obtained by contacting national biomass associations or the like. When lists overlapped, crosschecking could be done. Additionally, searches were made on the World Wide Web for wood pellet manufacturers. In order to confirm the information, the author, as far as possible, has been in direct contact with all the companies on the list, either by telephone or by e-mail.

It should be noted that some sources include the same company under different names so that confusion may arise as to what the correct name of the company is. In some cases, sources list a company without reference to whether the particular company manufactures wood pellets or only supplies them. In other cases, a company listed has nothing to do with wood pellets, or has ceased to exist.

For each company in this list, the company's name and the location is mentioned in addition to contact information (telephone number, e-mail address, etc.) but not the address of the company. When possible, the company's web site address is included. Sources are indicated in brackets.

Austria

Binder Franz GesmbH Holzindustrie (Jenbach and Fügen/Zillertal)
Production and supply. Capacity: 1,000 tonnes/year. Production 1999: 500 tonnes.
Tel. +43 (0)5244-6010, e-mail: <jenbach@binderholz.com>, web site: <http://www.binderholz.com>. [1,2,3,4]

Glechner GesmbH & Co KG (Mattighofen)
Production and supply. Capacity: 15,000 tonnes/year. Production 1999: 8,000 tonnes.
Tel. +43 (0)7742-2410, e-mail: <office@holzpellets.com>, web site: <http://www.holzpellets.com>. [1,2,3,4,5]

Hasslacher Holzwerke GesmbH (Kötschach-Mauthen)
Production and supply. Production: 200 tonnes/year.
Tel. +43 (0)471530344. [1,2,6]

Holzindustrie Leitinger GmbH (Wernersdorf)
see Holzindustrie Preding GmbH

Holzindustrie Preding GmbH (Preding)
Production: 40.000 tonnes/year.
Supply is managed by the parent company, Holzindustrie Leitinger GmbH (Wernersdorf).
Preding: Tel. +43 (0)3185 8623-0, fax: +43 (0)3185 8623-15, e-mail: <preding@leitinger.at>
Leitinger: Tel. +43 (0) 3466 42319-0, fax: +43 (0)3466 42319-28, e-mail: <holz@leitinger.at>
Web site: <http://www.leitinger.at> [2]

Johann Pabst Holzindustrie GesmbH (Obdach)
Production and supply. Capacity: 5,000 tonnes/year. Production 1999: 1,000 tonnes.
Tel. +43 (0)3578 4020-0, fax: +43 (0)3578 4020-5, e-mail: <office@pabst-holz.com>,
web site: <http://www.pabst-holz.com>.
[1,2,3,4]

Kaufmann Holz AG (Kalwang)
Production and supply. Production: 2,000 tonnes in 1999; 4,000 tonnes in 2000; est. 5,000 tonnes in 2001.
Tel. +43 (0)3846 8181. [1,2,7,8]

Krippl Julius Holzverarbeitungs GesmbH (Kirchberg an der Pielach)
Production and supply. Capacity: 300 tonnes/year. Production 1999: 300 tonnes.
Tel. +43 (0)2722-23550, e-mail: <krippl.michael@pgv.at>. [1,2,3,4]

LABEE Holzspäne GesmbH (Imst/Tirol)
Production and supply. Production: 12,000 tonnes/year.
Tel. +43 (0)5412-65359, fax +43 (0)5412-65491. [1,2,3,4,9]

Loitzl-Holz GesmbH (Steinach)
Production and supply. Capacity: 5,000 tonnes/year. Production 1999: 3,000 tonnes.
Tel. +43 (0)3682 24575-0, e-mail: <loitzl.holz@computerhaus.at>. [1,2,3,4]

Pfeifer Holzindustrie GesmbH (Kundl)
Production and supply. Capacity: 37,000 tonnes/year. Production 1999: 5,000 tonnes.
Tel. +43 (0)5338-7337-0, e-mail: <oskar.pfeifer@eunet.at>. [1,2,3,4,10]

Seppele Peter GesmbH (Feistritz an der Drau)
Production and supply. Capacity: 5,000 tonnes/year. Production 1999: 2,500 tonnes.
Tel. +43 (0)4245 2352-0, e-mail: <office@seppele.at>. [1,2,4]

UMDASCH AG (Amstetten)
Production and supply. Capacity: 5,000 tonnes/year. Production: 5,000 tonnes in 1999; 5,000 tonnes in 2000; est. 8,000 tonnes in 2001.
Tel. +43 (0)7472 6052276, e-mail: <Rudolf.Huber@umdasch.com>,
web site: <http://www.bio-brennstoffe.com>. [1,2,3,4,8]

Ökowärme Schörkhuber & Hörmann (Waldneukirchen)
Production: 10,000 tonnes/year.
Tel. +43 (0)72577024. [1,3,11]

Sources:
[1] List of wood pellet manufacturers and suppliers from Mr. Johannes Schmidl, Österreichischer Biomasse-Verband.
[2] *C.A.R.M.E.N. List of suppliers: Pellets* <http://www.carmen-ev.de/english/marktplatz/bezugsqu/pellets.html> (26 July 1999).
[3] Grübl et al. (1998), *Biomass Tank*, Annex.
[4] Malisius et al. (2000), *Industrial Network on Wood Pellets*, p. 31.
[5] Private communication with Mr. Glechner Gerhard (6 Nov. 2000).
[6] Telephone communication with Hasslacher Holzwerke GesmbH (6 Nov. 2000).
[7] Telephone communication with Kaufmann Holz AG (1 Nov. 2000).
[8] Private communication with Mr. Rudolf Huber, UMDASCH AG (6-7 Nov. 2000).
[9] Telephone communication with LABEE Holzspäne (8 Nov. 2000).
[10] Telephone communication with Pfeifer Holzindustrie GesmH (6 Nov. 2000).
[11] Telephone communication with Ökovärme Schörkhuber & Hörmann (2 Nov. 2000).

Bulgaria

Axis Ltd. (Sofia)
Production and supply. Capacity: 1,500 tonnes/year. Production: 300 tonnes/year.
Mr. Nikolay Dilkov, General Manager. Tel./fax: +359-2-718321,
e-mail: <axis@techno-link.com> or <axis@dir.bg>. [1]

[1] Private communication with Mr. Nikolay Dilkov (22 Nov. 2000).

Denmark

Hp briketter A/S (Vildbjerg)
Estimated production in 2000: 85,000-90,000 tonnes. Price: DKK 800/tonne excl. VAT.
Mr. Hans Poulsen, Manager. Tel. +45 97 13 24 00, e-mail: <hp@hpbriketter.dk>,
web site: <http://www.hpbriketter.dk>. [1]

Lerche-Heinrichsen & Møllller A/S (Vejle)
Production: has stopped producing at the moment (Jan. 2000) but plans to produce again from 2001: 1,000 tonnes/year.
Tel. +45 75 82 92 77, e-mail: <lhm@lhm.dk>. [2]

Neesund Biobrændsel ApS (Hurup)
Production: 20,000 tonnes/year. Price: DKK 880/tonne excl. VAT and transport.
Tel. +45 97 95 12 11. [3]

Nordjydsk Minkkorn A.m.b.a (Frederikshavn)
Production: 1,000-1,500 tonnes/year. Price: DKK 800/tonne excl. VAT.
Tel. +45 98 47 51 55. [4]

Pindstrup Bioenergi A/S (Auning)
No production since 1999, but the company buys wood pellets from agent.
Tel. +45 86 48 35 55, web site: <http://www.pindbio.dk>. [5]

A/S SPANVALL (Vejen and Neesund)
Tel. +45 76 96 07 00, e-mail: <spanvall@spanvall.dk>, web site: <http://www.spanvall.dk>.

