Session 2.

A Sustainable Baltic Region

ENERGY

From fossil fuels to sustainable energy resources

Editor
Jürgen Salay
Stockholm Environment Institute and Lund University

A Sustainable Baltic Region

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Energy

From fossil fuels to sustainable energy resources

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PREFACE

The subject of this book is the energy system in the Baltic region, its environmental effects and possible ways to make it more sustainable.

The book consists of seven chapters. The first chapter provides some basic facts and definitions related to energy conversion and different energy carriers. It describes how energy is utilized in industrialized societies and how it can be used more efficiently. The second chapter discusses energy in a global context. It reviews the energy sources available in the world and their implications for development, environment and security.

In chapter 3, the focus is on energy use in the Baltic region. The chapter presents an overview of the region's energy sources and energy use and discusses how changing economic and political conditions are influencing its energy production and trade. The topic of the fourth chapter is the environmental effects of energy use in the Baltic region. The environmental impact of different energy sources are described with respect to extraction, transportation, conversion and end-use.

Chapters 5 and 6 provide case studies of how renewable energy sources and energy efficiency can be applied to reduce the environmental impact of energy use in the Baltic region and at the same time have economic and social benefits, in particular on the local level. Chapter 5 presents case studies of biomass use in Sweden, conversion of heating boilers from fossil fuels to biofuels and energy savings in residential apartment buildings in the eastern Baltic region. Chapter 6 contains a review of wind power in Denmark and separate sections on hydropower and solar energy.

Chapter 7 concludes the booklet by taking a look at the future. It reviews the main arguments for a shift towards a sustainable energy system in the Baltic region. It discusses the potentials for renewable energy sources and improved energy efficiency, identifies barriers that obstruct their implementation and suggests possible ways to overcome these barriers.

The editor and the Baltic University Programme gratefully acknowledge the support of the Stockholm Environment Institute in producing this book and the assistance of the Swedish National Board for Industrial and Technical Development (NUTEK), which kindly provided material for the case study in Chapter 5 on boiler conversions in the Baltic states.

Lund, December 1996

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Lund University and
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Contents

All energy on Earth comes from the Sun. Living nature consumes only a tiny part of it for all life processes, photosynthesis, some 40 terawatts out of the 200,000 that the sun provides. Almost all of the sunlight warms the Earth's atmosphere (50%), lightens the planet (30%) and moves the material currents of the globe (20%). The human use of energy is a continuously growing spiral. In 1990 it was about 12 terawatts, 30% of the total amount captured in photosynthesis.

1.

ENERGY USE – FOR WHAT?

by Anders Mårtensson

1.1 Energy - the Basis of Life and Society

Life on earth depends on energy. Energy continually radiated from the sun is captured by plants in the photosynthesis process. Animals make indirect use of this energy through grazing and by eating other animals. Solar energy is also the driving force of the winds and the waves. Solar warming of the oceans and seas elevates water through evaporation thus creating the water cycle.

Human life is maintained by solar energy, captured in food. Early in human history we learned to utilize solar energy by burning biological material such as wood and dung. These important energy sources still supply energy for heating and cooking for millions of people.

Today's energy systems constitute vital parts of the infrastructure in society, particularly in industrialized countries. Energy services like room heating, lighting, cooling and transportation of goods and people are indispensable parts of everyday life. Industrial production of goods includes a number of energy services like melting, crushing, forming and heating. Most energy services are provided by utilizing non-renewable energy sources such as fossil fuels and uranium. Tracing a certain product through its life-cycle reveals the complex system of energy services that are involved. Much of the food that we consume, for example, has energy use linked to its production (including use of fertilizers, machines, etc.), transportation, processing and packaging which widely exceeds the energy content that we can utilize when we eat the food.

Detailed data are needed if we want to understand how and for what purposes energy is used. Generally, energy-use statistics are divided into a few economic sectors of society: industry, transportation and other, which includes residential, commercial (that is, offices, shops, banks, hospitals, etc.), and agriculture. Residential and commercial can together be categorized as energy for buildings. This categorization is of course very crude and we need a more detailed description of the energy services involved to see what energy is actually used for.

1.2 Energy Conversion and Energy Carriers

According to the first law of thermodynamics, energy cannot be created nor destroyed; it can only be converted from one form to another. Energy conversion takes place in all activities in the universe, be it plant respiration and growth or industrial production or, for that matter – star explosions.

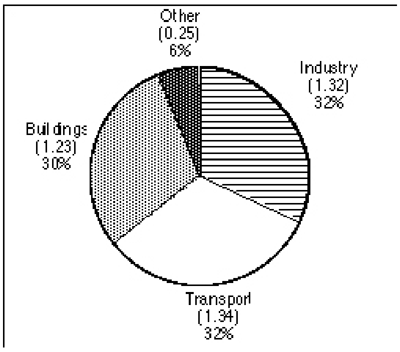


Figure 1.1 Distribution of energy use in OECD countries in 1993. Numbers in parentheses denote absolute energy use in TW (an abbreviation for TWyears/year). The distribution in developing countries is different. (Source: IEA/OECD, Energy Statistics and Balances 1992-1993, Paris 1995).

> Energy is used to provide services in society. Current energy systems are associated with a number of problems such as resource depletion and environmental pollution. A change of energy systems in a sustainable direction is inevitable if environmental and development goals as agreed by international bodies are to be fulfilled. Improvement of energy efficiency in all sectors of society is one important part of such a change. A host of technical and organizational opportunities are available which, if used, would mean that energy services for basic needs and more could be provided with much less energy than today.

Energy exists in several forms. An object in motion, for example a car, is associated with a kinetic energy: its magnitude depends on the speed and mass of the object. Thermal energy or heat is another common form of energy, characterized by the temperature of the heat-carrying medium. Energy can be stored. Food, wood, and oil are examples of matter which store energy that can be converted to other forms; for example, heat. Water in hydropower reservoirs represents another form of stored energy. Some of these stored energy forms are called energy sources.

Energy services are provided by the conversion of some energy form to another. Generally, several conversions are involved to provide the desired final energy service. Several energy carriers can be used such as electricity and

Table 1.1 Common energy conversions in society and the technologies frequently used for these conversions. Output energy form refers to the principal, desired energy output.

Input energy form	*Output energy form*	*Conversion technology*
Fuel (oil, coal, wood ...)	Heat (in water, air, food, steam, metal ...)	Combustion
Heat (in steam or gases)	Mechanical work (e.g. piston movement, rotation)	Steam turbine, gas turbine, explosion engine
Mechanical work (e.g. rotation)	Electricity	Generator
Streaming water	Mechanical work as rotation	Hydraulic turbine
Wind energy	Mechanical work	Airfoil rotor
Electricity	Heat	Resistance heater
Low temperature heat and mechanical work	High temperature heat	Heat pump
Fuel (hydrogen)	Electricity	Fuel cell

fuels. The distinction between energy carriers and energy sources is not always clear. However, an energy source is usually defined as a primary energy carrier as it is found in nature.

Energy systems consist of the extraction of energy sources, transportation of energy carriers, conversion (for example in a power plant), distribution and the final conversion that provides the desired energy service such as lighting or cooling. Further, the organizational framework needed to operate these complex structures can be seen as part of the energy systems. Hence, oil companies, power suppliers, transportation companies and the governmental authorities involved in energy system operations are all parts of energy systems.

As an example of the energy conversions that take place in an energy system we can consider the energy service 'food cooling' provided in a refrigerator. The chain of energy conversions may start from a coal mine. Coal is mined and transported to a power station where it is burned to produce steam. The heat energy in steam is converted to mechanical work in a turbine which drives a generator converting the mechanical work to electricity. The electricity is transported to the refrigerator (through several transformations) and is again converted to mechanical work driving a compressor. Through the compression of a heat-transfer medium, heat can be transported from the inner part of the refrigerator to cool the food.

Energy losses occur in each of these conversions. Only a small percentage of the energy contents of the source is utilized to provide the energy service. The rest is dissipated as heat, and it is generally not possible to make use of. Energy conversion processes are frequently characterized by their energy efficiency, usually defined as the useful energy output divided by the energy input. For example, an electric motor typically delivers 90 per cent of the input electricity as mechanical work (the useful energy). Its efficiency is thus 90 per cent (or 0.9). The rest of the input energy is converted to heat which in this case is considered as not useful. Figure 1.2 illustrates the conversion losses in an energy system providing the energy service "lighting".

In energy conversions the first law of thermodynamics is obeyed, namely, energy is not destroyed. However, some energy is converted to a form which is less useful. This is expressed as energy dissipation. This means that in each conversion the output energy is degraded in its quality compared to the input energy. This is described by the second law of thermodynamics. It tells us that all real world processes (that is, conversion of energy) are associated with energy dissipation.

Energy of a lower quality, for example low temperature heat, cannot be converted to the same amount of higher-quality energy without any other energy input. This is what we find in our daily experience. We know that, for example, a hot piece of metal put into a bucket of cold water delivers its energy to the water. The final temperatures of both the water and the piece of metal are higher than the original water temperature but lower than that of the metal. We cannot think of an example where the opposite would take place, namely, where the water would spontaneously

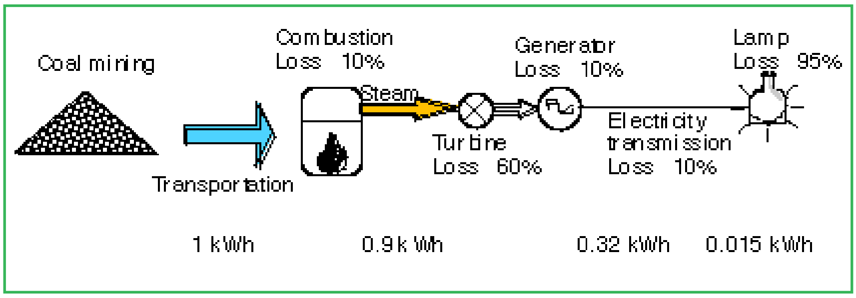


Figure 1.2 Energy system providing the energy service "lighting". Energy losses, usually in the form of low temperature heat, are indicated. Also shown are remaining energy quantities after conversion, starting with 1 kWh of coal.

deliver its heat energy to the piece of metal so that the water would be cool and the metal hot.

To express both the energetic value and the energy quality one can use the exergy value. This quantity is defined as the amount of mechanical work that can be extracted from a certain amount of energy, mechanical work being defined as the highest-quality energy form. Electricity has the same quality as mechanical work. For heat, the exergy value depends on the temperature of the heat-carrying medium compared to its surrounding environment.

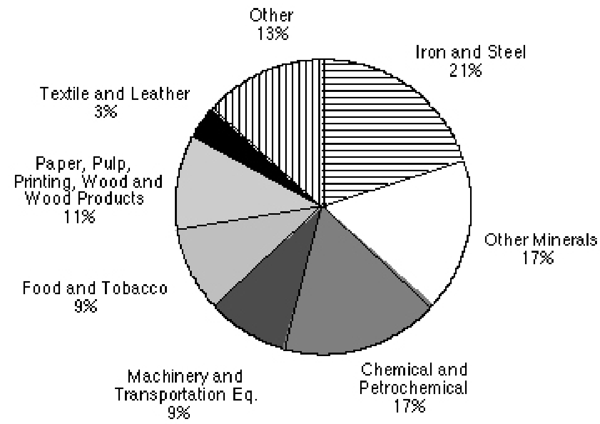


Figure 1.3 Energy use in industrial sectors of the European OECD countries in 1993. (Source: IEA/OECD, Energy Statistics and Balances 1992-1993, Paris 1995).

1.3 Energy Efficiency Improvements

There are thus two ways to use available energy more efficiently: to decrease energy losses and to decrease quality degradation in energy conversions. The latter implies, for example, that high-quality energy forms such as electricity should not be used where low-quality energy is sufficient as, for example, in heating a room. This example illustrates the usefulness of the exergy concept. If the efficiency of a resistance heater is calculated in energy terms only, it would be 100 per cent as all electricity is converted to heat. However, this low temperature heat is far from as useful as the electricity. It cannot easily be used for high-quality energy services such as mechanical work. By using the exergy concept, we can describe this quality degradation. We then find that the efficiency in exergy terms is less than 10 per cent. Taking into account the losses in electricity production, the total efficiency is much lower.

Different conversion technologies and practices can show very different results in terms of energy losses. As an example, let us consider the conversion of fuels to electricity. A common practice today is to combust the fuel in a boiler which provides steam used to drive a turbo-generator which in turn provides the electricity. The steam delivers part of its energy to the turbine; it is then cooled so it condenses to water which is fed back to the boiler. Most of the original energy is lost in this condensing process. This type of plant is called a condensing plant and its energy efficiency is typically 35-40 per cent from fuel input to electricity output. If, however, the energy remaining in the steam after the turbine is used to heat buildings or in industrial processes, the energy efficiency is greatly improved. Such combined heat and power plants are being increasingly utilized and their total energy efficiency can be as high as 80-85 per cent.

1.4 The Problems of Today's Energy Use

Energy conversions in society are not only associated with losses in the form of non-useful energy but also with the release of substances which can be harmful to the environment. Fuels, such as oil and coal, are by far the most common energy sources today. When combusting fuels, pollutants are emitted to the atmosphere: nitrogen oxides, sulphur oxides, hydrocarbons and particles (for example soot). Such emittants cause an environmental impact such as the acidification of land and waters and the eutrophication of waters such as the Baltic Sea. Global environmental impact includes the reinforcement of the greenhouse effect by increased atmospheric content of, for example, carbon dioxide.

Furthermore, the main energy sources in today's energy systems are non-renewable, that is, they are not renewed at a rate comparable with their extraction rate. This is a clear indication that current energy systems are not sustainable.

At the 1992 Rio de Janeiro United Nations Conference on Environment and Development, energy systems and sustainability were among the main themes. In Agenda 21, one of the documents from this conference, a programme for action in the direction of sustainable development was formulated. The governments of most countries have agreed to work along these lines. In Sweden, for example, municipalities have set up programmes to decrease current environmental impact. Extensive work has been initiated to improve practices for construction, waste handling and other activities in the municipalities. With regard to the future development of energy systems Agenda 21 states:

"The need to control atmospheric emissions of greenhouse and other gases and substances will increasingly need to be based on efficiency in energy production, transmission, distribution and consumption, and on growing reliance on environmentally sound energy systems, particularly new and renewable sources of energy." (Chapter 9)

The principles of Agenda 21 have a profound impact on energy systems. The necessary improvement of energy efficiency is a major challenge for the future. However, the potential of such an improvement is large as we will see in the following sections. It is particularly useful to apply an energy service perspective in the analyses of efficiency-enhancement opportunities. This means that we should start by asking what energy services are needed and then find out the most efficient way to provide these energy services.

This end-use perspective should be accompanied by a systems view, that is, we should be careful to analyze not only the energy service itself but also the circumstances and the surroundings in which this energy service will be provided. As we shall see, this approach will show that energy services can be provided with much less energy use than today.

Energy units

The standard SI (Système International) unit for energy is the Joule (J) which is equal to Ws (Wattsecond). A common unit, especially for electricity, is Wh (Watthour) or kWh (kilowatthour, that is, 1000 Wh). 1 Wh equals 3600 Ws.

The unit TWyears/year, often abbreviated TW, is commonly used for large annual energy use data.

Prefixes are used to denote orders of magnitude:

k (kilo)	=	1,000 (10^3)
M (mega)	=	1,000,000 (10^6)
G (giga)	=	1,000 M (10^9)
T (tera)	=	1,000 G (10^{12})
P (peta)	=	1,000 T (10^{15})
E (exa)	=	1,000 P (10^{18})

A number of other energy units occur in the literature:

1 toe (tonne oil equivalent)	≈	41.8 GJ
1 tce (tonne coal equivalent)	≈	0.7 toe ≈ 30 GJ
1 Btu (British thermal unit)	≈	1.055 kJ
1 Quad	=	1015 Btu
1 barrel of oil	≈	6.12 GJ

1.5 Energy for Industry

Energy use in industry is dependent on the type of product being produced, on the technologies being used during production and on how the production is operated. Naturally, the mix of production varies largely between countries and depends on, for example, the resources available, industrial tradition and the degree of technological development. To compare energy use in different countries for the same type of product, an indicator for energy intensity is usually specified. This can be defined as energy use per physical unit of the product, for example GJ per tonne of steel, or it can be defined as energy use per unit of economic value, for example GJ per dollar of value added. Such indicators measure the efficiency of production in terms of energy use. Efficiency is here related to the services provided rather than to a particular conversion technology. Naturally, efficient energy conversion technologies will make the total production energy-efficient.

The trend towards increasing energy efficiency has been around for a long time in industry. Energy intensity in physical output declined by about 40 per cent between 1970 and 1990 in OECD countries. This trend is due to structural changes, namely, a shift of economic activity to less energy-intensive sectors of the economy, and to the introduction of more energy efficient technologies. There is still potential for further improvement of efficiency; the driving forces are environmental regulations and energy costs. Generally, there are four available ways to increase efficiency:

- housekeeping, that is, preventing energy waste by improved insulation, etc.;
- refining existing processes;
- new processes;
- product changes, for example, lower weight, increased recycling.

When a detailed assessment of energy use in industry is made we find a number of energy services that are common to many industrial branches. Examples are heating, melting, crushing, evaporation, drying and freezing. Development of more efficient technologies for these services can be utilized in many sectors.

Process heating is the largest energy end-use in many industries. Steam is often used as an energy carrier for general heating and drying purposes because of its excellent heat-carrying capacity and controllability. This is a good example of an end-use where relatively straightforward cost minimization can be made. By, for example, improving the insulation of pipes, energy losses can be decreased and costs for energy purchases can be lowered. Such investments are often very cost-effective.

Process heat is often provided by combustion of fuels, such as coal or oil. It would be possible in many cases to use renewable sources of energy like wood-chips for this purpose. Furthermore, the efficiency of fuel utilisation is greatly improved if both process heat and electricity is produced simultaneously: steam produced in a boiler is used to drive a turbine and then used for process heating. This cogeneration technique is used in some industries but there is still potential for expansion.

The changes in the iron and steel industry, where energy intensity decreased by about 25 per cent in Sweden between 1978 and 1983, illustrate how efficiency in industry improves. Contributions come from good housekeeping, from refined processes and replacement of old equipment with new, more efficient technology and from extensive use of computerized process control. However, even more radical changes result from new concepts for iron- and steel-making. Several steps, like ingot casting and rolling, in the traditional process-chain have been by-passed through the introduction of continuous casting which can reduce the total energy use for steel-making by 10-20 per cent. Increased recycling also reduces overall energy demand since the energy-intensive steps of ore extraction and conversion are by-passed. Using 50 per cent scrap decreases the energy use for finished steel products by about 30 per cent as compared with completely ore-based production.

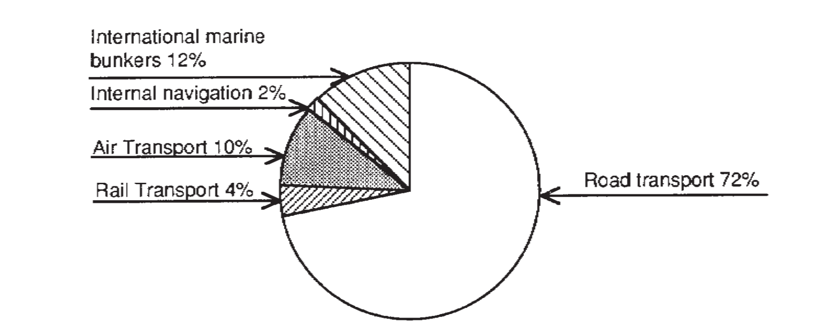


Figure 1.4 Energy use for transport in the EU countries 1992 by mode. Electricity use for rail transport is transfered to primary energy using a conversion factor of 0.39. (Source: Johansson, B. (1995) Energy Efficiency in Transportation in Blok, K., W.C. Turkenburg, W. Eichhammer, U. Farinelli and T.B. Johansson (eds.) Overview of Energy RD&D Options for a Sustainable Future. European Commission, Brussels, Belgium).