Sources:
[1] Telephone communication with Hp Briketter (27 Jan. 2000) and private communication with Mr. Hans Poulsen (9 Nov. 2000).
[2] Telephone communication with Lerche-Heinrichsen (27 Jan. 2000).
[3] Telephone communication with Neesund Biobrændsel (27 Jan. 2000).
[4] Telephone communication with Nordjydsk Minkkorn (27 Jan. 2000).
[5] Telephone communication with Pindstrup Bioenergi (27 Jan. 2000).

Estonia

Flex Heat AS (Rakvere)
Production: approx. 35,000 tonnes/year.
Mr. Kuido Kuntro, Manager. Tel. +372 32 25780, fax: +372 32 25790, e-mail: <kuido.kuntro@mail.ee>. [1,2]

AS Hansa Graanul Ltd. (Patküla)
Production: 25,000-30,000 tonnes/year.
Mr. Rainer Kuutma, Member of Board. Tel. +372 50-41099, fax: +372 76 69349, e-mail: <rkt@estpak.ee>, web site: <http://www.hansagraanul.ee>. [1,3]

Sources:
[1] Private communication with Ms. Meeli Hüüs, Estonian Biofuels Association (1 Dec. 1999).
[2] Private communication with Flex Heat (7 Dec. 2000).
[3] Private communication with Mr. Rainer Kuutma, AS Hansa Graanul (6 Nov. 2000).

Finland

Finncambi Oy (Vöyri)
Owned by Biowatti Oy and Vöyrin Sähkölaitos Oy. Capacity: 20,000 tonnes/year. Production: 20,000 tonnes/year.
Tel. +358 6 383 6112, mobile tel. +358 500 163 182, fax +385 6 383 6014. [1,2,3,4]

Hehkupelletti Oy (Saarijärvi)
Owned by Hehkupelletti Oy. Capacity: 5,000 tonnes/year. Production: 1,000 tonnes/year.
Tel./fax +358 14 421 503, e-mail: <hehkupelletti@hehkupelletti.inet.fi>. [1,2]

Ilomantsin tehdas (Ilomantsi)
Owned by Vapo Oy. Capacity: 45,000 tonnes/year. Production: (target) 40,000 tonnes/year.
Contact persons:
Mr. Jaakko Silpola, Tel. +358 40 554 69 54, fax + 358 14 623 5707, e-mail: <jaakko.silpola@vapo.fi>.
Mr. Timo Huhtanen, Tel. +358 400 757 952, e-mail: <timo.huhtanen@vapo.fi>.
Web site: <http://www.vapo.fi>. [1,2,5]

Keurak Oy (Keuruu)
Owned by Keurak Oy. Capacity: 5,000 tonnes/year. Production: 3,000 tonnes/year.
Tel. +358 14 754 0400, fax +358 14 754 0421, e-mail: <keurak@co.inet.fi>. [1,2,6]

Punkaharjun Pelletti Ky (Punkaharju)
Production started in 2000. Production: estimated 1,500 tonnes/year.
Contact: Mr. Aarne Tynkkynen, Tel./fax +358 15 441 850. [7,8]

PuuPrisma Oy (Kesälahti)
Production started in Dec. 2000. Production: estimated 500 tonnes/year.
Contact: Mr. Pasi Puputti, Tel. +358-13-372-294, mobile tel. +358 400 739 852, fax: +358-13-372-295, e-mail: <Pasi.Puputti@PuuPrisma.inet.fi>. [7]

Turengin tehdas (Turenki Pellet Factory) (Turenki)
Owned by Biowatti Oy. Capacity: 70,000 tonnes/year. Production: 20,000 tonnes/year.
Contact person: Mr. Savolainen Martti (Mill manager). Tel. +358 10 46 58149,
mobile tel. +358 50 532 0017, fax: +358 10 46 58298, e-mail: <martti.savolainen@biowatti.fi>,
web site: <http://www.biowatti.fi>. [1,2,9]

Umacon Oy (Kuopio and Anjalankoski)
Factories started in 2000 and 2001. Production capacity in Kuopio: 2,500 tonnes/year. Production capacity in Anjalankoski: 2,500 tonnes/year.
Managing director: Mr. Tuomo Salonen, Tel. +358-5-3636235, mobile tel. +358-400-552121, e-mail: <tuomo.salonen@umacon.fi>. [10]

Sources:
[1] Private communication with Mr. Mikko Ahonen, Central Finland Energy Agency (14 Mar. 2000).
[2] Private communication with Mr. Janne Nalkki, Central Finland Energy Agency (6 Nov. 2000).
[3] *Österbottens energikontor* <http://www.merinova.fi/energiatoimisto/fornybar.html> (6 Nov. 2000).
[4] Telephone communication with Finncambi Oy (8 Nov. 2000).
[5] Private communication with Mr. Jaakko Silpola, Vapo Oy (7 Nov. 2000).
[6] Private communication with Mr. Jussi Järvenpää and Mr. Mikko Järvenpää, Keurak Oy (7 Nov. 2000).
[7] Private communication with Mr. Janne Nalkki, Central Finland Energy Agency (14 Feb. 2001, 3 Apr. 2001 and 11 Apr. 2001).
[8] Telephone communication with Mr. Aarne Tynkkynen (19 Apr. 2001).
[9] Private communication with Mr. Savolainen Martti (27 Mar. 2001).
[10] Private communication with Mr. Erkki Pasonen, Finnish Business-Help Oy (5 March 2001).

France

Cogra 48 (Mende)
Production and supply. Started production in 1982. Production: 12,000 tonnes/year.
Mr. Bernard Chapon, Tel. +33 (0)466 65 34 63, fax +33 (0)466 65 22 24,
e-mail: <COGRA_48@wanadoo.fr>. [1,2]

SOFAG (Arc sous Cicon)
Production: approx. 2,000 tonnes/year.
Mr. Thierry Vandelle, Tel. +33 (0)381 69 99 79, +33 (0)384 52 52 97, fax +33 (0)381 69 99 80. [1,3]

SA Fontaine des Auges (Gendrey)
Production: 2,000 tonnes/year.
Mr. James Millot, Tel. +33 (0)384 81 01 04, fax +33 (0)384 81 09 38, e-mail: <cuma@terre-net.fr>. [1,4]

Sources:
[1] Mr. Frederic Douard, l'ITEBE, the European Institute of Wood Energy (22 Nov. 2000).
[2] Telephone communication with Cogra 48 (1 Dec. 2000).
[3] Telephone communication with SOFAG (1 Dec. 2000).
[4] Telephone communication with SA Fontaine des Auges (1 Dec. 2000).