1.6 Energy for Transportation

The transportation sector now has the fastest growing energy use of all sectors globally. In the countries of the European Union, energy use for transportation doubled between 1979 and 1992. This is mainly due to the rapid expansion of road traffic; particularly the increased use of passenger cars (see Figure 1.4).

Fossil energy sources are predominant in transportation. Oil refined to petrol or diesel oil are the main energy carriers. In cars, trucks, and buses the main technology for extracting propulsion energy is the internal combustion engine. These motors are not very efficient; most of the energy in the fuel is lost as heat and only about 10-20 per cent is utilized for propulsion.

There is potential to improve the efficiency of internal combustion engines and reduce the fuel consumption of road vehicles by 15-40 per cent. Another 10-20 per cent can be achieved by transmission improvements. Reductions in aerodynamic drag, rolling-resistance and vehicle weight can reduce energy use by some 40-50 per cent.

Sustainable development necessitates a switch to renewable energy sources for transportation. This can be accomplished in several ways: using heat engines fuelled by energy carriers from renewable sources or using electric motors where electricity is produced from renewable energy sources. Electric vehicles have a higher end-use efficiency. They can be powered either by batteries or by on-board fuel-cells, fuelled by hydrogen or, through a reformer, by methanol. Methanol and ethanol are typical fuels that can be derived from renewable energy sources. Hydrogen as an energy carrier would provide zero emissions when used in a fuel-cell or in a heat engine.

Radical changes in transportation energy use can be accomplished through transportation system modifications as well as changes in our travel habits. A switch from road and air to rail transport would mean a more energy-efficient transportation system. The location of residential, industrial and service areas in a way that minimizes transportation distances would also contribute to a decrease in energy use.

1.7 Energy for Buildings

In the countries in the Baltic region the amount of energy used to provide a comfortable indoor climate is considerable. Furthermore, much energy is used to run equipment in buildings. In residential buildings, washing, cleaning dishes, food-storage and cooking are important energy services. In office buildings, equipment such as computers and copying-machines account for a large proportion of the energy demand. In such buildings, the heat from all the equipment tends to create

Some abbreviations

EU	The European Union. Fifteen countries belonged to this organizationin 1996.
IEA	International Energy Agency.
IPCC	Intergovernmental Panel for Climate Change.
OECD	Organisation for Economic Co-operation and Development. 27 countries belonged to this organisation in 1996.
WEC	World Energy Council

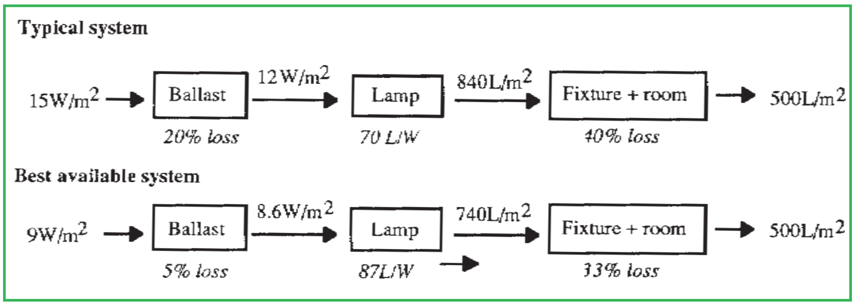


Figure 1.5 Lighting energy efficiency. Two fluorescent systems that provide the same amount of light, 500 lumen/m² (or lux); one system typical of today and one system with the best available technologies of today. Energy-efficient technologies include efficient fluorescent light, imaging-reflector luminaires, and high-frequency electronic ballasts. Numbers show installed capacity. L/W means lumen per Watt and is a common unit for lamp efficacy, i.e. a way of expressing the efficiency of a lamp in terms of light output per power input unit. Resulting energy use can be reduced by using daylight and lighting control systems. (Source: Christiansson, L. (1996) Electricity Demand Options – in a Time Dynamic Framework. Licentiate Thesis, Department of Environmental and Energy Systems Studies, Lund University.)

a need for cooling during a large part of the year. Demands for lighting and ventilation are common to all types of building.

In Sweden and Norway a large proportion of the energy required for room-heating is supplied by electricity through resistance-heating. This can be seen as wasteful because high-quality energy is used where low-quality energy would be sufficient. The use of electricity for this purpose is less common in other countries. Efficiency can be substantially improved if resistance-heating is substituted by heat pumps in which a low-temperature outdoor heat source is converted to a higher temperature useful for room-heating.

Combustion of fuels such as oil, coal, gas or wood in individual boilers is common in residential buildings. Another way of using fuels for heating is to distribute hot water or steam from a central plant to many buildings in a city. Such district-heating systems are common in, for example, Russia, Poland, Denmark, Sweden and the Baltic States. The central plant can be fuelled by coal, oil, or biomass (for example woodchips) and can be combined with the generation of electricity which makes the fuel use very efficient. This cogeneration technique is similar to that used in industry.

New technologies are being developed to increase further the efficiency of biomass-fuelled cogeneration plants. The principle is to gasify biomass and use the gas in a gas-turbine and further use its exhaust heat to supply steam which drives a steam-turbine. In such a combined-cycle plant, the efficiency of electricity generation is significantly higher than in a conventional steam plant.

One way of decreasing the energy use for room-heating is to improve the building shell by the application of more insulation material in the walls, floor, and roof as well as installing new energy-efficient windows.

Lighting accounts for a large proportion of the energy use in a building. New types of lamps, for example compact fluorescent lamps (CFLs), are about five times more efficient than the commonly used incandescent lamps. Even larger improvements in lighting efficiency can be achieved if a system approach is applied, that is, taking into account not only the lamp but also the lighting fixtures, the operational parameters, the room layout, etc. (see Figure 1.5) Due to more efficient lighting, the demand for the cooling of office buildings can be decreased thus creating combined effects of energy use reductions.

The efficiency of household equipment such as freezers and refrigerators has increased manifold during recent decades. The average installed refrigerator uses about 300–400 kWh per year whereas the best new one on the market uses only about 100 kWh per year. Also the efficiency of office equipment such as computers and copiers is continually being improved. Higher efficiency reduces the energy needed for the equipment and for air-conditioning and ventilation.

1.8 Energy for Food Production

Although energy use in the agricultural sector is relatively low, the efficiency of food production is poor in terms of the energy content that is available in food compared with the energy input. Usually only energy used directly in farming is accounted as agricultural energy use, that is, energy used for buildings, farming equipment, etc. However, energy is also used to produce fertilizers, for transportation of food and fertilizers and for food processing and packaging.

Fossil energy sources are common for agricultural purposes. Their substitution by renewable energy sources would be possible; for example to run farming machinery and tractors. A transition towards less use of artificial fertilizers would also contribute to more sustainable agriculture.

Less use of energy for food production would also be possible through structural changes and changes in habits. The transportation of food over long distances accounts for a large proportion of the energy use. A larger proportion of locally produced food would mean less energy for cooling, transportation and packaging. Additional gains are possible in the food processing industry with the development of more efficient processes as mentioned in the industry section above. A radical improvement in the use of natural resources for food production would take place if we changed our consumption to less animal and more vegetarian food.

2.

The global context

by Lars J. Nilsson

2.1 Energy demand is constantly increasing

Energy is one of the main commodities that fuels the world economy. Before the industrial revolution, we relied on the growth of plants and animals for our energy needs. Plants were used for food and fuel, animals for food and mechanical energy. The contribution from hydroelectric power and wind was small but important in providing mechanical energy for mills, ships, etc.

In the 18th century, coal became increasingly important for fuelling industry, followed by oil and natural gas in the late 19th and the 20th centuries.

In the last 100 years, fuel consumption has grown by, on average, 3 per cent per year. In 1990, total global primary energy use was 10.2 TW of which coal, oil and gas contributed 30, 36, and 22 per cent, respectively. In the 1940s and 1950s, nuclear power, based on new theories in physics a few decades earlier, entered the scene. Nuclear power now accounts for 2.3 per cent of global primary energy supply and 17 per cent of global electricity production. Corresponding figures for hydro power are 2.4 per cent and 18 per cent, respectively.

Wood fuel and other biomass derived fuels still make important contributions to world energy needs, in particular in developing countries. Estimates range from 6 to 15 per cent of global primary energy supply.

Global energy use is forecast to continue to increase by at least 1 per cent per year. The growth rate is likely to be lower in industrialized countries and considerably higher in many developing countries where present consumption levels are low. The richest 25 per cent of the people in the world use about two-thirds of total global energy. The other 75 per cent of the population use only one-third of global energy.

The future development of energy demand in former centrally planned economies, where energy demand and economic output decreased after the economic reforms, is more uncertain.

Changes in final energy demand result from changes in the level of activities, such as transport, and from changes in energy intensity, such as energy demand per unit of transport. On the national level, activity may be expressed as gross domestic product (GDP), and energy intensity expressed as energy use per unit of GDP. Analyses of long-term historical trends show that the energy intensities of some industrialized countries have been decreasing for several decades. Following a phase of industrialization and increasing energy intensities, they eventually peak, and a phase of declining energy intensities follows.These trends are likely to continue.

The trends are explained by structural changes, that is, shifting economic activity to less energy-intensive sectors of the economy when countries develop into post-industrial economies, and by increasing efficiency in the conversion and end-use of energy. In developing countries, there is great potential for an increased level of energy services as indicated by, for example, the low penetration of household appliances and cars, and the low per capita consumption of paper,

Many environmental problems result from the extraction, transportation, conversion and end-use of energy. They range from indoor air-quality problems associated with cooking in developing countries, to changes in the world's climate over decades and centuries.

The provision of energy services is also intimately linked to issues such as economic development and global security. If world energy use continues to grow, this would considerably aggravate these concerns. Thus, energy efficiency improvements are a key component in any strategy for a more sustainable energy future.

A shift away from dependence on fossil fuels to renewable sources of energy is the other key component. The recoverable renewable resource potential is great. Wind power and biomass are already cost-competitive with conventional options in many applications and various technologies for direct use of solar radiation are developing rapidly. The environmental impacts of renewable energy technologies are likely to be considerably less than, and certainly different from, the impacts of fossil fuels. A better understanding of the environmental impacts of renewable energy technologies will develop as experience from using renewable sources of energy grows. The development of renewable energy must also be sensitive to local and regional economic, social and cultural conditions.

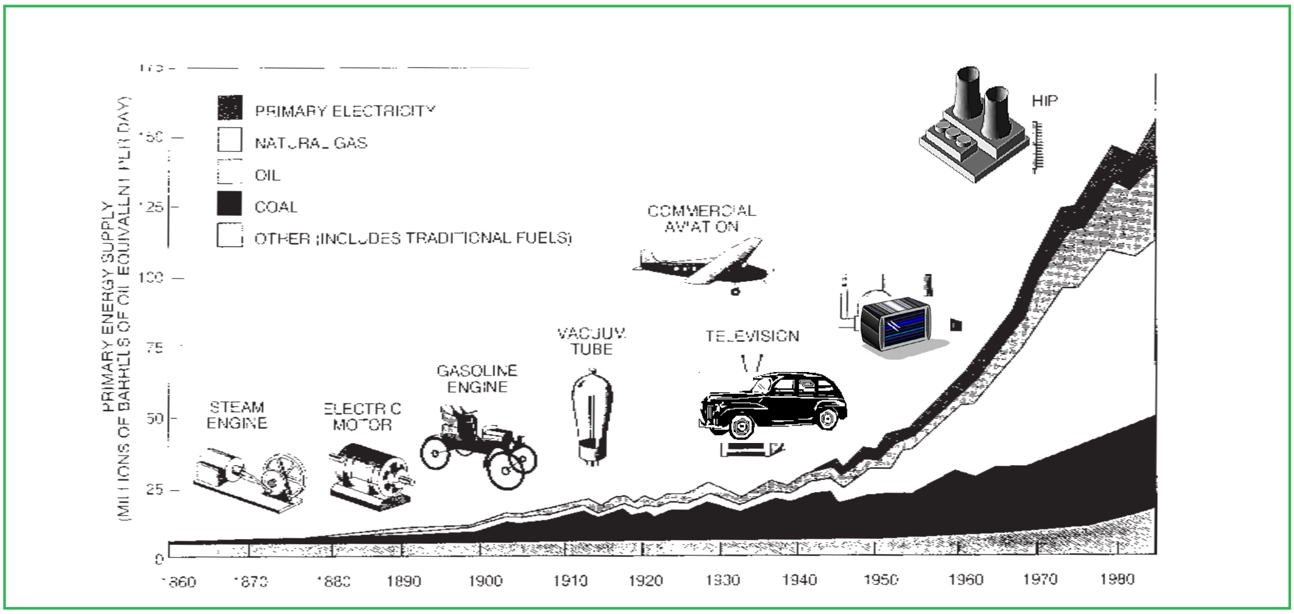


Figure 2.1 Rate of primary energy use in the world. Primary electricity includes nuclear power and hydro power. Source: Scientific American, Vol. 263, No. 3, p. 56.

steel, cement, plastics, etc. The expected increased consumption of energy services will result in increased energy use but the rate of this increase will depend on the energy efficiency by which these services are provided.

2.2 The change in the 1970s

It is widely recognized that, for many reasons, the present trends of increasing energy use and heavy reliance on fossil fuels cannot continue. The early 1970s marked the end of the era of cheap and convenient sources of energy. Between 1890 and 1970 the real price of fuels and electricity remained constant or declined. In that era, environmental and other external costs associated with fuel extraction and use were regarded more or less as local problems. This changed when the first oil-price shocks came in 1973–74, a time when oil constituted nearly half of the world's energy use. At this time, it was also increasingly appreciated that resources were finite and that no physically limited system could sustain exponential growth in the long run. In the late 1960s and early 1970s there was also a growing recognition of the scale of the environmental effects and other external costs associated with energy use. For example, acidification could no longer be considered simply a local problem resulting only in corrosion and health effects. Sulphur emissions, it was discovered, were transported long distances and resulted in long-term, large-scale acidification of soil and water.

The development, environment and security challenges that are linked to the energy sector would grow considerably if the present trends in energy demand and the energy-supply mix persist. It appears that these challenges cannot be met with minor adjustments of conventional energy systems, but will require a major shift away from the present situation.

A better life and an improved standard of living are fundamental aspirations of the more than two-thirds of the global population living in developing countries. A better life means satisfying basic human needs, including access to jobs, food, health services, education, housing, running water, sewage treatment, etc. Energy is an important element in providing for these needs.

Two major concerns related to socio-economic development are the burden of foreign exchange for oil imports and the availability of capital for energy-sector investments in developing countries. Economic growth and improving the quality of life in developing countries will result in increased demand for energy services. The resulting rate of increase in energy demand will depend on the composition of energy services demanded and on the efficiency with which they are produced. With continued dependence on oil, and anticipated oil price increases, foreign exchange requirements for imports will eventually increase again, as they did in the 1970s and early 1980s. The capital investment needs of the energy sector in developing countries may aggravate the situation if financial resources are withdrawn from other pressing development needs.

2.3 The global environmental threats

The chain from extraction, transport, conversion and distribution to the end-use of energy results in a number of environmental problems. These include, for example, urban air pollution, indoor air-quality problems from cooking, acid deposition from sulphur and nitrogen compounds, climate change from increased atmospheric concentrations of carbon dioxide and methane, emissions of heavy metals, electromagnetic fields and oil-spills. In addition, the problems often entail complex and non-linear interactions between various pollutants and between the pollutants and the environment. It is becoming clear that major changes are needed if energy systems are to develop in ways that are compatible with environmental goals.

Some environmental and health problems, such as oil-spills and poor indoor air quality, are largely the result of poor practices and/or management and could therefore, technically speaking, be handled relatively easily. Other problems, such as urban air pollution, acid deposition, and climate change appear to be much more difficult to address. For example, it appears that end-of-pipe or in-plant measures are not sufficient to reduce emissions from petroleum-fuelled cars or from fossil-fuelled power plants to acceptable urban air-quality levels, or critical-load levels (that is, levels below which significant harmful effects on specified sensitive elements of the environment do not occur according to present knowledge). This indicates that measures at the level of whole energy systems are required. Although the focus here will be on some of the sources and effects of transboundary air pollution, it must be stressed that concerted action is needed also to address the wide range of other problems.

Acid rain was high on the environmental agenda in the 1970s and 1980s when international negotiations led to the United Nations Economic Commission for Europe (UNECE) Convention on Long-range Trans-boundary Air-pollution which came into force in 1983. The sulphur protocol to this convention, under which the signatories committed themselves to reduce SO_2 emissions, was agreed at Geneva in 1984. The second sulphur protocol, which goes further in emissions reductions, was agreed in 1994.

Acidification in combination with other air-pollutants has caused serious forest damage in large parts of Europe and some forest die-back, notably in Poland and the Czech Republic. Large parts of northern Europe are also hard hit by acidification of surface waters.

Forest damage is also found in some areas in the eastern part of Canada and the United States and locally in China, Brazil and Venezuela. In Asia and South America, the acidification situation is expected to worsen considerably with current and projected rates of increase in coal and oil use and resulting SO_2 emissions. Emissions of NO_x are likely to aggravate the problem.

2.4 Global warming

An environmental issue that has received increased attention in recent years is the risk of climatic changes as a result of emissions of carbon dioxide and other greenhouse gases, more than half of which come from the energy sector and the rest from other anthropogenic activities. Measurements show that atmospheric concentrations of greenhouse gases are increasing. For example, atmospheric carbon dioxide concentrations have increased from the pre-industrial level of about 270 ppm to the present level of about 360 ppm (parts per million).

There is scientific consensus that a small increase, approximately 0.5°C, in the global average temperature has taken place over the last century. There is virtually unanimous agreement that increased concentrations of greenhouse gases in the atmosphere will result in global warming. The points of debate are what the rate of warming will be, how important different climate feedbacks from clouds, oceans and biota are, and how warming will lead to changes in other climate parameters, such as precipitation and ocean circulation.

In 1988, the World Meteorological Organization and the United Nations Environment Programme set up the Intergovernmental Panel on Climate Change (IPCC) to assess closely the state of knowledge on climate change. In its reports, IPCC predicts that atmospheric concentrations equivalent to a doubling of carbon dioxide will lead to a long-term change in the Earth 's surface air-temperature of 1.5 to 4.5°C. The impacts of IPCC's business-as-usual scenario, with a doubling of the equivalent carbon dioxide concentration by the middle of the next century, include a sea-level rise of three to ten centimetres per decade, changing vegetation zones and a northward retreat of the permafrost zones.

The IPCC reports were input for the negotiations towards the UN Framework Convention on Climate Change (FCCC) which was signed at the UN Conference on Environment and Development (UNCED) in 1992. The aim of this agreement is to stabilize atmospheric concentrations of greenhouse gases at levels that will prevent human activities from interfering dangerously with the global climate.