Germany

Allspan Spanverarbeitung GmbH (Karlsruhe)
Production and supply.
Tel. +49 (0)721-56580-0, e-mail: <info@allspan.de>. [1,2,3]

Biomassehof Schongau-Altenstadt (Altenstadt)
Plans production and supply from 2001/2002.
Tel. +49 (0)8861-2354-0, fax +49 (0)8861-2354-44, e-mail: <biomasse.hkw@telda.net> . [1,2,4]

Fichtwald-Trocknung GbR (Proßmarke)
Production and supply. Size of production: not known.
Tel. +49 (0)35364-257, fax +49 (0)35364-4181. [1,2,5]

Grasaufbereitungsgesellschaft (Calau)
Production.
Tel. +49 (0)35 41-2751. [1,2,6]

Holzenergie Klaus Fallert (Appenweier)
Production and supply.
Tel. +49 (0)7805 9676-0, e-mail: <fallert@holzenergie.de>,
web site: <http://www.holzenergie.de/fallert/index.htm>. [1,2]

Landwirtschaftliche Trocknungsgenossenshaft Neuhof an der Zenn und Umgebung eG
(Neuhof an der Zenn)
Production and supply. Production: approx. 500 tonnes/year.
Tel. +49 (0)9107-320, fax +49 (0)9107-1594, e-mail: <Trocknung-Neuhof@t-online.de>. [1,7]

Prohadi GmbH (Groß Düben)
Production and supply. Size of production: not known.
Tel./fax +49 (0)35773-70621. [1,2,8]

J. Rettenmaier & Söhne GmbH + Co (Rosenberg)
Production and supply. Production: approx. 30,000 tonnes/year.
Tel. +49 (0)7967-152-0, e-mail: <info@jrs.de>. Or contact person: Mr. Harald Schlosser,
Tel. +49 (0)7967 152-203, fax +49 (0)7967 152-222, e-mail: <Harald.Schlosser@JRS.de>.
Web site: <http://www.jrs.de>. [1,2,9]

Schellinger & Co Mühlenwerke (Weingarten)
Production and supply.
Tel. +49 (0)751-56094-0, fax +49 (0)751-56094-49. [1,2,10]

Trocknungsgenossenschaft Weißenburg (Ellingen)
Production and supply.
Tel. +49 (0)9141-3480, fax +49 (0)9141-7375-4. [1,2,11]

Sources:
[1] *C.A.R.M.E.N. list of suppliers: Pellets* <http://carmen-ev.de/english/marktplatz/bezugsqu/pellets.html> (26 July 1999).
[2] Malisius et al., p. 84.
[3] Telephone communication with Allspan Spanverarbeitungs GmbH (7 Nov. 2000).
[4] Telephone communication (16 Nov. 2000)/private communication with Biomassehof Schongau-Altenstadt (28 Nov. 2000).
[5] Telephone communication with Fichtwald-Trocknung GbR (7 Nov. 2000).
[6] Telephone commnunication with Grasaufbereitungsgesellschaft (3 Nov. 2000).
[7] Telephone communication with Landwirtschaftliche Trocknungsgenossenshaft Neuhof (7 Nov. 2000).
[8] Telephone communication with Prohadi (7 Nov. 2000).
[9] Private communication with Mr. Harald Schlosser, Rettenmaier & Söhne (9-10 Nov. 2000).
[10] Telephone communication with Schellinger & Co Mühlenwerke (7 Nov.2000).
[11] Telephone communication with Trocknungsgenossenschaft Weißenburg (8 Nov. 2000).

Hungary

Kék Bolygó "Bioenergia" KFT (Nagycenk)
Mr. Gyula Asztalos, Manager. Tel./fax +36 99 360 693, e-mail: <kekbolygo@yahoo.com>. [1]

[1] Private communication with Mr. Gyula Asztalos (5 Jan. 2000).

Italy

C & B CALOR (Limbiate)
Production: 44,000 tonnes/year.
Tel. +39 0299 66 146, fax: +39 0299 65 112. [1,2]

La TiEsse s.r.l. (S. Michele di Piave)
Tel. + 39 0422 803 030, fax: +39 0422 743 903, e-mail: <combustibili@latiesse.it>, web site: <http://www.latiesse.it>. [1]

Sources:
[1] Mr. Frederic Douard, l'ITEBE, the European Technical Institute of Wood Energy (22 Nov. 2000).
[2] Telephone communication with C & B CALOR (1 Dec. 2000).

Latvia

CED (Drabesi, Cesu district)
Latvian-German joint-venture. Production: 7,000-8,000 tonnes/year. [1]

Latgranula (Incukalns, Rigas district)
Production: 10,000-12,000 tonnes/year. [1]

Latvall, SIA (Iecava, Bauskas district)
Owned by Kaj Østergård and IØ. Production: 10,000-15,000 tonnes/year. [1,2]

SBE Latvia Ltd. (Lauciena, Talsu district)
Owned by SBE Svensk BrikettEnergi AB. Production: 40,000 tonnes/year. [1,3]

Sources:
[1] Private communication with Mr. Martins Gedrovics, Latvian Development Agency's Department of Energy (1 Nov. 2000).
[2] Telephone communication with A/S SPANVALL (1 Nov. 2000).

[3] Private communication with Ms. Birgitta Helmstein, SBE Svensk BrikettEnergi AB (13 Nov. 2000).

The Netherlands

Ekoblok BV (Almelo)
Production.
Tel. +31 (0)546 573670, fax +31 (0)546 574881, e-mail: <Ekoblok@worldonline.nl>,
web site: **<**http://www.carbo.nl**>.** [1,4]

Labee Group Moerdijk (Moerdijk)
Production and supply. Production level is not known.
Tel. +31 (0)168-382110, fax. +31 (0)168-382015. [1,2,3]

Sources:
[1] Private communication with Mr. Michel Arninkhof, NL-BEA (the Netherlands Bio-Energy Association).
[2] *C.A.R.M.E.N. list of suppliers: Pellets* <http://www.carmen-ev/english/marktplatz/bezugsqu/pellets.html> (26 July 1999).
[3] Telephone communication with Labee Group Moerdijk (6 Nov. 2000).
[4] Private communication with Ekoblok BV (6 and 8 Nov. 2000).

Norway

Cambi Bioenergi Vestmarka AS (Vestmarka)
Owned by Glommens Skogeierforening, Cambi AS and Gudbrandsdal Energi. Capacity: 30,000 tonnes/year. Production: 15,000 tonnes/year.
Tel. +47 62839188, fax: +47 62839330, web site: <http://www.cambi.no>.
[1,2]

Frya Bioenergi AS (Hundorp, Sør-Fron)
The company has no production of wood pellets presently (Nov. 2000) but is working on starting up the production.
Tel. +47 612 97300, e-mail: <roald.nilsen@fryabioenergi.no>. [3,4]

Norsk Trepellets AS (Brumunddal)
50% is owned by Statoil Norge AS. Production: 8,000 tonnes/year. Marketing and sales is handled by Statoil Norge AS.
Statoil Norge AS: Tel. +47 62519314, fax: +47 62531513, e-mail: <kundeservice@statoil.com> or <noeln1@statoil.com>, web site: <http://www.statoil.no>. [1,5]

Vaksdal Biobrensel AS (Dalekvam)
Capacity: 12,000 tonnes/year. Production: 500 tonnes/year.
Tel. +47 56597630, fax: +47 56597631. [1,2,6]

Vi-Tre AS (Røros)
Capacity: 3,000 tonnes/year. Production: 700 tonnes/year.
Tel. +47 72412855, fax: +47 72412991. [1,2,7]

Sources:
[1] Private communication with Mr. Arnold Kyrre Martinsen, NoBio.
[2] Telephone communication with Cambi Bioenergi Vestmarka (7 Nov. 2000).
[3] Malisius et al. (2000), *Industrial Network on Wood Pellets*, p. 86.
[4] Telephone communication with Mr. Roald Nilsen, Frya Bioenergi AS (7 Nov. 2000).
[5] Private communication with Ms. Elisabeth Nygaard, Statoil Norge AS (7-8 Nov. 2000).
[6] Telephone communication with Vaksdal Biobrensel (8 Nov. 2000).
[7] Telephone communication with Vi-Tre (8 Nov. 2000).