According to the IPCC assessment, stabilizing atmospheric carbon dioxide concentrations at

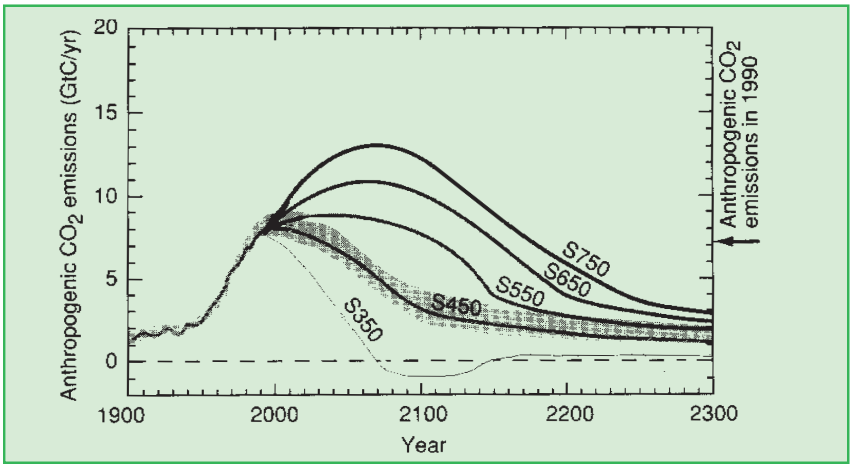


Figure 2.2 Stabilization scenarios for atmospheric carbon dioxide. The curves take off from today's emissions of 7 million kilotonnes per year and assume decreasing values after various times up to 2070. The vertical axis show the emissions in million kilotonnes per year for each future year that will lead to stabilization concentrations from 350 to 750 ppmv as indicated on each of the four curves. The range of results from different models is indicated on the 450 ppmv profile. (The negative emissions for stabilization at 350 ppmv are caused by an artefact of the method).

current levels requires that net emissions be reduced by 60 to 80 per cent, (See Figure 2.2). This has severe implications for the energy sector since 80 to 90 per cent of primary energy demand is now met by fossil fuels. The parties to the FCCC could not agree on specific targets for emissions reductions but a number of activities aimed at protecting the atmosphere are specified in the action plan, Agenda 21, from the UNCED meeting. The first session of the parties to the FCCC was held in Berlin in 1995 and it is expected that the parties, perhaps in 1997, will be asked to adopt a protocol – a separate legal agreement under the FCCC – defining emissions constraints for industrialized countries.

2.5 Energy and world security

One major security issue associated with the energy sector is world oil dependence. Oil resources located in limited regions of the world create strategic economic interests in oil leading to political crises, economic vulnerability and military conflicts. About two-thirds of the proven oil reserves are concentrated in the Middle East. Continued reliance on oil as a fuel will inevitably lead to increased world dependence on Middle East oil and probably to recurring crises.

The other major security issue related to energy is the risk associated with nuclear power. Nuclear power is one of the major potential sources of energy that could replace fossil fuels, thereby reducing emissions of greenhouse gases and other pollutants.

Although reactor safety and radioactive waste management are important concerns, perhaps the greatest risk is the spread of nuclear weapons. It is inherent in nuclear technology that materials used and produced in civilian nuclear reactors can be used for making nuclear explosives. In addition, limited uranium supplies would, at high levels of nuclear power, require breeder reactors and plutonium recycling as a means of improving the utilization of uranium (known uranium resources would last about 80–90 years at current rates of consumption and without plutonium recycling). With breeder reactors, where the isotope uranium–238 is converted to fissile plutonium, known resources would last 50–60 times longer. However, it is difficult to imagine human institutions capable of safeguarding the large quantities of plutonium that would be produced, and their flows, against diversions.

2.6 Primary energy sources – fossils and nuclear

There will always be a demand for primary energy, the amount of which should be determined by economic, environmental and other trade-offs between end-use and conversion efficiency improvements and supply alternatives for any given level of energy services. To meet the need for primary energy there are basically three classes of energy sources:

- fossil fuels
- nuclear power
- energy from the sun.

Fossil fuels

The proven reserves of coal, oil, and gas will last about 220, 40 and 60 years, respectively, at current rates of production. Proven reserves are generally taken to be what can be recovered with reasonable certainty from known reservoirs under existing economic conditions.

The estimated additional undiscovered coal resources are about ten times greater than the proven reserves. The estimated additional resources of oil are only about half of the proven reserves and those of gas are about equal to the proven reserves. Fossil fuels can continue to make an important contribution to world energy supply by using cleaner technology. In coal- and oil-fired power plants, advanced scrubber technology can reduce sulphur emissions in flue-gases by over 90 per cent. Nitrogen oxides and heavy metals emissions can also be substantially reduced.

Even with such measures, however, the need remains to reduce the rate of increase in atmos-pheric carbon dioxide concentrations. Carbon dioxide emissions can be reduced from about 0.25 kg CO_2/kWh in power plants with conventional steam-turbine technology to 0.20 kg CO_2/kWh in power plants using integrated coal-gasification technology.

A gradual shift to natural gas, which has a lower carbon content per unit of energy than coal and oil, would reduce emissions further. Advanced generating technology with natural gas as the fuel can reduce emissions to about 0.10 kg CO_2/kWh, with additional benefits in lower emissions of sulphur, nitrogen oxides, etc.

Fossil fuels could also be part of a transition to an energy system based on renewables, for example, by using coal and natural gas to produce methanol and hydrogen –- energy carriers which could

Table 2.1 World solar-energy resource base and estimated recoverable resources in TW.

	Resource base	recoverable[a]
Solar radiation	90,000	1,000
Biomass	30	10
Wind	300–1,200	10
Hydro	10–30	1.5–2
Wave	1–10	0.5–1
Tidal	3	0.1

[a] The recoverable resource estimates depend on various assumptions and may be different from estimates given in other sources but they give a representative picture of the relative size of the various sources. Source: Jackson T. (1992) "Renewable energy: summary paper for the renewables series," Energy Policy, Vol. 20, No. 9.

later be produced from a variety of renewable sources.

Nuclear power

Limited uranium supplies make the transition to a breeder technology necessary for nuclear fission to make a long-term, large contribution to world energy supply. As noted above, the foremost problem with the current conventional, and with the breeder reactor, technology is perhaps the link to nuclear weapons applications.

In the longer term, *nuclear fusion* may develop into an important source of nuclear energy. Fusion energy systems are less likely than fission energy systems to contribute to the acquisition of nuclear weapons' capabilities by terrorist groups and would be easier to safeguard against clandestine use for fissile-material production by governments. However, these and other risks, such as radiological and chemical hazards, should not be underestimated. If the safety and environmental aspects of fusion energy are adequately considered in the development of fusion, it can become a source of energy with considerably fewer problems than, for example, coal or nuclear fission. However, it will be at least 40 to 50 years before fusion technology reaches the stage of commercialization.

2.7 Primary energy sources – the sun

The energy from the sun that reaches the Earth's surface is of the order of 100,000 TW. Incoming solar radiation is captured in biomass, or converted to wind, hydro, wave, and tidal power. Since the global commercial energy demand is about 10 TW, the resource base for renewable energy is enormous; see Table 2.1.

Several technologies for utilizing solar energy are already cost-competitive with conventional sources of energy. For example, wind turbines doubled from about 2,000 MW in 1990 to about 4,000 MW of installed capacity in 1994/95, most of which are in California, Denmark, the Netherlands, India and Germany. Ethanol from sugar-cane is used in Brazil as an automotive fuel in millions of automobiles.

It is useful to distinguish between dispatchable and intermittent sources of energy in the case of electricity production. In the absence of inexpensive storage options, electricity production must balance demand at all times. Hydroelectric plants are generally dispatchable since they often have dam-storage capacity so that the electricity output can be easily regulated. Biomass-fuelled power plants are dispatchable since the energy is stored in the biomass. Power plants that convert solar radiation or wind directly into electricity, however, cannot be dispatched since the flowing energy resource must be utilized when it is available. Solar radiation and wind are therefore called intermittent sources of energy.

2.8 Dispatchable energy sources – hydropower and biomass

Hydropower provided about 2,200 TWh, or 18 per cent, of the world's electrical energy in 1990. It is therefore the largest renewable source of electricity. It has been estimated that only about 15 per cent of the world's technically exploitable hydropower potential is now used. The largest remaining resources are found in Asia, South America and Africa. However, the applications are limited by scarcity of capital, environmental effects and often by the cost of long-distance transmission.

Increased attention should be given to the social and environmental impacts associated with the exploitation of additional hydro resources. The cost of producing hydroelectricity is very site-specific, but nearly all of it is capital costs since hydropower plants are relatively simple and inexpensive to operate. The external costs are also site-specific. Hydro dams affect flora and fauna and may also require population resettlement. They can have seismic and climatic effects and change water quality, affecting sedimentation and aquatic ecosystems. In many areas, the spread of diseases, such as malaria and schistosomiatosis is also an important concern. In general, small-scale and mini-hydro plants (up to a few MW) pose fewer problems than large-scale projects.

Biomass is also an important energy source, especially in developing countries. Here it is often used inefficiently, mainly for cooking and heating in rural areas, and in small industries. In industrialized countries, some wood fuel is used for domestic heating, but most of the biomass energy is derived from waste in industry or used as an integral part of industrial processes such as chemical pulping for paper production. The major potential sources of biomass for energy are residues from agricultural and forest industries and from dedicated energy plantations.

The energy from the sun is stored in different forms in different types of plants. Sugar- and starch-rich plants can be used for ethanol production as in the Brazilian fuel-alcohol programme. The energy input for production and conversion of the sugar-cane is only 10 to 15 per cent of the output in the form of ethanol and bagasse (the cane residue) surplus. For the conversion of corn or wheat, for example, the energy balance is much less favourable and may even be negative. The viability of producing vegetable oils is limited for the same reason. More promising uses of biomass for energy include cogeneration of heat and electricity, methanol production through gasification and ethanol production through a chemical process called hydrolysis. In these applications the feedstock would be woody biomass.

The main environmental impacts from energy plantations are associated with land-use requirements, use of fertilizers and recycling of ashes to maintain soil fertility, use of pesticides and herbicides and atmospheric emissions during conversion. In the case of deforested or otherwise degraded lands, biomass plantations can, if properly managed, improve these lands ecologically. Research and development is needed to ensure the realization and sustainability of high biomass yields under a wide range of growing conditions in addition to local economic, social and cultural conditions.

2.9 Intermittent energy sources – sun and wind

A large number of technologies and applications are available for direct and indirect (through thermodynamic cycles) uses of solar radiation. Passive heating and cooling of buildings has traditional roots in many countries. Solar collectors are used for water-heating in households. Solar radiation is also used, for example, for drying crops and desalination.

Solar-thermal electricity production is an almost commercial technology in areas with good clear-sky conditions. High temperatures to run steam turbines or other thermodynamic cycles for electricity generation are achieved through various types of concentrator: mirrors directing radiation to central receivers, parabolic dish collectors and parabolic troughs. The principal environmental effect is the surface-area requirements.

Photovoltaic (PV) technologies based on semiconductor materials such as silicon can convert solar radiation directly into electricity. PV systems can be flat-plate or with concentrators. The variety of technologies, materials used and present and projected cell efficiencies are too numerous to discuss here.

The cost of PV electricity is currently five to ten times higher than the cost of electricity from traditional sources. However, there are many niche markets where PV technology is already competitive, for example, in a variety of remote applications and in consumer electronics. PV sales have grown steadily by 20 to 25 per cent per year, to the 1993 level of about 60 MW per year. Being a highly innovative technology under rapid development, PV-system prices are expected to continue to decline.

The major environmental impact is, as for solar-thermal electricity, space requirements. Potential environmental hazards include the use of CFCs as cleaning agents in the production process and the toxicity of some of the basic elements, such as arsenic, indium and cadmium, that might be used in the cells.

In addition to solar radiation, wind power is the main alternative for large-scale intermittent power production. In areas with favourable wind conditions, wind turbines are the least expensive renewable energy source for electricity production, with the exception of some hydropower and biomass applications.

Electricity production costs are currently roughly equal to the cost of electricity generated in conventional power plants and costs are projected to continue to decrease through technical improvements. These include advanced air-foil designs, variable speed operation and taller towers.

The environmental problems associated with wind turbines have been extensively investigated. These include noise, bird strikes, electromagnetic interference, safety and the aesthetic considerations of visual impact. In most cases, environmental impacts have proved to be minor or negligible or avoidable through careful siting. The visual impact, which is a matter of personal evaluation, appears to be the most serious problem.

2.10 Institutions, finan-cing and integration

Present energy systems are based on centuries of technological development and institution-building around fossil fuels and, recently, nuclear power in some countries. Government spending on energy research, development and demonstration shows a heavy bias towards fossil and nuclear sources. The proportion that was allocated to renewable sources of energy was only about six per cent in 1990 on average in the OECD countries. This is clearly inadequate given the important role that renewables can play in the future. The existing structures also create considerable technical, institutional and economic barriers to the introduction of renewables in energy markets. For example, monopolistic electricity systems have developed around ever larger-scale steam turbines for the last 100 years, often based on access to cheap, state-subsidized capital.

The electricity production costs for renewables will generally not be significantly lower than for conventional options. In addition, many of the renewable sources of electricity are inherently small-scale and capital intensive. Their small scale and the distributed resource sometimes make renewable sources suitable for exploitation by local non-utility generators. In such cases, the evaluation of renewables is seldom based on the same economic criteria as conventional options since independent power producers do not have the same access to capital as large utilities.

However, the future of renewable sources of energy is not only determined by the financing arrangements and their cost per produced kWh. It will also depend on how they are valued by the energy markets. At present, there is a variety of regulatory mechanisms in place in some countries to enable independent power producers, in particular those with renewables-based production, to get fair prices and access to utility grids.

Subsidies to competing traditional sources of energy should be removed in order to increase the value of electricity from renewables. Taxes, regulation and other policy instruments should ensure that investment decisions are based on the full cost, including environmental and other external costs. In addition, government regulation of electric utilities should be carefully reviewed to ensure that renewable sources are not discriminated against.

3.

Energy use and politics in the Baltic Region

by Jürgen Salay

This chapter is an overview of energy sources and the characteristics of energy use in the Baltic region. It also briefly reviews the changing economic and political conditions in the region and discusses their implications for energy production and trade.

3.1 Energy sources

The countries in the Baltic region are well endowed with energy resources. All kinds of fossil fuels are found in the region. There are large coal deposits in Germany, Poland and Russia. Hard coal is extracted in southern Poland, in western Germany and in several parts of Russia. However, the German and Russian hard coal mines are located outside the Baltic region. Lignite (also called brown coal) is exploited in eastern Germany and in south-western Poland. Oil-shale, a fossil fuel similar to coal but with lower heating value, is mined in north-eastern Estonia and across the Estonian border in Russia. Coal and oil-shale are used directly for heating or for electricity production in power plants.

Oil and gas are exploited both on land and off-shore in the Baltic region. The fields are located on land in north-eastern Germany, south-eastern Poland and northern Lithuania. However, the extracted volumes are small and do not meet the domestic demand of these countries. Oil is also prospected off-shore along the coast of Poland, Latvia and Lithuania. The largest oil and gas fields are located outside the geographical scope of the Baltic region; Russia's vast oil and gas fields are in Siberia, Norway's oil and gas and Denmark's gas fields are in the North Sea. Oil is refined into petrol and other oil products which are used in transportation. Oil is also used for heating and, to a smaller extent, for electricity generation. Gas is primarily used for heating and cooking. Oil and gas products are also utilized for non-energy purposes such as lubricants in industry.

Finland, Norway and Sweden have ample resources of hydro power. The largest hydro power stations are located in the northern parts of the countries where few people live. The generated electricity is transported by long transmission lines from the power stations in the north to electricity consumers further south. In Norway, electricity is produced almost exclusively by hydro power stations. In Sweden, about half of all electricity production comes from hydro power.

Besides hydro power, nuclear power is the most widely used non-fossil energy source in the Baltic region. Five countries have nuclear power plants: Finland, Germany, Lithuania, Russia and Sweden. Together these countries have 16 nuclear power plants and 33 reactors. There are three main types of reactor in the Baltic region: boiling-water reactors (BWR), pressurized-water reactors (PWR) and graphite-moderated reactors (RMBK). The RMBK was developed in the Soviet Union and is considered less safe than other types of reactor.

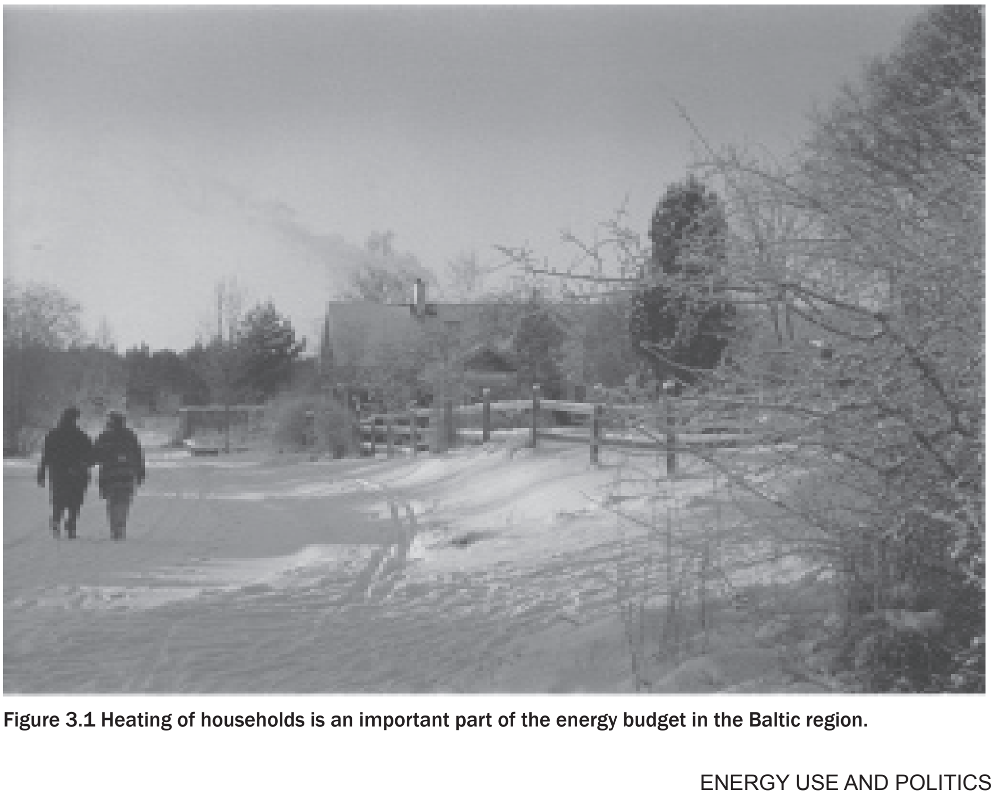
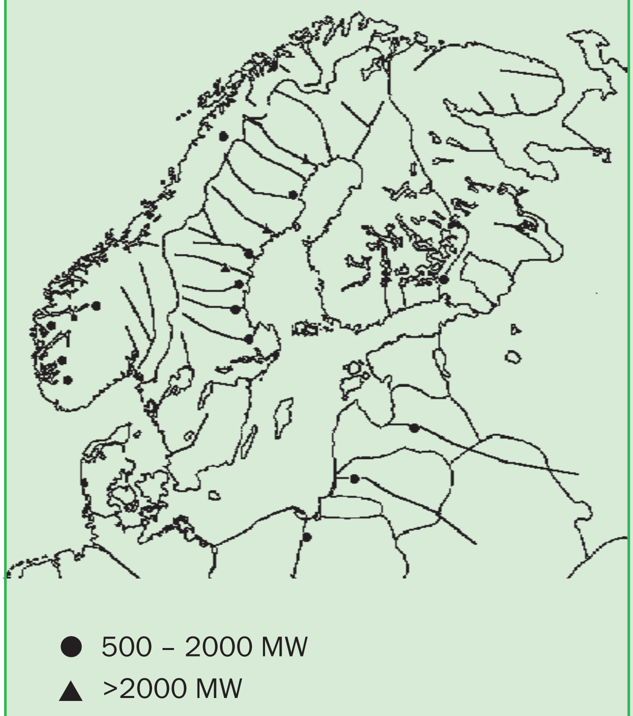


Figure 3.1 Heating of households is an important part of the energy budget in the Baltic region.