Spain

ECOFOREST SA (Villacañas)
Production: 9,000 tonnes/year.
Tel. +34 986 417 700, fax: +34 986 262 186, e-mail: <ecoforest@ecoforest.es>. [1,2]

Sources:
[1] Mr. Frederic Douard, l'ITEBE, the European Technical Institute of Wood Energy (22 Nov. 2000).
[2] Telephone communication with ECOFOREST (1 Dec. 2000).

Sweden

Bioenergi i Luleå AB (Luleå)
A subsidiary of Luleå Energi AB. The wood pellet factory is located in Aronstorp industrial area.
Production: 90,000 tonnes/year.
Tel. +46 (0)920-255025, e-mail: <pellets@luleaenergi.se>, web site: <http://www.luleaenergi.se>. [1,2]

BioNorr BioEnergi i Norrland AB (Härnösand)
Owned by SÅTAB Sågverkens Trädprodukter AB, SCANINGE TIMBER AB, and SCA.
Production: 85,000 tonnes/year.
Tel. +46 (0)611-15088, e-mail: <kent.johansson@bionorr.com>, web site: <http://www.sotab.se>. [1,2,3]

Bobergs Valltork Ek. För. (Borensberg)
Owned by 80 farmers. Production: 2,000 tonnes/year.
Tel. +46 (0)141-209690, e-mail: <bobergs@bobergs-ekfor.se>, web site: <http://www.bobergs-ekfor.se>. [1,2,4]

Bure Pellets AB (Bureå)
Started in 1998. Production: 8,000 tonnes/year.
Tel. +46 (0)910-780023, e-mail: <mariann.marklund@skelleftea.mail.telia.com>,
web site: <http://w1.910.telia.com/~u91002686/Pellets>. [1]

AB Forssjö Bruk (Katrineholm)
Production: 30,000 tonnes/year.
Tel. +46 (0)150-73400, e-mail: <pellets@forssjobruk.se>, web site: <http://www.forssjobruk.se>. [1,2,5]

MBAB Energi (Robertsfors)
Production: 25,000 tonnes/year.
Tel. +46 (0)934-40200. Fax +46 (0)934-40248. [1,2,6]

MEBIO Mellansvenska Bränsle AB (Främlingshem and Valbo)
Production: 40,000 tonnes/year.
Tel. +46 (0)26-36050, e-mail: <peter.sjobom@mebio.se>. [1,7]

Mellanskogs Bränsle AB (Valbo; Ljusne; and Orsa)
A subsidiary of Forest-owners' association Mellanskog. Production in Ljusne: 15,000 tonnes/year.
Production in Valbo: 40,000 tonnes/year. Production in Orsa: 40,000 tonnes/year.
Tel. +46 (0)26-134632 / +46 (0)26-134630, e-mail: <ingvar.fernstrom@mellanskog.se>,
web site: <http://www.mellanskog.se/forening/frame1.htm>. [1,2]

Mockfjärds BioBränsle AB (Mockfjärd)
Start of own production in 1998-1999.
Tel. +46 (0)241-20074, e-mail: <bernth@dalnet.se>, web site: <http://www.dalnet.se/~bernth>.

SBE Svensk BrikettEnergi AB (Norberg; Nävlinge; and Ulricehamn)
Production in Norberg 40,000 tonnes/year. Production in Nävlinge 15,000 tonnes/year. Production in Ulricehamn: 40,000 tonnes/year.
Tel. +46 (0)36-387870, e-mail: <info@brikettenergi.se>, web site: <http://www.brikettenergi.se>. [1,2,8]

Skellefteå Kraft AB (Skellefteå)
Product name: "SoLett". Production: 130,000 tonnes/year.
Tel. +46 (0)910-772524 / +46 (0)910-772500, e-mail: <pellets@skekraft.se>,
web site: <http://skekraft.se>. [1,2]

Statoil Pellets AB (Kil and Säffle)
Owned by Statoil (80.2%) and Vänerbränsle AB (19.8%).
Production in Kil: approx. 9,000 tonnes/year. Production in Säffle: approx. 16,000 tonnes/year.
The factory in Kil was sold by SÖDRA Skogsenergi in 1996 to Gotthard Nilsson (Älmhult), who later sold it to Värmlands Skogsägare. In 1999 it was sold to Statoil. The factory in Säffle was sold by Cambi Bioenergi AS to Statoil in 1999. In April 2000 the manufacturing company Statoil Pellets AB was created comprising the factories in Kil and Säffle.
Tel. +46 (0)533-10191, fax: +46 (0)533-419 67, e-mail: <venerbygdens.pellets@telia.com>. [1,2,9,10]

Sydpellets AB (Traryd)
Production and supply. Started in 2000. Capacity: 30,000 tonnes/year. Production: 15,000 tonnes/year.
Tel. +47 (0)433-626 27, fax. +47 (0)433-626 82, e-mail: <info@sydpellets.se>,
web site: <http://www.sydpellets.se>. [11]

SÖDRA Skogsenergi AB (Mönsterås)
Barkpellets. Production: 50,000 tonnes/year.
Tel. +46 (0)35-108970, e-mail: <mauritz.nilsson@sodra.se>, web site: <http://www.sodra.se>. [1,2,12]

SÅBI Pellets AB (Vaggeryd and Forsnäs)
Production in Vaggeryd: 50,000 tonnes/year. Production in Forsnäs: 40,000 tonnes/year.
The factory in Forsnäs was sold to SÅBI by Sydved Energileveranser AB.
Tel. +46 (0)36-198600, e-mail: <information@sabi.se>, web site: <http://www.sabi.se>. [1,2,13,14]

Våla Bioenergi (Östervåla)
Production: 1,000 tonnes/year.
Tel. +46 (0)292-40023, fax +46 (0)292-40056. [1,15]

Sources:
[1] Malisius et al. (2000), *Industrial Network on Wood Pellets*, p. 79.
[2] Skaugen et al. (1997), *Systemstudier – Brenselsiden* <http://nettvik.no/naeringsparken/bioscan/FerdigRapport%20P9.html> (13 Oct. 1999).
[3] Private communication with Mr. Kent Johansson, BioNorr (7 Nov. 2000)
[4] Private communication with Mr. Ulf Gustafsson, Bobergs Valltork (10 Nov. 2000).
[5] Private communication with Mr. Per Stenegard, AB Forssjö Bruk (14 Nov. 2000).
[6] Telephone communication with MBAB Energi (6 Nov. 2000).
[7] Telephone communication with MEBIO (1 Nov. 2000).
[8] Telephone communication with SBE BrikettEnergi AB (8 Sep. 2000) and private communication with Ms. Birgitta Helmstein, SBE BrikettEnergi AB (13 Nov. 2000).
[9] Private communication with Mr. Mauritz Nilsson, SÖDRA Skogsenergi AB (6 Nov. 2000).
[10] Private communication with Ms. Agneta Svensson, Statoil Pellets AB (7 Nov. 2000).
[11] Telephone communication with Sydpellets AB (15 Jan. 2001).
[12] Telephone communication with SÖDRA Skogsenergi AB (2 Nov. 2000) and private communication with Mr. Mauritz Nilsson, SÖDRA Skogsenergi AB (6 Nov. 2000).
[13] Telephone communication with SÅBI (8 Nov. 2000).
[14] Private communication with Mr. Anders Folkesson, Sydved Energileveranser (6 Nov. 2000).
[15] Telephone communication with Våla Bioenergi (7 Nov. 2000).

Switzerland

Bürli Trocknungsanlage (Gettnau)
Production and supply. Capacity: 3,000-5,000 tonnes/year. Production: 1,000 tonnes/year. Price: CHF 250/tonne.
Tel. +41 419701864/ +41 41 9703154, fax. +41 419700154,
web site: <http://www.holz-pellets-buerli.ch>. [1,2,3,4,5]

Interspan Tschopp (Buttisholz)
Produces only wood briquettes at present (Nov. 2000) but plans to produce wood pellets in 2001 or later.
Tel. +41 419281717. [1,6]

Sources:

[1] *C.A.R.M.E.N. list of suppliers: Pellets* <http://www.carmen-ev.de/english/marktplatz/bezugsqu/pellets.html> (26 July 1999).
[2] Telephone communication with Hans Nebriker AGf Tel. +41-619711511 (1 Nov. 2000).
[3] Telephone communication with Landwortschaftliche Genossenschaft Tel. +41-318590324 (1 Nov. 2000).
[4] Telephone communication with Bürli Trocknungsanlage (3 Nov. 2000).
[5] Telephone communication with Diemo Handels AG (2 Nov. 2000).
[6] Telephone communication with Interspan Tschopp (2 Nov. 2000).

United Kingdom

Envirofuel Ltd. (Birkenhead)
Mr. Mike Jones. Tel. +44 (0)1516470099, +44 (0)8003281088, e-mail: <sales@envirofuel.co.uk>, web site: **<**http://www.envirofuel.co.uk**>.** [1,2]

Sources:
[1] Telephone communication with British BioGen (3 Nov. 2000).
[2] Telephone communication with Mr. Mike Jones, Envirofuel (7 Nov. 2000).

B Organisations in Europe, U.S.A., and Canada Promoting Wood Pellets

Several organisations, e.g. biomass associations, work to promote the use of wood pellets as a fuel. However, below is listed the four associations known to the author which specifically promote wood pellets; these are located in Sweden, Austria, the United States and in Canada. Contact information is included for each association.

Pelletsindustrins Riksförbund (PiR) in Sweden has twelve member companies, which own and operate 16 manufacturing plants all over Sweden. The association has since the mid-80s worked “to establish pellets as an ecological alternative to fossil fuels”, and other aspects of the association’s work are quality certification, standardisation, development of distribution, R&D and information.[286]

Pelletsindustrins Riksförbund
Torsgatan 12, pl 3
111 23 Stockholm, Sweden
Tel. +46 08 441 70 96
Web site: <http://www.pelletsindustrin.org>

Pelletsverband Austria (PVA) does not explain about the organisation itself on its web site.[287] However, on the web site it is explained that through the “PVA quality certification”, the organisation guarantees the quality of wood pellets coming from suppliers that belong to Pelletsverband Austria. Around 15 wood pellet suppliers are listed on the web site. Furthermore, it seems that the organisation arranges seminars on different topics relating to wood pellets.

Pelletsverband Austria
Schönbergstr. 21b
A-4616 Weißkirchen, Austria
Tel. +43 (0)7243-60006
E-mail: <office@pelletsverband.at>
Web site: <http://www.pelletsverband.at>

The Pellet Fuels Institute (PFI), located in Arlington, Virginia, U.S.A., is a trade association with members in the United States and in Canada. Members are wood pellet manufacturers and industry-related suppliers. The Pellet Fuels Institute has dedicated itself to “the advancement and promotion of the fiber and densified (pellets) fuel technology that will help solve global ecological problems through the utilization of locally renewable energy sources”[288]. Among other things, it promotes the wood pellet industry and keeps its members updated with the latest industry news.

Pellet Fuels Institute
1601 North Kent Street, Suite 1001
Arlington, VA 22209, U.S.A.
Tel: +1 (703) 552-6778
E-mail: <pfimail@pelletheat.org>
Web site: <http://www.pelletheat.org>

[286] <http://www.pelletsindustrin.org> (28.08.00)
[287] *Pelletsverband Austria* <www.pelletsverband.at> (2 Sep. 2000)
[288] *Pellet Fuels Institute: Mission Statement*, <http://www.pelletheat.org/indudty/mission.shtml>(13 Oct. 1999)

BC Pellet Fuel Manufactures Association (BCPFMA), situated in British Columbia in Canada, was formed in 1996.[289] The association promotes wood pellets as "a natural choice".

BC Pellet Fuel Manufacturers Association
Box 2929
Prince George
B.C. Canada V2N 4T7
Tel: +1-250-963-7220 or +1-250-563-8833
E-mail: <mail@pellet.org>
Web site: <http://www.pellet.org>

[289] *Welcome – BC Pellet Fuel Manufactures Association* <http://www.pellet.org/welcome.html>(26 July 1999)

C European Organisation of Electricity Systems

Various associations and organisations are set up for the cross-border co-operation between transmission system operators in Europe. UCTE, Nordel and Baltic IPS are the main groups of synchronously interconnected power systems. These are described below, together with other European electricity organisations.

UCTE

UCTE[290] (Union for the Co-ordination of the Transmission of Electricity) was founded in 1951 with location in Luxembourg. The secretariat of UCTE rotates between the members, as it follows the chairman of UCTE, elected every two years; currently the UCTE-secretariat is located in Berlin. UCTE was called UCPTE (Union for the Co-ordination of the Production and Transmission of Electricity) until 1999 when its Articles of Association were amended and activities were concentrated on transmission system operation in order to comply with the requirements of the Electricity Directive. UCTE deals with technical aspects of the interconnected power system and co-ordinates the interests of its member transmission system operators, particularly in terms of reliability. The objective of UCTE is to guarantee the security of operation, and the organisation has developed rules and recommendations as a basis for the smooth operation of the power system.