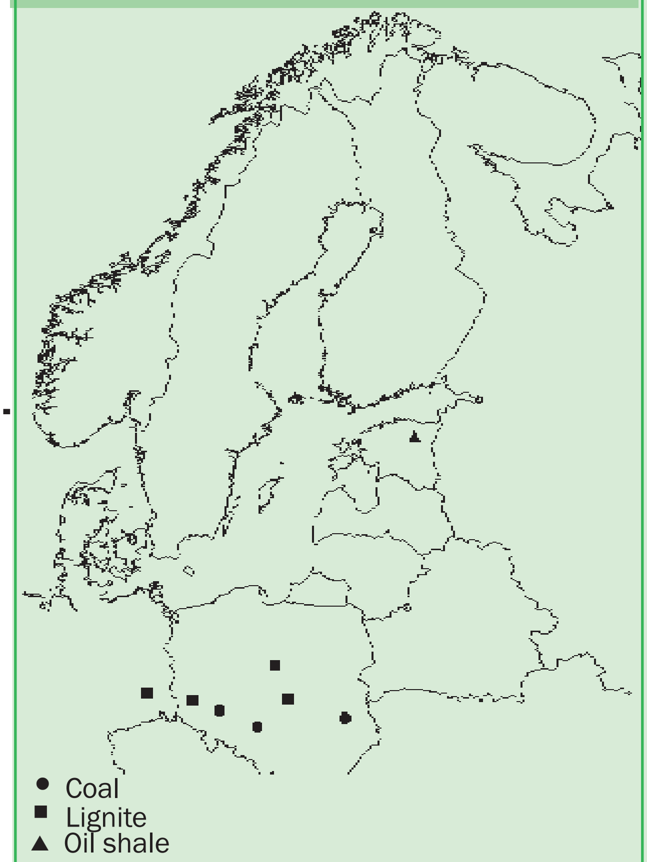
Energy Sources in the Baltic Region

HYDRO POWER



NUCLEAR POWER

COAL



The Baltic region has a considerable supply of energy resources. Hydro power stations, located in the north, provide a large share of electricity in Norway, Sweden and Finland. The hydro power plant in Daugava, although small, accounts for a large share of Latvia's electricity.

Further south nuclear power, in 16 nuclear power plants in Finland, Sweden, Lithuania, Germany and Russia, also provides a large share of the electricity in the region. A total of 33 nuclear reactors are located in the Baltic region.

Fossil fuel are found in large amounts in the south. Poland has large deposits of both hard coal and lignite. Lignite is also found in eastern Germany. Estonia has a considerable oil shale field in the Narva region accounting for most of the energy budget of the country.

Of the mentioned resources only hydro power meets the requirement for sustainability. In addition, there is a considerable potential for biomass production.

Table 3.1 Nuclear power stations in the Baltic region in the year 1995.

	number of locations	*number of reactors*	*installed net capacity (GW)*	*BWR*	*PWR*	*RBMK*
Finland	2	4	2.3	2	2	–
Germany[1]	7 (15)	7 (20)	7.9 (22.2)	2 (6)	5 (14)	–
Lithuania	1	2	2.4	–	–	2
Russia[2]	2 (9)	8 (29)	5.3 (19.8)	–	4 (9)	4 (11)
Sweden	4	12	10.0	9	3	–

BWR: boiling-water reactor; PWR: pressurized-water reactor; RBMK: graphite-moderated reactor of Soviet/Russian type.

[1] In northern Germany. The figures in brackets indicate the total number of locations/reactors in Germany.

[2] In north-western Russia. The figures in brackets indicate the total number of locations/reactors in Russia. Besides its PWRs and RMBKs, Russia has also one breeder reactor.

Sources: Jahrbuch der Atomwirtschaft 1996; Närings- och teknikutvecklingsverket, rapport B 1995:10.

The reactor that collapsed in Chornobyl (NB: 'Chornobyl' is Ukrainian) in 1986 was a RMBK reactor. In the Baltic region there are two power plants with reactors of this type; one in Sosnovij Bor outside St Petersburg in Russia with four reactors and one in Ignalina in Lithuania with two reactors.

The proportion of nuclear power in the total electricity production in Lithuania is one of the highest in the world – the nuclear power plant in Ignalina accounted for about 80 per cent of Lithuania's total electricity production in 1994.

Russia has nine nuclear power plants with 29 reactors. Two plants with a total of eight reactors are located in north-western Russia. They contribute about 50 per cent of this region's electricity production.

Germany has the largest amount of nuclear capacity of all countries in the Baltic region. Nuclear power accounted for about 30 per cent of total electricity production in 1994. It has 15 nuclear power stations with a total of 20 reactors. Seven of these reactors are located in northern Germany. The nuclear reactors of the Soviet type that were used in eastern Germany, in Greifzwald, were taken out of operation after the unification of Germany in 1990. There are no plans to construct new nuclear power plants in Germany.

Sweden has four nuclear power plants with a total of 12 reactors. In 1994, about half of Sweden's electricity production came from nuclear power. The Swedish parliament has decided to phase out nuclear power. A decision on how this phase-out is to be implemented is expected in 1997.

Finland's four nuclear reactors provide about 30 per cent of the country's electricity production.

3.2 Renewable energy resources

A review of the use of renewable energy sources in the Baltic region is provided in Table 3.2. Finland, Norway and Sweden have the largest proportions of renewable energy sources in their energy supply. The most important renewable is hydro power. In 1993, hydro power accounted for half of Norway's TPES and all of its electricity production. Hydro power supplied 20 per cent and 51 per cent of the electricity in Finland and Sweden respectively and 18 per cent in Russia. More than 70 per cent of Latvia's electricity production was hydro power in 1993.

Besides hydro power, biomass is the most widely used renewable energy source in the Baltic region. In Finland, Norway and Sweden, wood-waste products are used for heat production in industry and in district-heating stations. In Denmark and Sweden, vegetal waste products from agriculture are increasingly used for heat production. Wood is also used as fuel by private households in most countries in the Baltic region. Because this kind of wood consumption is usually not covered in energy statistics, it is difficult to estimate its actual share of total energy consumption. Peat and wood from forests are used for heating by households, in particular in the rural areas in the Nordic countries, the Baltic states and Russia. The burning of fuel wood is likely to have increased in the past few years in Russia and the Baltic states as a result of increasing prices of other fuels, such as oil and coal. In the Nordic countries, wood wastes and other biofuels are increasingly utilized by district-heating plants and in industry.

In 1993 wind power accounted for 3 per cent of Denmark's electricity production, but is still of small significance elsewhere in the Baltic region. However, wind power has become increasingly popular as a small-scale energy source in the past 10 to 15 years. There are good wind conditions along the coasts of the Baltic Sea thus the potential for an expansion of wind power is large. Several thousand wind turbines are located in Denmark and in northern Germany and are producing a growing proportion of those countries' electricity.

Solar and geothermal energy are used locally for heating build-

Table 3.2 Use of Renewable Energy Sources in 1993

Country	*RES in % of TPES*	*Most significant renewables*	*Amount of electricity or heat production*	
Denmark	5	wind power	3 %	of elec. prod
		biomass	4 %	of heat prod
Finland	18	hydro	20 %	of elec. prod
		biomass	15 %	of heat prod
Germany	1	hydro	3 %	of elec. prod
Latvia	5	hydro	73 %	of elec. prod
Norway	50	hydro	100%	of elec. prod
		biomass	8 %	of heat prod
Russia	2	hydro	18 %	of elec. prod
Sweden	26	hydro	51 %	of elec. prod
		biomass	15 %	of heat prod

RES = Renewable Energy Sources

TPES = Total Primary Energy Supply

Latvia only produces half of its electricity supply, the rest is imported from fossil and nuclear power plants outside Latvia.

Source: Energy balances of OECD Countries 1992–1993, International Energy Agency 1995.

ings but are insignificant as energy sources on a national scale.

3.3 The Baltic region is among the most energy intensive in the world

A country's total use of energy, both domestic energy sources and imported energy products, is expressed as its total primary energy supply (TPES). Fossil fuels, such as coal, oil and gas account for the major proportion of TPES in the Baltic region. In Belarus, Denmark, Estonia, Germany, Latvia, Poland and Russia, fossil fuels provide more than 85 per cent of TPES. Poland is perhaps the most extreme case. It is almost totally dependent on fossil fuels, of which coal accounts for almost 80 per cent of TPES (one of the highest proportions in the world). In contrast, Sweden and Norway have much lower proportions of fossil fuels in their energy balances; 38 per cent and 52 per cent, respectively. In Norway, electricity is produced almost exclusively by hydro power, while Sweden's electricity production is covered by hydro and nuclear power (about 50 per cent each).

The energy consumed by end-users is called Final Energy Consumption (FEC). This consumption includes electricity, heat, gas for cooking, petrol and other oil products for transport, as well as other fuels that are used directly for various purposes. Most of the final energy consumption occurs in industry, in households (residential consumption) and in transportation. Figure 3.3 displays the total final energy consumption of eight countries in the Baltic region in 1993. Industry accounted for almost a third, and the residential and transport sectors for a quarter each of the final energy consumption. The remaining amount of final energy was consumed in the service sector (11 per cent) and in various other parts of the economy (7 per cent).

The drastic economic changes in central and eastern Europe in the 1990s make it difficult to collect reliable statistics to compare the structure of their final energy consumption with that of countries in western Europe. However, some general observations can be made. Transportation and services account for a larger proportion of final energy consumption in western Europe than in central and eastern Europe. The established market economies in the West also tend to have a higher per capita consumption of electricity compared to the former centrally planned economies in the East. In central and eastern Europe, the continuing shift from heavy industry to manufacturing and services, and increasing ownership of appliances in households will gradually increase electricity consumption per capita closer to western European levels.

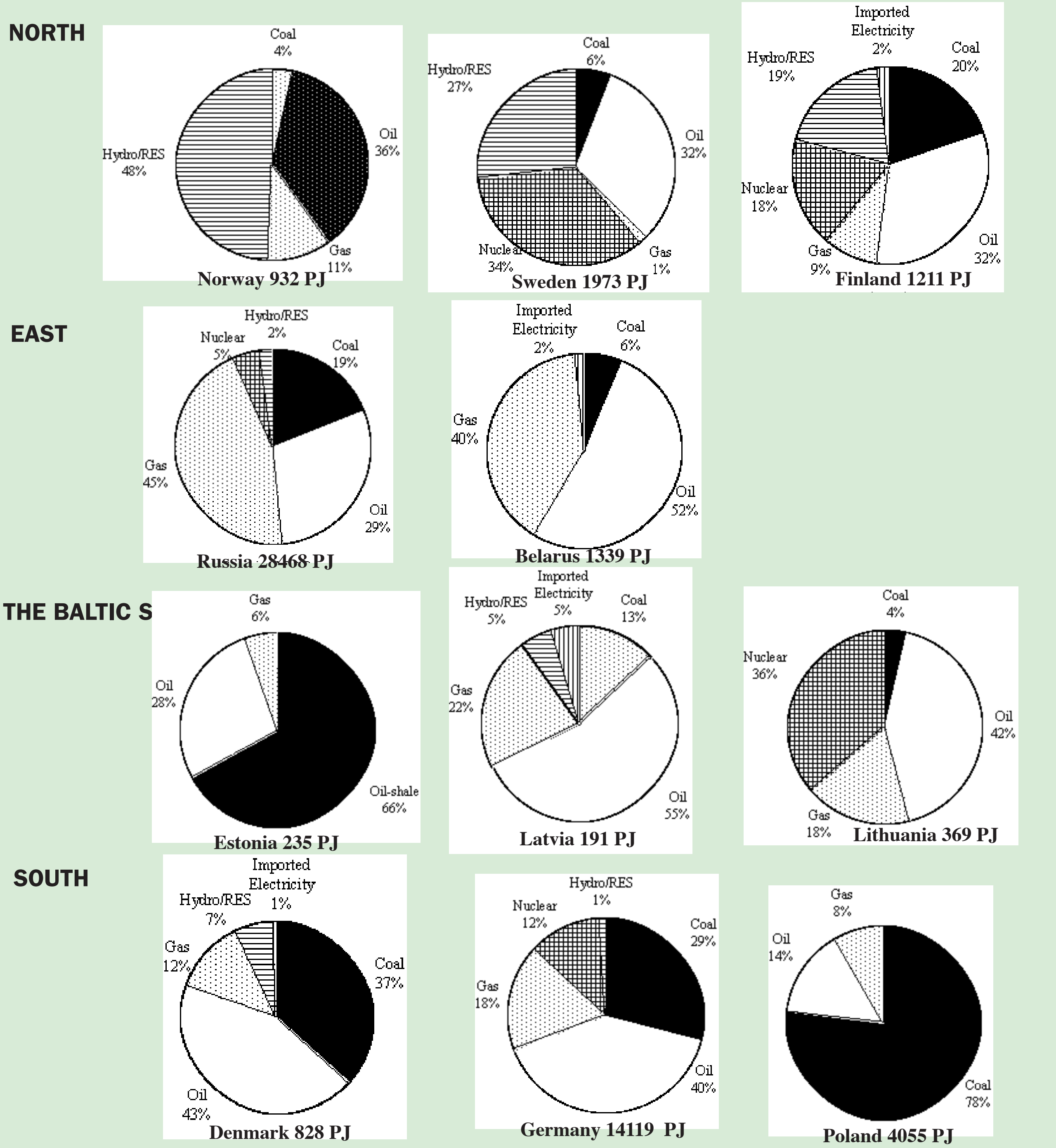
Energy consumption per capita is frequently used as a measure to compare the energy use of different nations. In the Baltic region in 1993, per capita levels ranged from about 70 GJ/capita in Latvia to almost 240 GJ/capita in Finland. The per capita levels of Finland, Norway, Russia and Sweden are among the highest in the world. The levels of energy consumption per capita of the other countries in the Baltic region are also high by international standards and are typical for industrialized economies.

3.4 Energy intensity has large variations

Although their per capita levels of energy consumption are in the same range, there are large differences among the countries in the Baltic region with respect to their energy efficiency. One measure of how efficiently energy is used in a economy is to calculate its energy intensity, that is, energy use per unit of gross domestic production (GDP). Energy intensities are easy to calculate for individual countries. Unfortunately, comparing intensities across countries is not always as simple.

The energy intensities of former centrally planned economies are several times higher than those of established market economies in western Europe. The most important explanation for this difference in energy efficiency is that energy prices were heavily subsidized in the centrally planned economies. Other reasons are the bias toward heavy industry, monopolistic energy supply systems and lack of market discipline to encourage cost-effective investments that were typical in

Total Primary Energy Supply in the Baltic Region in 1993



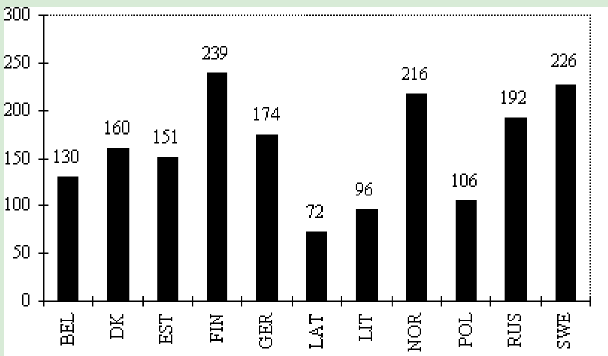


Figure 3.2 Total Primary Energy Supply Per Capita 1993 (in GJ). (Source: IEA 1995) Energy balances of OECD countries; Energy statistics and balances of non-OECD countries)

The total primary energy supply per capita in the region in 1993 varied from Latvia's 72 GJ to some 230 GJ in Finland and Sweden. The compositions of the energy supply are shown in the circular diagrams. They typically contain more hydro and nuclear power in the north, gas in the east and coal in the south. Estonia is heavily dependent on its oil shale. Denmark, Germany, Lithuania, Latvia and Belarus are particularly dependent on large imports of oil and gas. (RES = Renewable Energy Source)
(3.6 PJ = 1 TWh)

centrally planned economies. The legacy of this economic system still burden the countries in central and eastern Europe.

The environmental impact of the energy system is much larger in the southern and eastern parts of the Baltic region than in its northern parts. One reason for this imbalance is that the southern and eastern parts are much more densely populated than the northern parts. Another reason is the heavy reliance on fossil fuels in Denmark, Germany, Poland, the Baltic states, Belarus and Russia. This reliance is not surprising since these countries have based their energy supply on domestic resources of fossil fuels such as coal, oil-shale and oil.

The environmental burden is further aggravated by the inefficient use of energy in the former centrally planned economies in the region. High energy intensities in countries like Poland and Russia, in combination with insufficient pollution abatement, make them more polluting than other fossil fuel-dependent countries such as Denmark and Germany.

3.5 Dramatic changes in energy use in the eastern Baltic region

The world's energy requirements have risen considerably in the past 30 to 40 years. In 1960 the world used 138 exajoules (EJ = 1,000 PJ) of energy. In 1990 the world used 368 EJ – almost three times more than in 1960 or an increase of 3.3 per cent per year. Energy use in western Europe increased steadily until the mid-1970s when energy prices jumped as a result of the oil crises. When energy prices stabilized in the 1980s, consumption of energy picked up again, although at a slower rate than in the 1960s and early 1970s. In 1990, the TPES of the European Union was 55 EJ; 30 per cent more than in 1970.

Eastern Europe's energy consumption followed a slightly different pattern. The eastern European countries could rely on domestic energy and deliveries of oil and gas from the USSR at subsidized prices, so they were less affected by the increase in the world market price of oil and other fuels in the 1970s. Between 1972 and 1990, the TPES of eastern Europe (including the former USSR) increased by 58 per cent.

However, the collapse of the centrally planned economy in 1989–1991 and the economic transition that followed have had a profound effect on energy use in eastern Europe. Because of falling industrial production and declining economic activity in the first years of transition, the central and eastern European countries have experienced the most drastic drop in energy use since World War II. While TPES in the EU increased slightly between 1990 and 1993, eastern Europe's TPES dropped by 20 per cent in the same period. In Poland, TPES fell by 24 per cent between 1988 and 1992. In Estonia, Latvia and Lithuania, it fell by about 50 per cent between 1990 and 1993. The sharp decline in the Baltic states' energy consumption is explained by a deeper fall in their GDP than in the case of Poland and by repeated shortfalls in oil and natural gas supplies from Russia.

The 1990s have so far been a period of changing conditions for energy use in the Baltic region. The changes have been particularly drastic in the eastern part of the region. But important modifications are also taking place within the energy industry in the region's western part. In the next 5 to 10 years there are several factors that will affect the conditions for energy production and consumption in the Baltic region.

One factor is the future rate of economic growth. In Poland, after several years of declining energy use in the early 1990s, energy use is slowly increasing again as a result of growing economic activity. Poland's TPES is expected to grow by an annual rate of 2.5 per cent for the remainder of the 1990s. Even at this growth rate, Poland will still use less energy in 2000 than it did in 1988. Forecasts are harder to make for the Baltic states, Belarus and Russia, but their energy consumption will probably not reach the 1990 level before 2005.

The positive side of these scenarios is that they allow time for policy reorientation from the short-term to the long-term. So far, the focus in these countries has been to secure energy supplies, especially in the Baltic states. This is understandable, but decision-makers now urgently need to learn how the demand for energy is changing as a result of ongoing structural changes in their economies.