Current (2001) members of UCTE comprise transmission system operators of most of Western and Central Europe, covering Austria, Belgium, Bosnia-Herzegovina, Croatia, Czech Republic, Federal Republic of Yugoslavia, F.Y.R.O. Macedonia, France, Germany, Greece, Hungary, Italy, Luxembourg, the Netherlands, Poland, Portugal, Spain, Slovakia, Slovenia and Switzerland. The members of CENTREL, a regional group consisting of 4 power companies in Czech Republic, Hungary, Poland, and Slovakia, were associated members of UCTE since 1999 but became full members of UCTE from May 17th 2001.[291] Denmark is technically a part of UCTE considering that the western part of the country operates synchronously with the UCTE grid, but according to UCTE[292] Denmark is not represented as a member, since it chose to be a member of Nordel; it is possible that Denmark will become an associated member of UCTE in October 2001. The UCTE grid has been split up as a result of the Balkan Conflict, which began in 1991, and Greece is therefore currently disconnected from UCTE. Greece operates synchronously with Albania, F.Y.R.O. Macedonia, Bulgaria and Romania.

Nordel

Nordel,[293] founded in 1963, is an association for co-operation between system operators in the Nordic countries: Denmark, Finland, Iceland, Norway and Sweden. The highest decision-making body of the association is the Annual Meeting, comprising representatives from each member countries. The chairmanship and the responsibility of the secretariat rotates between members every two years. The secretariat is currently (2001) located in Oslo, Norway. The primary objective of Nordel is to develop further an efficient Nordic electricity market. Nordel serves as a forum for technical co-operation and co-ordination between system operators. Nordel gives advice and recommendations, and deals with among other things system development and operation, rules for network dimensioning, reliability of operation and exchange of information, principles for pricing for network services, and international co-operation. The synchronously interconnected system of Nordel comprises the transmission systems of eastern Denmark, Finland, Norway and Sweden. Iceland and western Denmark therefore do not operate synchronously with the Nordel grid.

Baltic IPS

The Baltic IPS (Interconnected Power System)[294] is a synchronously interconnected area covering transmission lines of Estonia, Latvia and Lithuania. Formerly a part of the UPS (Unified Power System) of the Soviet Union, the Baltic IPS was founded in 1992 after the Baltic states regained independence. The

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290 *UCTE* <http://www.ucte.org>
291 Telephone communication with Magyar Villamos Művek Rt. (MVM), Hungary (23 May 2001).
292 Telephone communication with UCTE Secretariat, Berlin (23 May 2001).
293 Nordel <http://www.nordel.org> (26 May 2001).
294 Telephone communication with Eesti Energia, Estonia (23 May 2001).
Baltic IPS <http://www.dc.riga/page_0.htm> (25 May 2001).

Baltic IPS operates synchronously with the UPS (Unified Power System) of Russia and the power system of Belarus.

Baltic Power Systems Regional Control Centre (Dispatch Centre Baltija) located in Riga, Latvia, supervises the Baltic IPS. DC Baltija is responsible for dispatching the entire Baltic IPS with neighbouring countries, ensuring reliability of the system and co-ordinating the maintenance of major generation units and transmission lines.

ETSO

The Association of European Transmission System Operators (ETSO)[295] was founded in Frankfurt in July 1999 by 4 founding member organisations: UCTE, Nordel, United Kingdom Transmission System Operators Association (UKTSOA) and the Association of Transmission System Operators in Ireland (ATSOI). However, member countries are only the 15 EU Member States, Norway and Switzerland. ETSO is governed by a Council representing the four member organisations, and a Steering Committee in which each member country is represented. ETSO deals with political and commercial aspects of transmission system operation in EU. ETSO was created as a response to the Electricity Directive and the emergence of the internal electricity market in EU. The 4 founding members recognised a need for an EU-wide harmonisation of network access and conditions for usage, especially for cross-border trade.

Union of the Electricity Industry – EURELECTRIC

Union of the Electricity Industry – EURELECTRIC,[296] located in Brussels, Belgium, seeks to “contribute to the competitiveness of the industry, to provide effective representation for the industry in public affairs, and to promote the role of electricity in the advancement of society”. EURELECTRIC’s purpose is moreover to identify the common interests of its members, help in formulating common solutions and co-ordinate their implementation. The association also acts as the electricity association of the EU. The association was formed in December 1999 through a merger of two large associations representing European electric companies, EURELECTRIC, a European grouping of electricity companies created in 1989, and UNIPEDE (International Union of Producers and Distributors of Electrical Energy) created in 1925. EURELECTRIC’s full members include electricity associations or electricity companies of EU Member States and countries of Central and Eastern Europe, while international affiliate members are located in North America, Russia, Japan and Africa.

CDO

The Central Dispatching Organization (CDO)[297] of the Interconnected Power Systems was created in 1962 when an agreement was signed between the governments of Bulgaria, Czechoslovakia, East Germany, Hungary, Poland, Romania, and Soviet Union. The purpose was the co-ordination of the Interconnected Power Systems. In 1979, the UPS (Unified Power System) of Soviet Union was linked to the Interconnected Power Systems, forming the world’s largest synchronously interconnected system, reaching from Berlin to Ulan Bator. From 1993, however, the interconnected power systems were again split into non-synchronously operating parts.

The present (2001) members of CDO comprise Bulgaria, Czech Republic, Hungary, Germany, Poland, Romania, Russia, and Ukraine. Slovakia stopped participating in 1998, and it is likely that Czech Republic stop participating in the organisation from 2001.[298] Each CDO member is represented in the CDO Council, which is the supreme body of the organisation. The secretariat is located in Prague, Czech Republic. Although previously CDO had a role similar to UCTE and Nordel, its purpose is now strategic co-operation rather than co-ordination of a synchronously interconnected system. These changes are reflected in the 1996 Statutes of CDO according to which co-operation takes place in areas such as power systems development, operation and maintenance. Furthermore, mutual exchange of information takes place concerning operation of electricity companies and power systems in addition to legislation and environment.

CENTREL

CENTREL,[299] founded in 1992 in Prague, is a regional group consisting of 4 Central European power companies: CEPS, a.s. of Czech Republic, Magyar Villamos Művek Rt. of Hungary, Polskie Sieci Elektroenergetyczne SA of Poland and Slovenské Elektrárne, a.s. of Slovakia. The presidency and secretariat

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[295] *ETSO* <http://www.etso-net.org> (25 May 2001).
[296] *EURELECTRIC* <http://www.eurelectric.org> (25 May 2001).
[297] *Central Dispatching Organization* <http://www.cdo.org> (25 May 2001).
[298] Telephone communication with Magyar Villamos Muvek Rt., Hungary, CDO representative (23 May 2001).
[299] *CENTREL* <http://www.centrel.org> (25 May 2001).

of CENTREL rotates between the members, and a new president of CENTREL is elected by the Council every two years, whereupon the president appoints the Secretariat. The Hungarian member holds the presidency and secretariat in the period 2001-2002.

When established in 1992, a major goal was to achieve membership of UCPTE (now UCTE). This goal was achieved when the CENTREL member companies were accepted as full members of UCTE in May 2001. The foundation was laid by reaching the required UCTE quality level, making it possible to launch synchronous operation between UCTE and CENTREL in 1995, and becoming associated members of UCTE in 1999. According to the Charter of CENTREL 1998, the main objectives and tasks of the organisation are the optimal use of generation and transmission capacity, reliable synchronous operation with UCTE, improvement of operational conditions of the members' electricity systems and monitoring of EC legislation. In the recent CENTREL Memorandum (2000) it is stated that a major goal of the CENTREL members is to achieve membership of ETSO.

BALTREL

BALTREL (Baltic Ring Electricity Co-operation Committee)[300] was created in 1998 as a discussion forum with the ambition of developing co-operation between members in the Baltic Sea Region. The members consist of 18 electricity companies and associations in 11 countries in the Baltic Sea area. The aim is to create a common electricity market in the region, and areas of discussion include trading rules, transmission grid issues, market development, environmental issues and taxation. Working groups of BALTREL conduct studies of relevant issues in creating a common electricity market.

[300] BALTREL <http://www.baltrel.com> (22 May 2001).
Telephone communication with BALTREL-Secretariat, c/o Vattenfall AB, Sweden (22 May 2001).

D Statistics on Space Heating and Hot-Water Supply in European Households

The following two long tables concern space heating and hot-water, respectively in selected countries in Western and Central/Eastern Europe. Table D.1 gives an overview of the share of dwellings that have no heating, central/district heating and local heating by the type of fuel used. Table D.2 gives an overview of the share of dwellings which have no water heating equipment for hot-water supply, have water heating equipment connected to the central/district heating system and have local water heating equipment by the type of fuel used. All figures are taken from *Energy consumption in households: European Union and Norway, 1995 survey, Central and eastern European countries, 1996 survey*, Eurostat (1999)

Table D.1 Space heating by space heating equipment and fuel in % of dwellings in selected European countries (1995/1996).

Country	Albania	Austria	Belgium	Bulgaria	Czech R.	Denm.	Estonia	Finland	France
NO HEATING	**0.0**	**-**	**-**	**0.1**	**0.1**	**0.0**	**0.0**	**-**	**-**
CENTRAL H.	**0.1**	**68.0**	**63.4**	**19.3**	**97.2**	**91.1**	**65.5**	**92.9**	**85.1**
-Fuel oil	-	24.1	35.7	0.3	-	23.2	2.9	18.0	18.7
-Natural gas	-	18.2	24.1	-	20.5	11.5	5.1	0.4	31.8
-LPG	-	0.8	0.4	-	0.1	-	1.7	-	2.0
-Electricity	-	1.1	2.7	0.4	-	0.7	2.5	21.2	24.8
-Solid fuels	-	3.8	0.4	-	4.0	0.7	3.3	0.2	2.4
-Wood	0.1	10.1	0.0	-	16.5	0.3	6.0	4.7	-
-Other	-	1.5	-	0.6	15.4	0.2	2.0	0.3	0.7
District heating	0.0	11.1	1.1	17.0	27.2	54.5	44.7	48.1	4.7
LOCAL H.	**100.0**	**32.0**	**36.6**	**94.7**	**27.1**	**8.9**	**36.1**	**7.1**	**14.9**
-Fuel oil	-	4.5	6.8	1.4	-	0.7	-	-	1.5
-Natural gas	-	6.7	14.1	-	8.1	0.2	0.1	-	0.5
-LPG	2.4	0.2	1.1	1.3	0.0	-	0.2	-	-
-Kerosene	4.6	-	-	-	-	-	-	-	-
-Electricity	35.9	9.0	6.2	28.9	9.1	6.2	8.0	-	5.3
-Solid fuels	-	3.1	6.9	-	0.7	0.6	0.1	7.0	1.8
-Wood	46.7	8.2	1.2	47.9	4.7	-	31.6	-	5.5
-Other	-	0.3	0.3	33.8	4.1	0.2	5.2	0.1	0.3
-Open fires	22.0	-	-	0.6	0.3	-	3.1	-	-
ADDITIONAL	**0.0**	**21.5**	**42.6**	**5.1**	**14.6**	**-**	**21.5**	**-**	**46.6**

Country	Germany	Greece	Hungary	Ireland	Latvia	Lithuania	Luxembourg	Netherlands	Norway
NO HEATING	**-**	**0.8**	**0.1**	**1.8**	**0.0**	**0.0**	**-**	**-**	**-**
CENTRAL H.	**78.0**	**56.7**	**55.6**	**71.8**	**70.0**	**91.7**	**86.3**	**82.7**	**10.0**
-Fuel oil	30.5	54.9	0.3	26.2	3.8	0.6	51.2	0.7	2.3
-Natural gas	33.2	0.1	18.1	14.7	3.1	3.2	28.1	78.1	-
-LPG	-	0.1	0.2	1.1	-	-	1.2	0.2	-
-Electricity	0.5	0.6	0.6	2.3	-	-	4.8	0.4	0.9
-Solid fuels	1.6	0.5	1.7	21.4	8.1	9.1	0.2	-	-
-Wood	0.5	0.5	8.0	-	5.1	17.9	-	0.1	0.3
-Other	-	-	6.3	6.1	0.5	1.3	0.8	0.1	5.7
District heating	11.7	-	16.6	-	49.4	54.3	-	3.1	0.8
LOCAL H.	**22.0**	**42.5**	**70.6**	**26.4**	**33.6**	**21.6**	**13.7**	**17.3**	**90.0**
-Fuel oil	3.4	15.1	1.4	2.3	-	-	3.3	0.2	8.0
-Natural gas	4.2	-	24.2	1.0	0.5	0.1	3.1	16.5	-
-LPG	-	4.0	3.3	1.1	0.3	2.6	0.6	0,1	-
-Kerosene	-	-	-	-	-	-	-	-	-
-Electricity	5.9	10.1	5.6	1.6	0.5	-	2.2	0.1	55.0
-Solid fuels	7.8	0.6	1.3	19.1	0.1	2.0	2.2	0.1	-
-Wood	0.7	16.6	22.7	1.3	31.9	16.4	2.2	0.3	22.0
-Other	-	0.0	12.1	-	0.3	0.3	0.1	0.0	5.0
-Open fires	-	-	0.0	-	0.3	0.2	-	-	-
ADDITIONAL	**43.5**	**-**	**8.3**	**47.0**	**18.8**	**6.2**	**-**	**52.7**	**83.0**

Country	Poland	Portugal	Romania	Slovakia	Slovenia	Spain	Sweden	UK
NO HEATING	**0.0**	**27.4**	**0.0**	**0.0**	**0.0**	**10.4**	**-**	**-**
CENTRAL H.	**67.0**	**3.0**	**40.0**	**91.5**	**86.4**	**39.9**	**100.0**	**83.6**
-Fuel oil	-	0.0	0.3	3.1	40.2	14.3	12.4	3.0
-Natural gas	7.0	-	1.1	42.1	5.9	12.1	0.4	65.5
-LPG	-	0.3	0.0	-	1.0	3.3	-	0.8
-Electricity	-	0.7	-	4.0	0.3	6.0	19.4	9.8
-Solid fuels	20.8	-	-	5.4	-	2.4	-	3.2
-Wood	5.2	2.0	0.8	8.1	19.2	1.8	2.2	-
-Other	-	0.0	0.4	8.1	7.1	0.0	24.6	-
District heating	34.0	-	37.4	23.2	12.7	-	41.0	1.3
LOCAL H.	**33.3**	**69.6**	**70.6**	**46.5**	**56.5**	**49.7**	**-**	**16.4**
-Fuel oil	24.8	-	0.3	-	2.7	0.3	-	0.0
-Natural gas	-	-	5.1	9.6	0.3	0.1	-	10.9
-LPG	-	6.8	4.3	0.1	1.3	11.2	-	0.5
-Kerosene	-	-	0.1	-	-	-	-	-
-Electricity	-	39.1	0.1	2.7	19.7	29.4	-	2.5
-Solid fuels	8.2	2.0	1.1	3.0	-	1.9	-	2.5
-Wood	-	34.1	53.4	15.2	28.3	6.2	-	-
-Other	-	-	6.2	7.0	4.2	0.6	-	-
-Open fires	0.0	-	0.0	0.3	0.0	-	-	-
ADDITIONAL	**-**	**1.4**	**1.2**	**10.4**	**23.0**	**35.0**	**17.5**	**41.9**

Source: Eurostat (1999), Energy consumption in households, p. 24 and 124.