Another important factor is the increasing energy prices in central and eastern Europe. More expensive fuel imports and pricing reforms have led to a

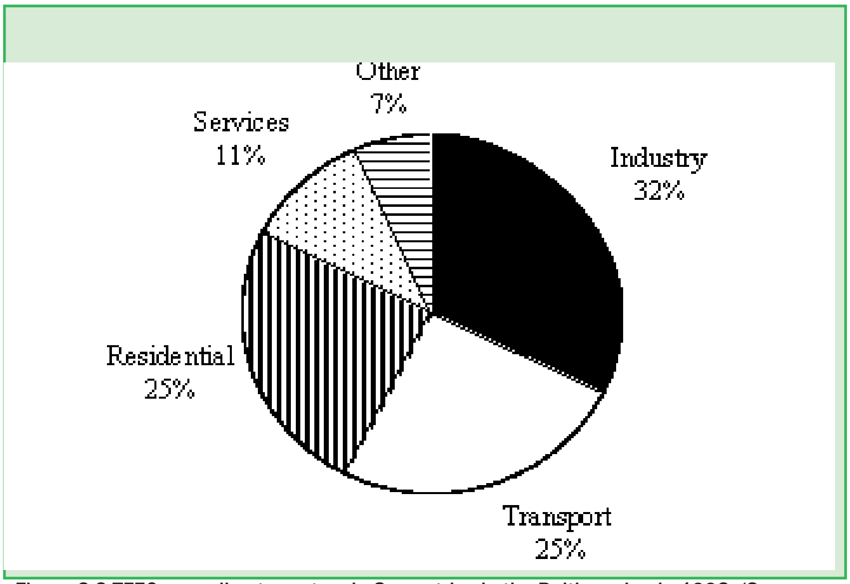
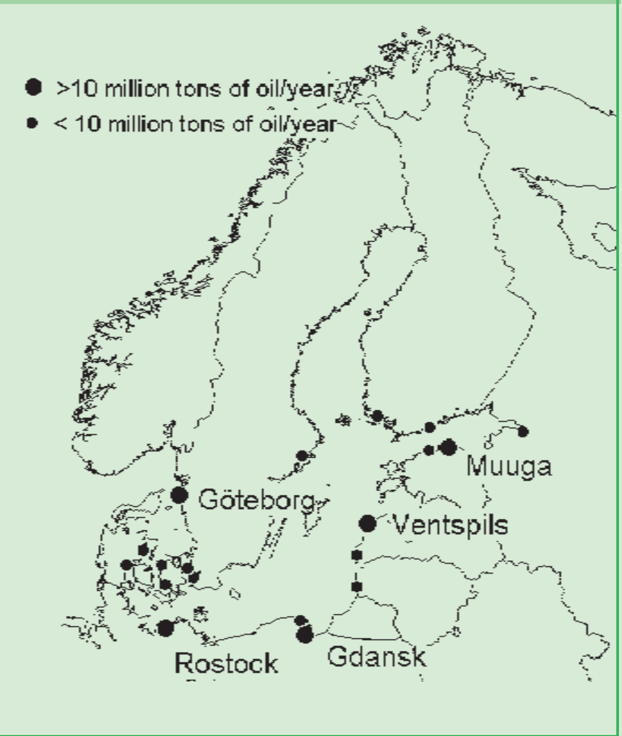


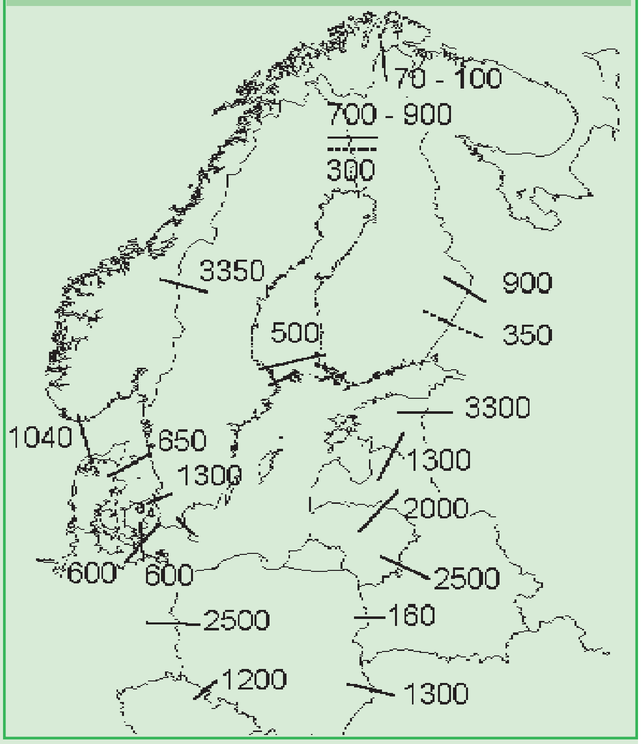
Figure 3.3 TFEC according to sectors in 8 countries in the Baltic region in 1993. (Source: See figure 3.3)

Energy trade

OIL TERMINALS



ELECTRIC POWER TRANSFER CAPACITY



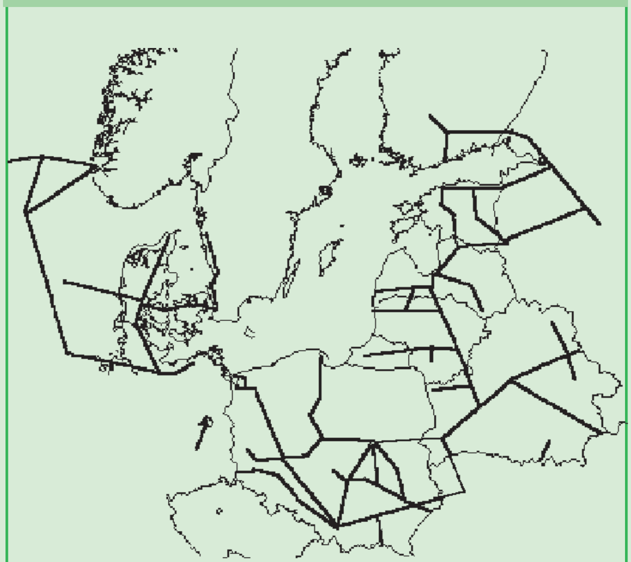
Imported oil and gas accounts for a large proportion of the primary energy use in the region. The newly independent states in the east which previously received all their oil from the Soviet oil fields are now turning to the west. The capacity of oil terminals on the Baltic Sea is being expanded at several locations in Estonia, Latvia, Lithuania and Russia. Russia sees St Petersburg as a potential large scale export terminal. Oil trade on the Baltic Sea may double from the present approximate 80 million tonnes to some 170. The environmental risks for accidental oil spills are thus increasing.

Large investments also take place for gas export from the North Sea fields. Pipelines from Sibera supply gas to Finland, the Baltic states, Belarus and Poland.

Capacity for transfer of electric power is well developed between the Nordic countries as well as Germany. There are plans to establish an interconnected power grid around the Baltic Sea – the 'Baltic Ring'. The weak points consist today of connections between Finland and Estonia and Poland and Lithuania respectively.

Trade with fossil fuels is not a long term sustainable solution to energy needs. From a sustainbility perspective gas is however better than oil. A well functioning power grid connected to the large hydro power stations is an excellent platform for the use of renewable energy resources, as these may provide for needed storage capacity.

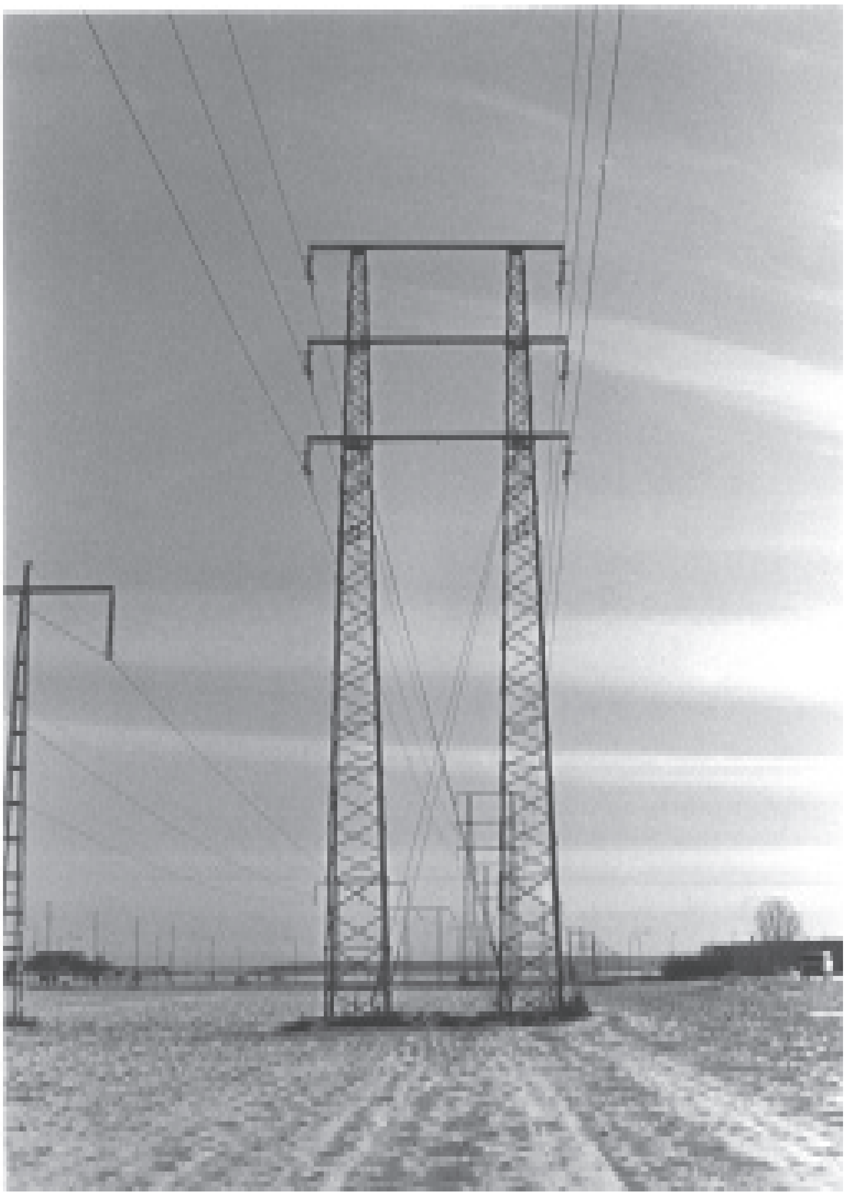
GAS PIPELINES



drastic increase in energy prices in Poland, the Baltic states and Russia. Households, which used to pay less than industry for their energy use, are now charged more. Direct state subsidies have been phased out for all energy industries except districtheating. It may be difficult for people in western Europe to understand the extreme constraints that the sudden increases in energy prices have put on households in eastern Europe. In the winter, costs for heat, hot water and electricity for a normal household in the Baltic republics now account for up to half of its monthly income. The corresponding costs for a household in Scandinavia are typically 5–10 per cent.

The increasing cost of energy has become a serious social problem in the Baltic republics and Russia. Many households have difficulty in paying their energy bills. Electricity and gas distribution companies and district-heating companies have accumulated substantial debts owed by both domestic and industrial consumers. Non-payment by customers reduces the energy companies' revenues and makes it difficult for them to finance necessary investments in equipment for energy conversion and distribution.

However, the combination of economic reform, rationalization of production and increasing energy prices is having a positive effect on the efficiency of energy use. Poland's energy use per GDP fell by almost 20 per cent between 1987 and 1993. The improved energy efficiency is partly the result of structural change. The growth of privately owned industry has led to a shift from heavy industry to less energy-consuming manufacturing and services.



3.6 Energy trade

The breakdown of the Soviet Union in 1991 has led to new trade patterns in the Baltic region. The new and re-emerging states on the territory of the former USSR are concerned about dependence on Russia for their energy imports. Russia, in its turn, is interested in exporting oil and gas to other markets. In the past few years, the construction of several new oil terminals has started along the Baltic coast in Estonia, Latvia, Lithuania and Russia. As a result of these activities, the transportation of oil on the Baltic Sea is increasing and so is the number of oil spills from tankers.

In western Europe, deregulation of the power industry is changing the conditions for electricity trade in the Baltic region. Power companies in Germany, Denmark, Sweden and Finland are interested in trading electricity with Poland, the Baltic states and Russia. There are plans to establish an interconnected power grid around the Baltic Sea – the 'Baltic Ring'. Such a connection would make it possible for the countries in the Baltic region to exchange electricity and to optimize power production with respect to generation costs.

Environmental concerns are resulting in stricter regulation of the energy industry both in the East and in the West. Stricter environmental standards will increase the pollution abatement costs for power plants burning fossil fuels.

4.

Environmental effects of energy use in the Baltic Region

by Tihomir Morović and Ilja Tuschy

All stages of energy use have environmental effects: the exploitation, transportation, conversion and final consumption of energy, as well as the storage of waste products. Energy-related environmental problems include water pollution and land degradation from mining and extraction of fossil fuels, oil spills from transportation, air pollution from fuel combustion and the storage of radioactive waste from nuclear power plants. This chapter describes typical environmental effects that result from the use of different energy sources in the Baltic region.

4.1 Fossil fuels; the coals – hard coal, and lignite

In the Baltic region three types of solid fossil fuel are extracted: hard coal (in Poland), lignite (in eastern Germany and Poland) and oil-shale (in Estonia and western Russia).

Hard-coal mining has significant environmental effects. To mine the coal below the Earth's surface, numerous underground corridors have to be excavated which make the mining area look like a gigantic underground anthill. For this reason the Earth's surface can become unstable which often makes the mining areas uninhabitable. The material extracted from the coal mines consists not only of pure hard coal but also of other substances unsuitable for energy use. The separation of coal from these substances results in huge waste deposits which inhibit other activities in the coal-mining areas. During the mining process, methane is emitted. Part of it can be used for energy production, but certain amounts are emitted into the atmosphere. Since methane is a so-called greenhouse gas, it contributes to global climate change. Apart from the environmental damage, there are also health risks to miners from hazardous gases in the mines, or mining accidents, and anthracosis (so-called 'coal miner's lung').

Depending on the quality of the coal (for example its carbon content or calorific value), it is broken into small pieces or pulverized. The resulting product is then shipped to the end-users.

Further environmental problems from hard coal result from its conversion into electricity or heat. During the combustion of hard coal, dust and various polluting gases are emitted into the atmosphere. Since the plants have high smoke-stacks, a substantial amount of the emissions is carried far away. Sulphur, in the form of sulphur dioxide, is the most conspicuous of these pollutants. In 1993, about 7.5 million tonnes of SO_2 were emitted in the Baltic region (excluding north-western Russia). Most of these emissions came from coal combustion. In Poland, coal combustion for electricity and heat production accounts for more than 70 per cent of all SO_2 emissions.

In the atmosphere, SO_2 is converted into sulphuric acid which can be transported for long distances before it falls to the Earth as raindrops and leads to the acidification of water and soil. This so-called 'acid rain' is a major contributor to forest damage and the acidification of many lakes in the Baltic region.

Beside SO_2, many other polluting gases and particles, for example, nitrogen oxides (NO_x), dust and carbon monoxide (CO), are emitted when burning coal.

Lignite is typically extracted in open-cast mines. As a result of lignite extraction, thousands of hectares in eastern Germany have been spoiled and have to be reclaimed and recultivated. Mining also lowers the groundwater level in the mining regions and leads to methane emissions. Lignite is used by power plants and district-heating plants. Before transportation to the power plants, it is pulverized at the mining site. The waste material from the lignite mines is mostly used for landfills but sometimes it is just stored close to the mines in high heaps which are washed out by rain. Heavy metals and other pollutants leaking from these deposits contaminate surface and ground waters.

Like hard coal, lignite emits SO_2 when combusted. Due to the lower calorific value of the lignite, the SO_2 emissions per tonne of lignite are approximately three times higher than those for hard coal. As regards other pollutants, the situation is rather similar to the emissions from hard coal use. Because of the lack of desulphuri-zation equipment at some lignite-burning power plants in eastern Germany and Poland, those plants have the highest emissions of SO_2 in the Baltic region. Dust emissions are also high compared to similar plants in western Europe.

4.2 Other fossil fuels – oil, gas and oil-shale

The exploitation of oil and gas which occour in rather limitied amounts in Germany, Poland, Lithuania and Kaliningrad leads

Major air pollutants: sources and effects

SULPHUR DIOXIDE (SO_2)

Sulphur dioxide is formed in the combustion of sulphurous coals and fuel oils. More than 90 per cent of the emissions in Europe come from power stations and other combustion of coal and oil. SO_2 has direct effects, particularly in combination with other pollutants, on both vegetation, resulting in reduced growth, and animals. Human uptake through respiration causes smarting of the nose and mouth, weeping of the eyes, and exacerbates asthma, bronchitis and emphysema. SO_2 emissions, together with nitrogen oxides and ammonia emissions, also lead to acid rain and acidification of soil and water and to a range of corrosion damage. In addition to damaging flora and fauna, acidification leads to health risks through increased concentrations of aluminium and copper in drinking water.

NITROGEN OXIDES (NO_x)

Nitrogen oxides are formed in combustion processes. Roughly 60 per cent of European emissions come from cars and other mobile sources and the rest come from power generation and other stationary fuel combustion. Nitrogen oxides and nitric acid (HNO_3), to which some NO_x is converted have direct effects on vegetation, especially in combination with other air pollutants. Human exposure can cause headaches, increase susceptibility to viral infections, irritate the lungs and airways, and increase sensitivity to dust and pollen in asthmatics. NO_x emissions cause acid deposition, eutro-phication of soil and water and contribute to nitrification of groundwater. NO_x is also an important precursor to ground-level ozone formation.

PHOTOCHEMICAL OXIDANTS

Ozone and other photochemical oxidants are the result of sun-driven reactions with NOx and so-called volatile organic compounds (VOCs), primarily hydrocarbons. Mobile sources and solvents probably account for about 40 per cent each of man-made VOC emissions in Europe. Several VOCs have known toxic or carcinogenic effects. Ozone and other oxidants cause damage to vegetation resulting in reduced agricultural productivity and are thought to be a significant factor in the forest decline observed over large areas in Europe.

GREENHOUSE GASES

Man-made emissions of greenhouse gases (notably carbon dioxide, methane, nitrous oxide, chloro-flourocarbons (CFCs) and tropospheric ozone) are projected to contribute to climate change. More than half of the change in radiative forcing comes from emissions of carbon dioxide, 80 per cent of which results from fossil fuel combustion. Many of the other emissions of greenhouse gases are also associated with energy use, for example, leakage of methane from natural gas networks and CFC emissions from refrigerators, air-conditioners and heat-pumps. CFCs also cause depletion of strato-spheric ozone.

(by Lars J. Nilsson)

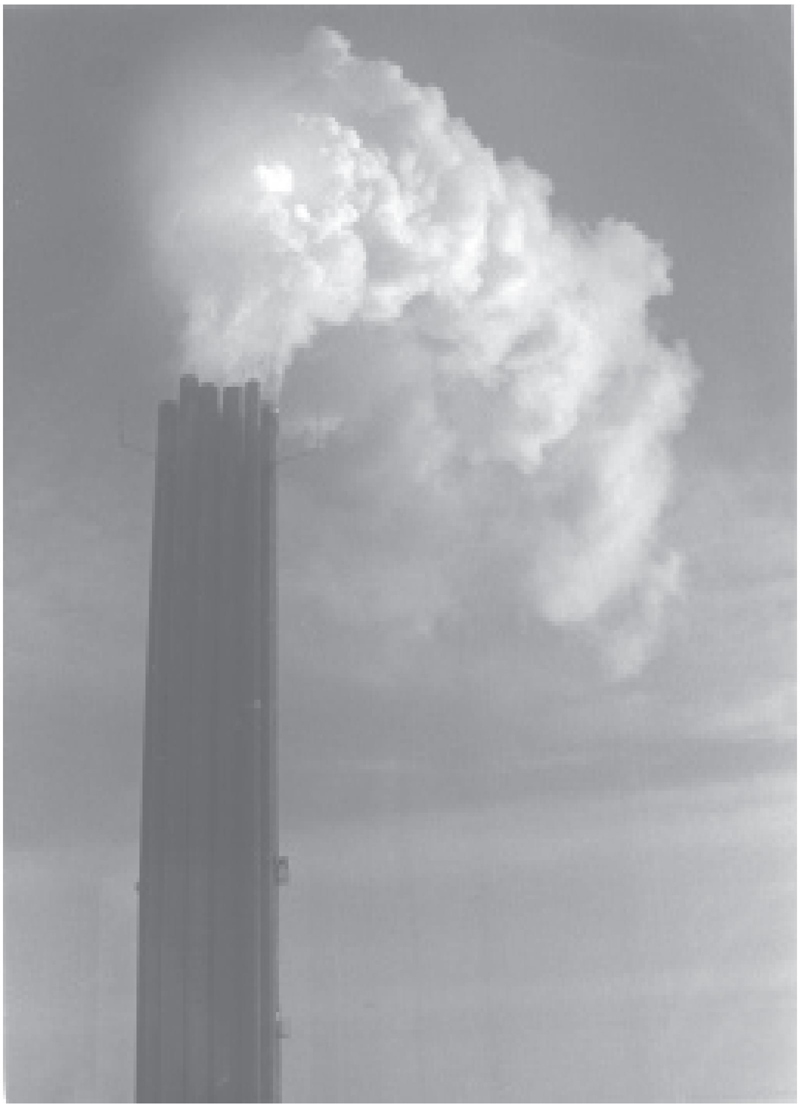
to certain losses of oil and gas which contaminate the soil and increase the concentration of greenhouse gases in the atmosphere. One litre of crude oil is enough to spoil one million litres (1,000 m^3) of drinking water. Sometimes gas explosions occur at the drilling sites which can produce long-lasting fires. Burning oilfields in Kuwait during the Gulf War caused serious environmental damage.