Note:

For Central and Eastern Europe local heating is calculated even if there is central heating, i.e. houses with both central and direct heating are included in two places.

Open fires and kerosene are not mentioned as a category for EU Member States and Norway.

Table D.2 Water heating by type of equipment and fuel in % of dwellings in selected European countries.

Country	Albania	Austria	Belgium	Bulgaria	Czech R.	Denmark	Estonia	Finland	France
NO WATER H. EQUIPMENT	**72.5**	**1.9**	**4.0**	**21.0**	**0.0**	**0.0**	**48.4**	**-**	**2.2**
CONNECTED TO CENTRAL H	**0.0**	**42.6**	**37.1**	**0.3**	**19.0**	**91.1**	**5.0**	**93.0**	**34.8**
-Fuel oil	-	12.4	22.0	-	-	23.2	0.2	18.0	10.3
-Natural gas	-	11.7	14.0	-	6.5	11.5	0.4	0.4	18.8
-LPG	-	0.8	0.1	-	0.0	-	0.0	-	1.1
-Electricity	-	-	-	0.1	-	0.7	0.3	21.0	.-
-Solid fules	-	1.4	0.1	-	1.7	0.7	1.4	0.2	1.0
-Wood	-	9.3	-	-	5.7	0.3	3.6	5.0	-
-Other	-	1.0	0.9	0.2	5.1	0.2	1.0	0.3	0.0
District heating	-	5.8	-	-	-	54.5	-	48.0	3.5
INDEPENDENT	**27.5**	**55.6**	**59.0**	**79.6**	**95.6**	**8.9**	**61.7**	**7.0**	**63.0**
-Natural gas	-	17.7	23.0	-	16.5	0.2	5.5	-	12.4
-Electricity	28.8	35.0	30.0	55.6	38.8	6.2	11.3	7.0	45.1
-Fuel oil	-	-	-	0.1	-	-	0.0	-	-
-LPG	-	-	6.0	0.3	0.2	-	0.4	-	5.5
-Kerosene	0.7	-	-	-	-	-	-	-	-
-Solid fuels	-	-	-	-	0.3	-	0.3	-	-
-Wood	-	1.1	-	8.8	1.3	-	4.0	-	-
-Other	-	-	-	3.2	1.1	2.5	0.8	-	-
-Heat	0.0	-	-	16.1	37.4	-	40.9	-	-

Country	Germany	Greece	Hungary	Ireland	Latvia	Lithuania	Luxembourg	Netherlands	Norway
NO WATER H. EQUIPMENT	**0.8**	**5.3**	**13.5**	**4.6**	**43.6**	**25.6**	**0.2**	**-**	**-**
CONNECTED TO CENTRAL H	**52.4**	**11.3**	**2.9**	**71.9**	**2.3**	**16.4**	**74.6**	**45.8**	**10.0**
-Fuel oil	24.0	10.9	0.0	27.1	0.0	0.5	35.6	0.1	2.3
-Natural gas	12.9	0.0	2.1	15.2	0.4	1.5	33.3	43.0	-
-LPG	-	0.1	0.0	1.2	-	0.0	-	-	-
-Electricity	7.3	-	-	-	-	-	5.7	-	0.9
-Solid fuels	1.2	0.2	0.0	22.1	0.5	4.5	-	-	-
-Wood	-	0.1	0.2	-	1.3	9.1	-	-	0.3
-Other	-	-	0.6	6.3	0.1	0.8	-	0.2	5.7
District heating	7.0	-	-	-	-	-	-	2.6	0.8
INDEPENDENT	**46.8**	**83.3**	**90.8**	**23.5**	**56.2**	**66.8**	**25.2**	**54.2**	**90.0**
Natural gas	12.6	0.0	20.9	0.5	1.7	2.1	9.5	43.5	-
-Electricity	30.5	65.9	47.1	17.0	3.1	2.1	15.7	10.7	90.0
-Fuel oil	-	-	0.0	-	-	0.1	-	-	-
-LPG	0.5	0.4	1.1	0.1	-	0.0	-	-	-
-Kerosene	-	-	-	-	-	-	-	-	-
-Solid fuels	-	-	0.1	-	0.4	1.9	-	-	-
-Wood	-	-	1.8	-	2.4	2.9	-	-	-
-Other	3.2	17.0	0.6	6.0	-	0.2	-	-	-
-Heat	-	-	19.2	-	48.6	57.5	-	-	-

Country	Poland	Portugal	Romania	Slovakia	Slovenia	Spain	Sweden	UK
NO WATER H. EQUIPMENT	**20.0**	**19.8**	**58.6**	**8.2**	**7.6**	**3.5**	**-**	**0.2**
CONNECTED TO CENTRAL H	**0.0**	**1.0**	**1.1**	**8.3**	**50.9**	**22.0**	**100.0**	**70.9**
-Fuel oil	-	0.0	0.1	-	28.3	7.8	11.1	2.9
-Natural gas	-	-	0.3	5.1	1.9	11.3	0.4	63.2
-LPG	-	0.2	0.1	-	0.6	2.3	-	0.7
-Electricity	-	-	-	-	0.1	0.0	21.0	-
-Solid fuels	-	-	-	0.7	-	0.5	-	3.0
-Wood	-	0.8	0.6	1.3	15.6	-	2.0	-
-Other	-	-	0.0	1.2	4.4	0.0	25.0	-
District heating	-	-	-	-	-	-	41.0	1.2
INDEPENDENT	**80.0**	**79.2**	**40.8**	**94.4**	**59.7**	**74.9**	**-**	**28.9**
-Natural gas	30.0	6.2	0.9	14.3	1.0	7.0	-	6.6
-Electricity	15.0	13.7	0.3	30.0	47.3	13.3	-	19.9
-Fuel oil	-	-	0.1	-	-	-	-	-
-LPG	-	55.5	0.1	0.1	0.3	53.5	-	0.1
-Kerosene	-	-	-	-	-	-	-	-
-Solid fuels	12.0	-	-	1.1	-	-	-	-
-Wood	3.0	-	2.3	4.0	2.8	-	-	-
-Other	-	3.8	0.2	2.3	0.0	1.1	-	2.1
-Heat	20.0	-	36.9	42.6	8.3	-	-	-

Source: Eurostat (1999), Energy consumption in households, p. 26 and 126.

Note:
For Central and Eastern Europe "independent" includes dwellings which usually use central heating boilers but have independent means of providing heat in case of failure of main supply.

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