Natural gas is usually transported by pipelines, while oil and refined oil products can be transported by pipelines, oil tankers and trains. Pipelines or tankers are used for the long-distance transportation of oil. There are several oil and gas pipelines from Russia to the Baltic states, Poland and Germany. Russian oil is also exported via ports on the Baltic sea. The supply of oil to service stations and smaller consumers is carried out by trucks.

Transportation of gas and oil by pipelines is usually safe and efficient. Pipeline leaks can, however, cause severe damage to the environment. Methane emitted by damaged natural gas pipelines contributes to the greenhouse effect, while oil can pollute soil and water. Accidents in Russia have shown that many of its pipelines are in bad condition. Careful maintenance of oil and gas pipelines on the territory of the former Soviet Union is necessary to prevent further accidents and damage to the environment.

Oil and gas are not only consumed by major power plants and at industrial locations but also in the heating of buildings and in transportation. Air pollution related to the combustion of oil and gas is caused both by stationary and mobile sources which makes it difficult to calculate the total emissions of various pollutants from these fuels in the Baltic region. The combustion of oil products results in emissions of carbon dioxide, nitrogen oxides, sulphur oxides and so-called volatile organic compounds.

The specific emission of carbon dioxide for oil products is less than for coal but higher than for natural gas. Natural gas is considered the most environmentally friendly fossil fuel since it has comparably low emission rates of carbon dioxide and hazardous pollutants. To provide a given amount of energy by natural gas, half as much CO_2 is emitted as compared to lignite. Moreover, natural gas contains almost no sulphur. In the case of nitrogen oxides from oil and gas combustion, the emission rate depends on the combustion temperature and technology.



After the disintegration of the Soviet Union, the structure of oil supply in the Baltic region is changing. In the Leningrad region and the Baltic States, new oil terminals have been built and are under construction. Estonia, Latvia and Lithuania are trying to become less dependent on Russia for the supply of fuels and crude oil. The governments of Latvia and Lithuania are showing growing interest in off-shore exploitation of oil in the Baltic Sea. For these reasons, the amount of oil transported by tankers on the Baltic Sea oil is increasing which, in turn, increases the risk of oil spills from tanker accidents and illegal discharges of oil at sea.

Oil-shale is a sedimentary rock, containing 35–40% of organic matter (kerogen) and 60–65% limestone and clay. It has a calorific value similar to that of lignite. In the north-east of Estonia, the mining of oil-shale, now-adays mostly from underground mines, has a long tradition. It is used as a raw material in the chemical industry and as a fuel in thermal power plants. The utilization of oil-shale for energy purposes is important for the Estonian economy since it makes Estonia self-sufficient in electricity and a potential exporter of electricity to its neighbours, Latvia and Russia. The mining of oil-shale is thus a key issue for the future of Estonia's economy.

The mining of oil-shale has severe environmental consequences. Approximately 10,000 hectares are affected by mining activities and although 70–80 per cent of the spoiled landscape has been the subject of reclamation and recultivation, waste materials from oil-shale mining still cover thousands of hectares. Washed-out heavy metals, phenols and other pollutants contaminate soil and ground water. Another negative effect of oil-shale mining is the lowering of the ground-water level in the affected region.

The oil-shale is not transported over long distances but is burned in two thermal power plants in Narva close to the mines. This gives rise to millions of tonnes of oil shale ash yearly. The two plants in Narva are responsible for approximately 75 per cent of the country's total sulphur and carbon emissions. These emissions do not only cause local air pollution. As a result of high smoke stacks, a considerable amount of the emissions is carried away far over the borders of Estonia. Sulphur dioxide and nitrogen oxides emitted by the power plants in Narva contribute, for example, to the acidification of lakes and soil in the southern part of Finland. Although Estonia's SO_2 emissions have dropped since 1990 because of falling electricity production, the power plants in Narva still need to install desulphurization equipment to reduce their pollution further.

4.3 Nuclear power

Nuclear power stations use uranium for fuel. One advantage of uranium is that relatively small volumes of it, in comparison to fossil fuels, are needed to produce heat and electricity. Nuclear power plants have low emissions of pollutants as compared to power plants burning coal or oil. Although there are uranium deposits in Russia, Sweden, Finland and Germany, extraction of uranium today is very limited in the Baltic region. (The Russian deposits are outside the Baltic region.)

Most of the nuclear fuel demanded in the Baltic region is imported. However, until its closure in the late 1980s, one of the largest uranium mines in Europe was located in eastern Germany (the former GDR) from which uranium was exported to the Soviet Union for the production of nuclear fuel and plutonium. Because of careless exploitation, ground and surface waters close to the mine have been seriously contaminated by radioactive and toxic substances. The costs of cleaning up the mine and its surroundings amount to several billion DEM. Thus, the environmental impact of uranium mining can be considerable.

In the case of nuclear power, environmental concerns are focused on the safety at power stations and the transportation and storage of radioactive waste. Although the possibility of a serious accident in a nuclear power stations is small, it can have severe consequences if it happens. The disaster at the nuclear power station in Chornobyl (the Ukrainian name form of the power station) in Ukraine, in 1986 showed that accidents at nuclear power stations can spread radioactive substances over very large areas. As a result of the Chornobyl disaster, radioactive fallout was carried by the wind thousands of kilometres before it was deposited. Several areas within the Baltic region were seriously affected by radioactive deposition from Chornobyl; in particular Belarus, south-eastern Poland and northern Sweden.

The Russian nuclear power industry has experienced serious financial problems in the past few years. Because of delayed payments from customers, the power plants have not been able to cover their costs for fuel, maintenance, spare parts and salaries. In 1995 and 1996, staff at several nuclear power plants went on strike because of unpaid or delayed salaries.

To improve security at nuclear power plants in Lithuania and Russia, these countries have been offered assistance from the West. Lithuania has received about 100 million USD in international support for safety upgrades at Ignalina, while cooperation between Russian and western nuclear experts has increased considerably. Most experts agree that both technical and operational improvements are necessary at nuclear power plants in eastern Europe. However, there is less agreement on the future of nuclear power. The Lithuanian and Russian governments want to run their nuclear power industries as long as possible and even plan to build new nuclear power stations. Many energy experts in the West recommend that the oldest and most unsafe nuclear reactors in eastern Europe should be closed as soon as possible and they point out that the high investment costs for nuclear power make it less interesting as an energy source in the future.

Continued international support will be necessary to enhance the safety of those eastern European nuclear power stations that do not meet international safety standards.

Besides the risks concerning the operation of nuclear power plants, the storage of nuclear waste (that is, the spent fuel from nuclear reactors) is an important environmental problem. This concerns both the handling of exhausted nuclear fuel and the disposal of building materials from old power plants that have been taken out of operation. To minimize the risks to the environment and the population, the safe storage of radioactive materials has to be guaranteed. The most difficult problem to solve in this respect is the final storage of the spent nuclear fuel. In, for example, Germany and Sweden, nuclear waste is planned to be finally stored in special deposits in the bedrock deep below the Earth's surface. This solution is criticized by many opponents of nuclear power, since they consider that the long-term impact of this type of storage is unpredictable. In Germany, the final storage of nuclear waste is an important issue in political discussions about the future of nuclear power. In Sweden, it has been difficult to find a final storage location that can be accepted by the local inhabitants.

Finally, there is the problem of controlling the transportation and storage of spent nuclear fuel. The exhausted fuel can be used to produce plutonium from which nuclear weapons are made. For this reason, nuclear waste from nuclear power plants must be handled under strict security controls to avoid its falling into the hands of terrorists or other groups who might use it to produce nuclear weapons.

4.4 Renewable energy sources

The utilization of renewable energies, like water, wind, solar energy and biomass generally has a lesser environmental impact than the use of other energy sources. In contrast to fossil fuels, wind power, hydro power and solar energy do not cause any emissions of carbon dioxide or other pollutants when converted into heat or power. Energy from biomass does not create any net emissions of CO_2 provided that the biomass (wood or other biofuels) is replaced at the same rate as it is harvested. Renewable energy sources are, however, not totally free of environmental effects.

Hydro power is the most important renewable energy source in the Baltic region. In Norway and Sweden hydro power is of great importance in electricity production. Almost all of Norway's and about half of Sweden's electricity production is supplied by hydro power. Compared with fossil and nuclear power plants, hydro power stations have very limited environmental effects. The construction of dam sites for hydro power stations, however, requires large areas of land and has changed the river landscape in the northern parts of Scandinavia. For this reason there are no plans to install further hydroelectric power stations in Sweden and Norway, although there is a remaining potential.

Because of the climate with long, cold winters, the potential for solar energy in the Baltic region is small. The geographical conditions for wind energy are more favourable. The utilization

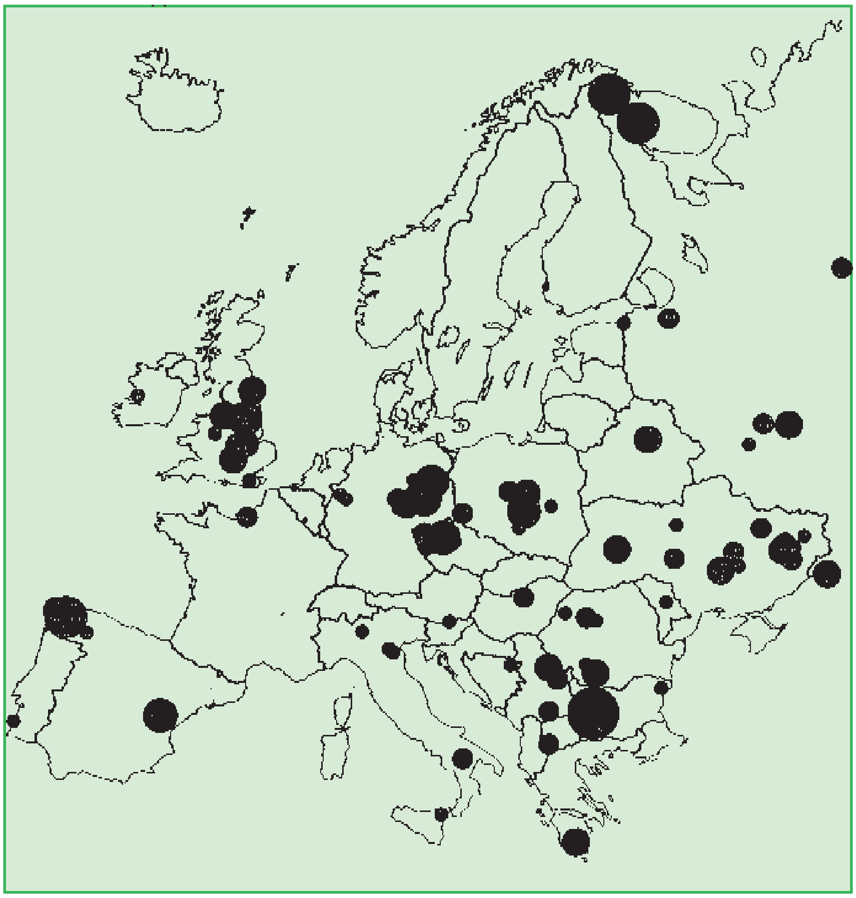


Figure 4.1 The largest sources of sulphur emissions in Europe. Southern Poland and eastern Germany, where large amounts of sulphur-containing coal and lignite are burnt in power plants, are hot spots in the Baltic region. The largest emission sources in the region, on the Kola peninsula, are the metallurgic plants extracting metals from sulphide ores.

of wind power is growing steadily in Denmark, where it provides four per cent of total electricity production, as well as in Germany, Sweden and Finland. The potential for wind energy is particularly high in coastal areas. there are also plans to install wind farms off-shore in the future.

The environmental effects of wind power are similar to those caused by high-voltage transmission lines: noise and visual impact from wind turbines, increased risks for birds and telecommunication interference. The disturbance caused by the noise produced by wind turbines can make it difficult to locate them close to inhabited areas. Another difficulty is the turbines' visual impact on the landscape. Wind turbines have a much smaller capacity than conventional power plants. To increase the capacity, so-called 'wind farms' are used with tens or even hundreds of turbines in the same area. When wind turbines are used individually by farms or households, one or two turbines may be sufficient.

The use of biomass for energy production has a long tradition in the Baltic region, especially in the northern parts where there are large forests. In Sweden and Finland, wood and other waste materials from the paper and pulp industry are increasingly used for energy production. Another important source of biomass is agriculture. In Sweden, farmers are increasingly shifting from food crops to energy crops. The growing demand for biofuels makes it important to develop sustainable forms of forestry and agriculture to limit the environmental effects of biomass cultivation. The combustion of biomass causes emissions of various air pollutants but these emissions tend to be less hazardous than emissions from coal or oil.

4.5 Air pollution from energy use

As demonstrated earlier in this chapter, all forms of energy use that occur in the Baltic region have various environmental effects. However, there are some energy-related environmental problems that can be considered more urgent than others to solve. Besides the nuclear safety problem, which was discussed in the previous section, the most important problem to address in the Baltic region is local and trans-boundary air pollution from the use of fossil fuels.

Local air pollution in is a serious health hazard in many cities and industrial areas in the Baltic region. Among the worst affected areas are Upper Silesia in southern Poland, Eastern Saxony in eastern Germany and the Narva region in north-eastern Estonia. They are all heavily industrialized mining areas. In Silesia and Saxony, emissions are mainly caused by the utilization of coal and lignite in power plants and industry. Small heating boilers and stoves burning coal are also significant air-pollution sources. The smaller facilities have low smoke stacks and tend to use low-quality coal, which make their emissions particularly hazardous to the local population. The situation is further aggravated because most of the large emitters, and all of the small ones, lack the equipment to reduce emissions of sulphur dioxide and other gaseous pollutants. Insufficient pollution abatement in combination with high energy intensities in industry lead to high pollution loads.

In the Narva area, air pollution is caused by the combustion of oil-shale for electricity and heat production. The two towns of Narva and Kothla-Järve have extremely high air-pollution loads. At the beginning of the 1990s, the annual sulphur deposition in the near vicinity of the power plants in Narva was 5 grams per m^2 – among the highest concentrations in Europe. In Kothla-Järve, where oil-shale is processed, the air-pollution load also includes hazardous hydrocarbons. Although the production of electricity in the two

Table 4.1 Emissions of CO_2, SO_2 and NO_x in the Baltic region in 1993: total emissions, and emissions per total primary energy supply.

	CO_2		SO_2		NO_x	
	mio t	*t / TJ*	*1000 t*	*kg / TJ*	*1000 t*	*kg / TJ*
Denmark	59	71	157	189	264	318
Estonia	30 (1990)	72 (1990)	240	1348	66	371
Finland	55	46	121	100	253	209
Germany	897	64	3869	274	2904	206
Latvia	18 (1990)	48 (1990)	82	471	54	310
Lithuania	35 (1990)	46 (1990)	136	372	56	153
Norway	32	34	37	39	225	241
Poland (1992)	339	87	2830	724	1130	289
Sweden	52	26	101	51	399	202

Sources: Calculations based on data from the OECD, IEA and Norwegian Meteorological Institute; data for Poland in 1992. For Estonia, Latvia and Lithuania: SO_2 and NO_x data estimated by Norwegian Meteorological Institute, CO_2 data in 1990 estimated by the EU.

Table 4.2 Emissions of CO_2, SO_2 and NO_x in the Baltic region in 1993: emissions per capita, and emissions per gross domestic product in USD.

	CO_2		SO_2		NO_x	
	t / capita	*kg / GDP*	*kg / capita*	*g / GDP*	*kg / capita*	*g / GDP*
Denmark	11	0.6	30	2	51	3
Estonia	19 (1990)	n.a.	152	39	42	11
Finland	11	0.7	24	2	50	3
Germany	11	0.6	48	3	36	2
Latvia	7	(1990) n.a.	31	11	20	7
Lithuania	9	(1990) n.a.	36	17	15	7
Norway	7	0.4	9	0.5	52	3
Poland	9	2.0	74	17	30	7
Sweden	6	0.4	12	0.7	46	3

Sources: Calculations based on data from the OECD and IEA; data for Poland in 1992; n.a. = not available. Estonia, Latvia and Lithuania: data for CO_2 in 1990, population data for SO_2 and NO_x refer to the year 1992, GDP estimated by using data from the OECD and the Bank of Finland.

thermal power plants in Narva has dropped by about 50 per cent since 1990, the air-pollution problems remains.

A drastic reduction of the pollution load is necessary in Estonia as well as in Upper Silesia and Eastern Saxony where the utilization of other fossil fuels causes similar problems.

The acidification of soil and water caused by local and transboundary air pollution is a serious problem in the Baltic region; especially in Sweden and Finland. Acidification is also believed to cause forest damage, which is a common problem in the Baltic region. Because emissions of sulphur dioxide and nitrogen oxides can be transported over long distances before they are deposited, international cooperation is necessary to solve the air-pollution problem in the Baltic region. In particular, SO_2 emissions from large power plants burning fossil fuels in Poland, Germany and the Baltic states must be reduced.

Compared with the desulphurization of power plants and the safety of nuclear power stations on the territory of the former Soviet Union, long-term tasks of environmental protection such as reduction of energy-related CO_2 emissions seem to be of second priority in the Baltic region. This problem, however, needs to be addressed too. CO_2 and other greenhouse gases are emitted, not only from power plants and other stationary sources, but also from mobile sources such as cars and aeroplanes. While air pollution from stationary sources has decreased by 30-40 per cent since 1990 in central and eastern Europe, emissions from transportation are increasing. In western Europe, where the number of cars per inhabitant are two to three times higher than in eastern Europe, transportation is already the main source of air pollution.

4.6 How much we pollute the air – some data

Tables 4.1 and 4.2 show emission data for 1993 for the countries in the Baltic region. (Data for northwestern Russia were not available.) Three types of emission are displayed: carbon dioxide (CO_2), sulphur dioxide (SO_2) and nitrogen oxides (NO_x). The tables are based on estimated data which should be treated as indicative rather than absolute.

Total emissions and emissions per primary energy use vary considerably among the different countries. Germany and Poland, which have the largest popula-tions in the region, are the largest emitters of CO_2, SO_2 and NO_x. A comparison of the various countries in terms of emission intensity, that is, emissions per energy consumption, reveals that Poland, Estonia, Denmark and Germany have the highest CO_2 emission rates. These countries base their energy supply on fossil fuels. Since only few of the power plants in Poland and Estonia have desulphurization equipment, their SO_2 emission rates are higher than those of Denmark and Germany where desulphurization technologies are widely used. Norway and Sweden, which have a high proportion of hydro and nuclear power, also have the lowest CO_2 and SO_2 emissions per energy use.

Another reason for the different emission rates is the lower energy efficiency in former planned economies such as Poland and the Baltic states. Emissions per GDP are several times higher in those countries than in Scandinavia, Finland and Germany. This difference is particularly evident in the case of SO_2 and NO_x. Despite similar per capita emission levels in Germany and Poland, Poland's emissions per GDP are several times higher than Germany's.

Thus, the combination of inefficient energy use and poor pollution abatement leads to higher emission intensities in central and eastern Europe.

Per capita emissions of NO_x are slightly higher in western Europe than in central and eastern Europe. This can be explained by higher car density in western European countries. Transportation is an important source of NO_x. The reason why the difference in per capita emissions is so small between western European and eastern European countries is the low energy efficiency in the latter countries, despite the high number of cars in the West.

4.7 Starting a change – recent improvements

Although air pollution still is a serious environmental problem in the Baltic region, the situation has improved in the past 10 to 15 years. Table 4.3 illustrates the development of emissions for selected countries in the Baltic region between 1980 and 1993. The changes in emissions of carbon dioxide and nitrogen oxides in the Baltic region demonstrate the close relationship between fuel use, energy efficiency and air pollution.

Total emissions of CO_2 and NO_x decreased by up to 30 per cent in Denmark, Finland, Germany and Sweden during the period. Emissions related to energy use decreased even more in spite of growing energy consumption. The large decrease that occurred in Sweden can be explained by Sweden's increased utilization of nuclear power in the early 1980s. The decrease in the other three countries was a result of improved energy efficiency and a shift to fuels such as natural gas with lower emissions of CO_2. Norway was the only country in the region where emissions of carbon dioxide and nitrogen oxides increased between 1980 and 1993. This increase may have been caused by Norway's extraction of oil and gas in the North Sea, which expanded considerably in the 1980s.

In contrast to Scandinavia and Germany, the considerable reduction of total CO_2 and NO_x emissions in Poland was caused by a drastic drop in primary energy consumption after 1988. The increase in emissions per energy use in the same period indicates that Poland's energy efficiency worsened in the 1980s..

The largest decrease in emissions occurred with sulphur dioxide, which fell by almost 80 per cent in Scandinavia, Finland and Germany between 1980 and 1993. This remarkable reduction was the result of improved air pollution control by, for example, the installation of desulphuriza-tion

Table 4.3 Emission trends of air pollutants in the Baltic region in 1980–1993. Percentages of total emissions and emissions per total primary energy supply (1980=100 %).

	CO_2		*SO_2*		*NO_x*	
	total	*per energy use*	*total*	*per energy use*	*total*	*per energy use*
Denmark	–6	–8	–65	–66	–4	–5
Finland	–7	–19	–79	–82	–4	–17
Germany	–17	–12	–48	–45	–16	–10
Norway	+3	–12	–74	–78	+21	+2
Poland	–24	+0.6	–31	–8	–25	+0.4
Sweden	–29	–38	–80	–83	–6	–18

Sources: Calculations based on data from the OECD and Norwegian Meteorological Institute; trends for Poland refer to the period 1980-1992; due to lack of data no trends were calculated for the Baltic States and Russia.

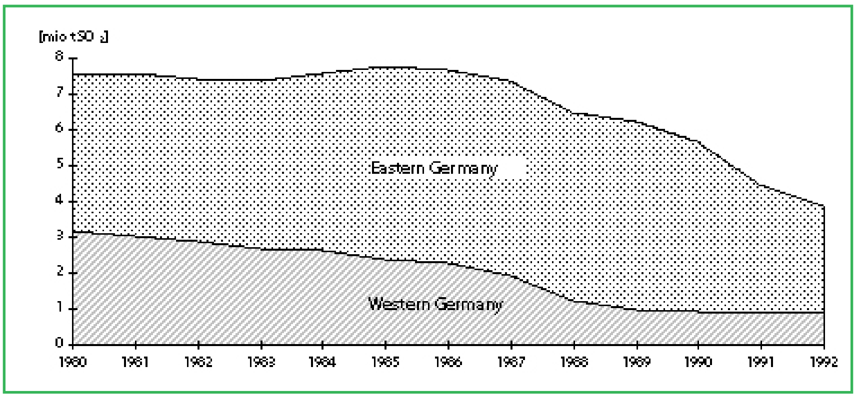


Figure 4.2 SO_2 Emissions in Germany in 1980-1992 (in million tonnes) (Sources: OECD and Norwegian Meteorological Institute.)

equipment and a switch to cleaner fuels. In the 1980s, an increased awareness of the environmental damage caused by acidification prompted many governments in western Europe to reduce SO_2 emissions. Pollution control was technically easy to implement since most of the sulphur dioxide was emitted by stationary sources such as power plants.

The efforts to curb SO_2 emissions in Germany are particularly interesting because of the unification of West and East Germany. In the beginning of the 1980s, desulphurization equipment was installed in West German power plants. Emissions of sulphur dioxide decreased steadily in the 1980s and then stabilized on a level of about one million tonnes per year. In 1992, total SO_2 emissions in West Germany were only 27 per cent of the emission level in 1980.

By contrast, virtually no actions were taken in East Germany to reduce SO_2 emissions in the 1980s. Between 1980 and 1993, total emissions increased by 20 per cent because of a growing energy demand and an intensified use of lignite. East Germany's total SO_2 emissions exceeded 5 million tonnes in 1989. After the unification of Germany, air pollution control in East Germany was adapted to West German standards and total emissions fell sharply. Power stations and industrial plants with high emission rates were taken out of operation. Another reason for the decrease in East Germany's SO_2 emissions after 1989 was that coal consumption fell as a result of decreasing energy demand.

Like East Germany, Poland's sulphur dioxide emissions fell drastically after 1989. Between 1988 and 1994, total SO_2 emissions dropped by more than 30 per cent. The Polish emission reduction was not a result of desulphurization at power plants; it was caused by other factors. Because of higher coal prices and stricter emission control by authorities, power plants and other emitters switched to coal with lower sulphur content and improved their efficiency. The fact that such a substantial drop in emissions was possible in Poland without the installation of de-sulphurization equipment proves that the organization of energy production in the former centrally planned economies was very inefficient. The stricter enforcement of air-pollution control that was introduced by the Polish government in 1990-1991 has also influenced power plants. Many power stations are now installing desulphurization equipment to reduce their SO_2 emissions further.

Developments in Estonia, Latvia, Lithuania and Russia in the 1990s have been similar to those in Poland. Total emissions decreased markedly as the result of falling energy demand and reduced consumption of fossil fuels. However, it remains to be seen whether these countries will be successful in controlling their emissions. Most power plants and other large emitters in eastern Europe still lack equipment to control sulphur dioxide emissions. They also lack the necessary financial resources to invest in such equipment.

5.

Renewable energy I

Efficient use of biomass

5.1 Efficient use of biomass in Sweden

(5.1–5.2 Per Svenningsson and Pål Börjesson)

The fact that biomass has become a modern, established and mature part of Sweden's energy supply can be attributed to a number of factors:

- favourable natural conditions with a mix of boreal forests, fertile arable soils and sufficient precipitation, as well as a low population density;
- a tradition of biomass use and an appropriate infrastructure, including a large forest industry and extensive use of district heating;
- an institutional structure in which both forest fuels and agricultural fuels are produced, traded and used by well-established actors and
- political support for the use of renewable resources.

Since the oil crises in the 1970s, Swedish energy taxes have been high by international standards. In 1993, the tax structure was revised to reflect better the environmental impact of energy use. Emission taxes on fuels producing nitrogen-, sulphur-, and carbon-dioxide were introduced. The taxes were sufficiently high to make biomass cheaper than coal and oil. There is no carbon dioxide tax for electricity production, however, and the tax level is much lower for industrial users than for private users.

The largest potential sources of biomass are logging residues from forests, biomass from managed plantations on agricultural land and residues from food production, mainly straw (Table 5.1). Today, 10–20 per cent of potential logging residues is used, while biomass plantations in the form of short-rotation forests (SRF) and energy grasses play a minor but rapidly growing role. By-products of the forest industry, such as digester liquors and bark are also used extensively.

> Biomass plays an important role in the Swedish energy system. It provided 16 per cent of the total energy supply in 1994. The average for industrialized countries is 3 per cent. Biomass fuel use in Sweden could potentially inacrease by some 150 per cent, that is, up to a level matching Sweden's current oil use but, even at that level, it would still not suffice for both electricity/heat production and transportation. This highlights the importance of efficient systems for the production, conversion and end-use of biomass fuels.

Substitution of fossil fuels by biomass reduces net anthropogenic CO_2 emissions and thereby has a mitigating effect on climate change. The production and use of biomass, however, must be acceptable in an overall environmental perspective. Strategies for achieving and sustaining high biomass yields must consider nature conservation and biodiversi-ty. Such strategies may include:

- the choice of perennial crops, like SRF and energy grasses, which maintain or increase the content of organic matter in the soil and also reduce nutrient leakage in comparison with annual crops;
- compensation for nutrient losses at harvest by leaving some crop and logging residues at the site and by recirculating ashes; and
- protection of areas for native flora and fauna in order to maintain biological diversity.

SRF cultivation, in particular, is being recognized for additional environmental benefits. It may be used to absorb nutrients from sewage water (resulting in a higher biomass production) and thereby reduce investments in water-treatment plants or to absorb cadmium from agricultural soils. With an appropriate plantation layout, SRF cultivation may also reduce soil erosion.

Compared to fossil fuels, energy crops and logging residues show a strongly positive energy balance, that is the energy content of the biomass divided by the direct and indirect energy input needed for production, including tractor fuels, energy consumption for the production of fertilizers, etc. The balance is between 20 and 30 on present production conditions.

The net energy yield per hectare (energy output – energy input) is another important indicator since the number of available hectares is limited. Breeding efforts, technological development and improved cultivation systems could significantly increase the energy balance and the net energy yield. If, for example, 800,000 ha of set-aside land were used for SRF production in Sweden in 2015, about 70 TWh/year could be produced. Energy use for biomass transportation could, with proper logistics, be kept at less than 5 per cent of the energy content of the transported biomass. Annual

Biofuels in the Swedish energy system in 1994

In 1994, Sweden's use of biofuels was 71 TWh, corresponding to 16 per cent of its total energy supply. Biofuels include digester liquors from pulp mills, wood fuels (logs, bark, sawdust and energy plantations), straw and energy grasses. They are used in four main areas: a) the forest products industry, b) district-heating plants, c) single-family houses and d) for electricity production.

a) THE FOREST PRODUCTS INDUSTRY

Digester liquors in the cellulose industry provided 30 TWh (excluding electricity production) for internal use. Wood residues, mainly wood chips, bark and other wastes, were used in the cellulose industry (8.5 TWh) and in sawmills (7.4 TWh).

b) DISTRICT-HEATING PLANTS

District-heating plants used 11 TWh of biofuels (20 per cent of its total primary energy use): 10 TWh of wood fuels and 1 TWh of unrefined tall oil (a residue from pulp production). The use of wood fuels in district-heating tripled between 1989 and 1994 and, in 1994, increased by 2.2 TWh or almost 30 per cent. Logging residues and forest by-products dominate, although the use of refined fuels such as briquettes and pellets is increasing. Energy crops, such as Salix (short-rotation forests, SRF), straw and energy grasses have been used experimentally since the beginning of the 1990s and about 100 GWh of straw and energy grass and 50 GWh of Salix were used during 1994. Salix plantations have increased significantly during recent years and the area already planted corresponds to 1 TWh/year. A minor proportion (0.5–1.0 TWh) of biofuels were imported.

c) SINGLE-FAMILY HOUSES

About 12 TWh of wood fuels, mainly in the form of logs and chips, were used in single-family houses for heating. Wood-firing is common in agricultural and rural areas.

d) ELECTRICITY PRODUCTION

2.4 TWh of biofuels were used for electricity production, mainly in combined heat and power (CHP) plants in the forest industry, using digester liquors. About 0.2 TWh were produced by wood fuels in CHP plants in district-heating.

crops, such as wheat and rape, may have net energy yields close to those of energy grasses but have a larger environmental impact and a less favourable energy balance.

5.2 Biomass for heat, electricity and fuel

Biomass production costs (mainly for logging residues) decreased by more than 40 per cent in Sweden between 1984 and 1994 as a result of improvements in forestry and agriculture. The price difference, excluding taxes, between biomass and fossil fuels has thus decreased. On an energy content basis, the world market price of oil is about 20 per cent lower and the price of coal is less than half of current biomass prices. If taxes are included, coal and oil cost more per energy unit than biomass for the Swedish consumer. This is an effect of energy and environmental taxes, notably the CO_2 tax on fossil fuels. For heat production in district-heating systems and individual boilers, biomass is now the most cost-effective alternative. For electricity production and industrial use, however, there is no clear tax incentive for biomass.

If biomass is to account for a large proportion of heat and electricity production, it must be used efficiently and in an environmentally acceptable way in a wide range of heat and power plants. At least three energy system sizes may be identified: systems for heating single houses, heating a few buildings from a central system and large-scale systems for district heat and electricity production. In the first two cases, refined biomass fuels, such as

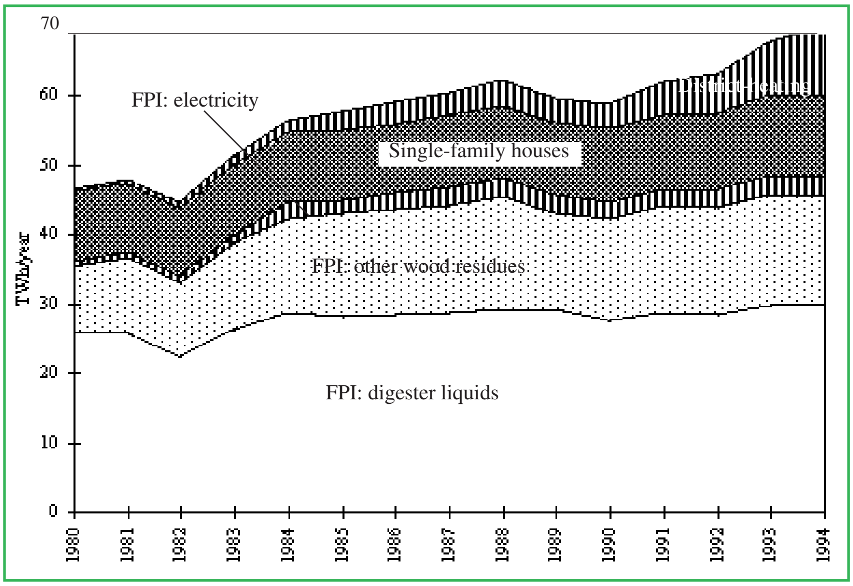


Figure 5.1 Biofuel use in Sweden 1980-1994 (FPI = Forest products industry)

pellets or briquettes, are preferable for economic and environmental reasons. Larger systems can convert unrefined fuels at low emission levels with proper combustion control.

Heat production from biomass is a mature and established technology. Large boilers for district-heat production have very high efficiencies (> 90 per cent), and flue gas condensation could be utilized to increase efficiencies further. Normally, cyclones are used for particle emissions' control. In small-scale heating, emissions of volatile organic compounds may occur, in particular from intermittently fired boilers with poor control systems. Modern boilers, however, have acceptable emission levels. New technologies exist for the conversion of small-scale oil boilers to biomass in the form of pellets.

For electricity production, in cogeneration or condensing mode, standard steam-turbine technology may be used. Large plants may have electric efficiencies of 30–40 per cent, while small steam-turbine systems (<25 MW) are generally expensive and inefficient.

Thermochemical gasification is a promising option to make biomass an available fuel for new and advanced electricity-production technologies, such as different gas-turbine systems. This technology has a higher electricity efficiency than conventional technologies and is close to being commercially viable, with a few demonstration projects operating or under construction.

District-heating systems offer excellent opportunities to use biomass resources for cogeneration of heat and electricity on an appropriate scale. A broad implementation of such cogeneration plants could yield some 20 TWh/year of electricity (about 15 per cent of Sweden's current electricity production) with only half the fuel input of conventional condensing plants.

Electricity production costs (excluding taxes) are higher for biomass than for fossil fuels, although the difference is small for most cogeneration schemes. The successful development of new biomass-based technologies will decrease the costs further. If the CO_2 tax on fossil fuels were to include electricity production, the development of such technologies would probably accelerate.

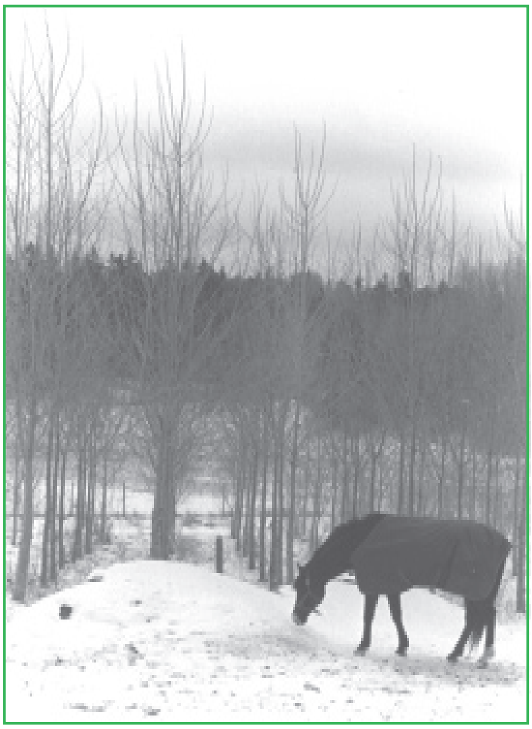


Figure 5.2 Energy forest outside Uppsala, Sweden.

Table 5.1 Estimated potential for biomass production in Sweden within 10–20 years. Total Swedish energy supply in 1994 was 460 TWh.

Biomass resources	*Energy potential (TWh / year)*
From the forestry sector[a]	
Logging residues	48–59
By-products from the forest industry	43–47
Recycled wood products (mainly from demolished buildings)	4
Total	95–110
From the agricultural sector[b]	
Short-rotation forest	38–46
Energy grass	2
Straw	11
Total	51–59
Total potential from forestry and agriculture	**146–169**

[a] From an Official Report of the Swedish government. Other estimates suggest a larger potential.

[b] Energy crops cultivated on 800,000 hectares of set-aside land not needed for food production; equivalent to 30 per cent of total arable land.

Transportation accounts for about 20 per cent of final energy use in Sweden and more than 40 per cent of the total CO_2 emissions from fossil fuels. Several energy carriers (including electricity) that are capable of replacing fossil fuels for transportation can be produced from biomass. Vegetable oils, biogas, ethanol, methanol and hydrogen are available options. They can all be used in internal-combustion (IC) engines, although slight construction changes are required for some biofuels to convert the standard petrol or diesel engines.

The most versatile and energy-efficient biomass-based transportation fuel appears to be methanol. It could be produced from a variety of feedstocks, in particular wood-fuels, which are the most abundant fuel resource. It could in the short term be mixed with petrol, in the medium term it could serve as stand-alone fuel in IC engines and in the long-term it could be used as a hydrogen-carrier for use in fuel cells. One hectare of SRF could supply methanol for about ten cars with fuel cells and up to five cars with IC engines. One hectare of rape seed oil or ethanol from wheat could supply 1–2 cars, while

Renovation of apartment buildings in the Baltic states and Russia

by Eric Martinot

MUCH TO BE SAVED

Multi-family apartment buildings in Estonia, Latvia, Lithuania and Russia were constructed to similar Soviet standards in the 1960s, 1970s and 1980s. These buildings typically consume 20–50 per cent more heat and hot water than multi-family buildings of equivalent size in comparable climates in other European countries because the thermal level of wall insulation is lower, the ventilation systems transfer more heated air to the outside, the heat supply to the building is poorly regulated and heat distribution within the building is poorly controlled and balanced. Various retrofit measures can be applied to these buildings to improve the efficiency of energy use and reduce energy consumption by 10–50 per cent depending on the retrofit measures applied. A basic set of measures could save about 25 per cent of the heat and hot-water consumption, cost 600,000 to 1 million SEK (90,000 to 140,000 USD) and reimburse the investment cost after about five years of energy savings.

In some renovations, retrofit measures not only save energy but contribute to lower maintenance costs and other benefits. These types of retrofit measure are important economically to residents because monthly heating costs for a typical apartment may approach 50 per cent of the average monthly wage in these countries now that government subsidies are eliminated or decreasing and energy is market-priced. Heat for these buildings is produced in centralized district-heating systems and improvements in the energy efficiency of the district-heating systems themselves are also important.

A HOUSE IN TALLINN

In Tallinn, Estonia, one 5-storey 80-unit residential apartment building was renovated for greater energy efficiency in 1993 and 1994 as a demonstration, with grants from the Estonian and Finnish governments. The total cost of the project, including design, project management, materials and equipment and installation, was about 3 million SEK (420,000 USD). The project was intended as a show-case for all the different types of measure possible, although it was too expensive to represent a typical retrofit project. In this building, all of the internal hot-water pipes were replaced with insulated pipes (and the cold-water pipes were also replaced for consistency). A new sub-station was installed in the basement with a controller to regulate the heat supply to the whole building and with new heat exchangers for space-heating and hot water. New radiators with radiator thermostat valves were installed so that residents could control heat supply to their apartments. Ventilation systems were improved with roof-top fans to keep the air-infiltration rates constant. Windows were repaired and weatherproofed (or 'tightened'). New building-entrance doors reduced outside air flow into the inside stairwells. Wall insulation was applied to the outside of the building on the two windowless sides and underneath the roof on the top floor (wall insulation is generally very expensive but when combined with other measures can prove cost-effective). The roof of the building had already been insulated the year before these retrofits.

The estimated energy savings from this complete package of improvements were 40–55 per cent,

wood-based ethanol would have a slightly better yield.

Commercially and technically, the option of producing heat and electricity from biomass is closer to being realized than the alternative of using biomass for transportation and efficiency in reducing fossil CO2 emissions appears to be greater for heat and electricity production which have a higher energy-conversion efficiency than IC engines.

5.3 Conversion of heating boilers from oil to biomass

(5.3–5.4 by Jürgen Salay and Eric Martinot)

In many smaller towns in Estonia, Latvia, Lithuania and Russia, small heating boilers supply hot water to centralized district-heating networks to provide space-heating and domestic hot water for buildings. These boilers often operate on heavy fuel oil or coal which are among the greatest sources of additional carbon-dioxide (CO_2) emissions to the atmosphere. The sulphur dioxide (SO_2) emissions from these boilers are significant causes of acid rain and environmental disruption and the heat and hot water costs based upon these fuels comprise a significant proportion of monthly income for most residents. These small boilers can be converted to burn biomass fuels (wood wastes, forest clearings and thinnings and peat).

resulting in a simple pay-back time of 10–15 years depending on the existing level of heat supply and on whether non-energy-related renovation measures like staircase repairs are included in the costs. If some of the less cost-effective measures were removed from the package, the simple pay-back time would be under 10 years. The World Bank has been following the results of this demonstration in considering loans for energy-efficiency retrofits to buildings in Estonia and the demonstrated cost-effectiveness of different retrofit measures has provided valuable experience for similar projects elsewhere.

THE INSTITUTIONAL QUESTIONS

The institutional issues of these types of renovation are complex. Residents may own their own apartments after privatization but the municipal government still maintains and operates the building itself and is responsible for improvements to it. For residents to be able to make energy-efficiency investments in their building, several institutional changes are required. The residents must form a legal entity, a so-called 'owner association', that will take over responsibility for maintenance, operations and improvements to the building. But residents may be reluctant to assume responsibility for these buildings, because they are in poor repair and may even be dangerous, and municipal governments may not surrender responsibility until all debts owed by tenants are paid. Then the owner association must either save up capital over many years with which to make improvements or must try to secure a loan from a commercial bank.

But collateral for such a loan is a problem; the owner association may not be able to pledge the apartments of its individual members as collateral for the loan. (In Lithuania a law now exists that enables owner associations to borrow money and force its members to repay the loan with the penalty of eviction and apartment confiscation if tenants do not comply, but the viability of such a law in practice is still an open question). Then to make the renovations, the owner association must either contract with a third-party general contractor to design, purchase and install energy-efficiency retrofits, or must try to perform these functions itself or contract for them individually. Here, access to information about technical measures and economic and financial analysis is a barrier. The requirement for management ability by the owner association itself is another barrier.

HOW MUCH SHOULD WE PAY?

Metering and billing represents another complex issue in the Baltic states and Russia. Today, individual tenants pay a fixed monthly amount for heat according to the floor area of their apartments. If a heat meter is installed to measure heat consumption by the building as a whole, and the building as a whole is billed for heat according to the aggregate reading, a collective incentive is created to save heat. But individual tenants still do not reap the full rewards of their individual energy-saving behaviour or additional energy-efficiency improvements they may make in their apartments, since the energy savings will be divided among all the residents in the building (the so-called 'free-rider' problem). Individual meters can be installed in each apartment to create individual incentives to save heat, but individual metering is costly and impractical. Radiator stick-on heat allocators may be used to allocate better the aggregate consumption to individual tenants, but these allocators are prone to being tampered with. Developing innovative institutional, technical and social arrangements to meter and bill for individual heat consumption is important to create incentives for energy-saving actions and energy-efficiency investments.

Sweden's experience in transforming and developing its heating system shows that great improvements can be obtained if renewable energy sources such as wood waste and other biofuels are used to a larger extent. If wood wastes or forest resources that are harvested sustainably are used, the net CO_2 emissions are zero after the conversion which is another important benefit because of the impact of atmospheric carbon dioxide on global climate change.

The biomass fuels can be significantly cheaper than fuel oil or coal, thus providing important economic benefits in these regions. Domestic-equipment production and the installation of these boiler conversions can also provide local economic development benefits. The three Baltic states and Russia have favourable preconditions for an increased use of biofuels because of their ample forest resources.

5.4 A Programme for boiler conversion in the Eastern Baltic region

The Swedish programme for an Environmentally Adapted Energy System in the Baltic Region and Eastern Europe (EAES) started in 1993. It is managed by the Swedish National Board for Industrial and Technical Development (NUTEK). The EAES programme is formulated in line with the United Nation's Framework Convention on Climate

Change (FCCC) and is the Swedish contribution to the pilot phase for activities implemented jointly under the Convention.

The aim of the programme is to improve energy systems in the Baltic region through energy-efficiency measures and the use of renewable energy sources. The main programme activities are directed towards reductions of emissions hazardous to the climate and the environment from oil- and coal-fired energy production plants, as well as the upgrading of heat-distribution systems. (See Figure 5.2) For these purposes, a total of 277.5 million SEK (about 40 million USD) was allocated between 1993 and 1996 by the Swedish government for the EAES programme.

Three main goals were formulated for the EAES programme: the projects should be quick, simple and affordable, and use reliable technology. Priority was given to small and medium-sized projects which can be implemented within a year and do not require extensive coordination or expensive feasibility studies. To make the projects simple and affordable the avoided costs of the fossil fuels formerly used at the project sites pay for the new equipment and fuel within a reasonable time. Reliable technology, that is, technology that has proved to function well in earlier cases, is used in the projects.

Other important features of the programme are partnership, cost-efficiency and sustainability. The partnership attitude is demonstrated through adaptation to the local situation with regard to economy and technology in combination with a demand for local engagement and the commitment of the plant owner throughout the whole implementation process of a project. Another element is to use local expertise and technological skills, focusing the Swedish assistance on management and market-economy principles.

To cover the investment costs, NUTEK offers a loan to the plant owner (for example, a municipality). NUTEK also supports the plant owner with a consultant who works closely together with the local project leader through all the phases of implementation, namely, the drafting of and the invitation to tender, evaluation of offers, procurement of equipment and entrepreneurial works, supervision of installations and construction works, training of staff, etc.

5.5 Financing

Cost-efficiency means that procurement of equipment and services are made in open competition where local companies have equal opportunities to participate, thereby making it possible to take full advantage of differences in wages and other costs. The sustainability requirement is met by evaluating the performance and operation results of implemented projects as well as through measurements of emissions. The owners of the converted boiler plants are supplied with adequate measuring equipment.

For the investment costs, NUTEK offers the plant owners loans on favourable conditions. The loans are paid back in 10 years with the possibility of a period of grace of two years before repayment of the loan has to start. Depending on the ownership, the security can be in the form of a mortgage of the plant, a guarantee from the municipality or a state guarantee. The pay-back time (that is, the time needed for the avoided costs to cover the investment costs) for conversion projects is estimated at 3–6 years. An indication of the economic viability of the boiler conversions is that a number of plant owners have chosen to start repayments earlier than set out in the loan agreements because of the positive economic results of the conversions. The repayments and interest paid on the loans are invested in a so-called 'revolving fund', which allows the money

The United Nation's Framework Convention on Climate Change (FCCC)

The Framework Convention on Climate Change (FCCC) was signed at the UN Conference on Environment and Development (UNCED) in Rio de Janeiro in 1992. The aim of this agreement is to stabilize atmospheric concentrations of greenhouse gases at levels that will prevent human activities from interfering dangerously with the global climate. The signatory parties of the FCCC agreed to implement national programmes to achieve the objective of the convention. They also agreed to promote and support transfer to developing countries and to so-called 'countries in transition' (that is, the former centrally planned economies) of technologies, practices and processes that control, reduce or prevent anthropogenic emissions of greenhouse gas. In this context, the possibility of implementing measures jointly was particularly stressed. One such area pointed out as especially important and suitable for activities to be implemented jointly (AIJ) is the energy sector.

The parties to the FCCC could not agree on specific targets for emissions reductions, but a number of activities aimed at protecting the atmosphere are specified in the action plan, Agenda 21, from the UNCED meeting. The first session of the parties to the FCCC was held in Berlin in 1995 and it is expected that the parties, perhaps in 1997, will be asked to adopt a protocol - a separate legal agreement under the FCCC - defining emission constraints for industrialized countries. At the Berlin meeting, it was decided to begin a pilot phase for AIJ. The projects within the Swedish EAES programme are included in this pilot phase.

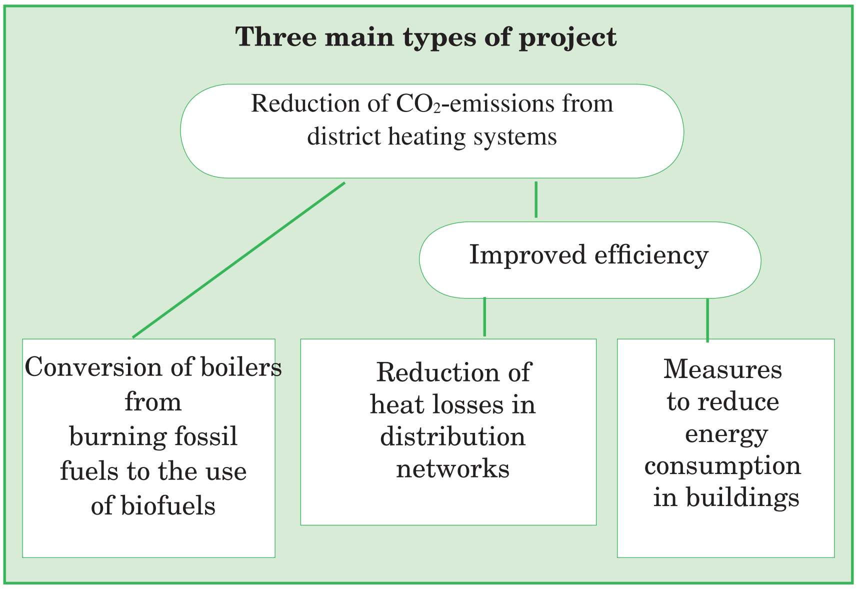


Figure 5.2 The Swedish programme for an Environmentally Adapted Energy System in the Baltic Region and eastern Europe

from the EAES programme to be used for financing future projects.

By the beginning of 1996 about 50 projects had been supported by the EAES programme, of which 35–40 had been implemented. About half of the projects were boiler conversions at different locations in Estonia, Latvia, Lithuania and Russia. Data on the costs and results of the boiler conversion projects are summarized in Table 5.2. The total converted boiler capacity amounts to about 100 MW at an average cost of 0.96 million SEK (about 0.14 million USD) per MW. Total emission reductions are estimated at about 200,000 tonnes CO_2 per year and 2,313 tonnes SO_2 per year. Four of the boiler conversion projects are described below.

5.6 Four cases

Paldiski

Paldiski in Estonia was, during the time of the Soviet Union, a military city which was restricted for civilians. After Estonia regained independence, the military left and the city, which has about 4,500 inhabitants, is being restructured. In the central boiler plant of the city, one boiler was converted to burning wood chips through the installation of a pre-furnace. The investment

Table 5.2 Data on boiler conversion projects in the Baltic States and the Russian Federation.

Plant	*Investment* *MSEK*	*Capacity* *(MUSD)***	*Inv/Cap* *MW*	*Energy productions* *MSEK/MW*	*MWh/y*	*Reductions* SO_2 *tonnes/y*	CO_2 *tonnes/y*	NO_x *tonnes/y*
Valga	3.8	0.542	5.0	0.76	20,000	98	6,400	6.8
Haabneeme/Tallinn	4.7	0.671	6.0	0.76	38,000	189	12,400	1.1
Aaardla/Tartu	5.6	0.800	6..0	0.93	30,000	149	9,800	2.0
Vorusoo/Voru	5.0	0.714	7.0	0.71	35,000	174	11,400	3.6 *
Balvi	2.1	0.300	2.4	0.88	15,000	51	13.200	5.6 *
Aluksne	5.6	0.800	5.0	1.12	28,000	98	25.400	12.5
Janmuiza/Cesis	3.9	0.557	3.0	1.30	12,000	30	2,800	2.1 *
Slampe	3.5	0.500	3.0	1.17	12,000	60	3,900	1.0 *
Ugale	1.5	0.214	3.0	0.50	12,000	68	4,400	2.7
Birzai	5.2	0.742	6.2	0.84	35,000	174	11,400	8.1
Kazlu Ruda	2.4	0.342	3.0	0.80	12,000	68	4,400	2.7
AS ESRO, Viljandi	5.0	0.714	6.0	0.83	30,000	149	9.800	4.5
Narva-Joesuu	6.3	0.900	6.0	1.05	25,000	125	8,100	3.7
Paldiski	6.5	0.928	6.0	1.08	25,000	125	8,100	3.7
Jurmala	5.9	0,842	6.0	0.98	40,000	0	9,400	–
Daugavgrieva	7.0	1.000	6.0	1.17	30,000	169	11,100	6.7
Baisogala	3.9	0.557	3.0	1.30	12,000	42	10,900	4.9
Vienybe, Ukmerge	6.0	0.857	6.0	1.00	38,000	215	14,000	8.5
Varena	6.0	0.857	8.0	0.75	60,000	299	19,500	9.0
Lisino	2.4	0.342	2.0	1.20	10,000	30	3,900	2.6
Sum	**92.3**	**13.179**	**98.6**		**519,000**	**2,313**	**201,300**	**91.8**
Average	**4.6**	**0.659**	**4.9**	**0.96**	**25,950**	**115**	**10,065**	**4.6**
Specific investment SEK/kg						**39.9**	**0.46**	**1,005**

* These measurements were done under adverse conditions. Their long-term NO_x savings are expected to be higher.
** 1 UD = 7 SEK

cost was 6.5 million SEK (about 1 million USD). The wood chips will replace about 3,500 tons of fuel oil per year. The output power after conversion is 6 MW and the estimated annual heat production is around 25,000 MWh. The converted plant was commissioned in March 1996.

Slampe

Slampe is a small Latvian town west of Riga. It has 2,500 inhabitants. Heat for the whole town is produced by a boiler plant with two heating boilers burning oil. One of the boilers was converted to biofuel use. Automatic fuel storage, a wood-chipper and flue-gas cleaning were also included. After conversion, the capacity of the boiler is 3.0 MW. The annual heat production of the converted boiler is 12,000 MWh, which corresponds to a consumption of 1,300 tonnes of light fuel oil per year. Total conversion cost was 3.5 million SEK (0.5 million USD). The converted boiler was commissioned in October 1994.

Birzai

The district-heating company in Birzai in northern Lithuania has two heating plants. At one of the plants, one of two oil-fired heating boilers was converted to wood-chip firing. The equipment installed is similar to that at Slampe. The boiler capacity after conversion is 6.2 MW and the annual heat production is 35,000 MWh. Investment cost was 5.2 million SEK (0.74 million USD). As a result of the conversion to biofuels, about 3,600 tonnes of heavy fuel oil are avoided annually. The converted boiler was commissioned in January 1994.

Lisino

The Forest College at Lisino outside St Petersburg in Russia has a long tradition of education in forest management. The college has 700 students and 400 employees and is the owner of 91,000 hectares of forest land. A new 2.0 MW boiler was installed with a pre-furnace for wood-chip firing. It will replace about 1,000 tonnes of oil per year and have an estimated annual heat production of 10,000 MWh. The investment cost is 2.4 million SEK (0.34 million USD). The boiler was commissioned in April 1996. Since the Forest College is an institution of higher education, its converted boiler will have a great demonstration value. The college will also arrange training courses in sustainable wood-fuel production techniques.

Wood-fuel markets and environmental regulations are important issues for this type of conversion. The markets for biomass fuels and their price and availability depend very much on wood-waste availability, overall demand and forest-harvesting policies and practices. If wood-fuel prices increase relative to fuel-oil prices, the economic attractiveness of such investments decreases (although the environmental benefits remain) and plants may be left with a loan for which they have no net operational savings to repay it.

Many factors can influence wood-fuel markets and it is difficult to predict how they will develop in the three Baltic states and Russia. Increased market demand for wood can also have adverse environmental effects on forest resources if adequate forest management and harvesting regulations do not exist or are not enforced.

6.

Renewable Energy II
Sun, wind and water

6.1 Wind power in Denmark

(6.1 – 6.5 by Peter Helby)

Wind power has always fascinated the Danes. The geography of the country made Denmark a sea-going nation with a large merchant fleet and lots of fishing boats. On the sea, wind was hugely important as a source of power. On land, other nations fuelled their technological and economic development with domestic energy sources such as hydropower, wood or coal. Denmark had precious little of these. Like Holland, it depended on wind as the major form of mechanical power.

Even in the twentieth century, wind has been an important power source in Denmark. Danish farmers had tens of thousands wind turbines in action – pumping water, threshing crops and providing other mechanical energy. Wind power was often quite competitive in comparison with more sophisticated technologies. Wind power was not dependent on imports. That was a major advantage during the two World Wars and in the 1930s, when the international trade system broke down. In the 1950s, however, wind turbines disappeared from the landscape, being replaced by Otto- and diesel-engines and electric power.

The first adaptation of a wind turbine to produce electric power happened in 1891 at an educational centre of the Danish farmers' movement. Large-scale electric-power-producing wind turbines were built during the Second World War and in the 1950s. The culmination was the 1.2 MW Gedser wind turbine built in 1956. (Modern wind turbines are mostly between 250–750 kW). After that, wind power was forgotten for two decades. Cheap Middle East oil flooded the country and energy planners were dreaming of nuclear power 'too cheap to meter'. Wind is an abundant, but not a cheap, source of power.

In the past 15 years, wind power has truly come of age in Denmark. Wind turbines now provide 4 per cent of Denmark's electric power – the highest proportion in Europe. Wind turbines and associated components are now major export commodities. 85 per cent of Danish wind turbines are produced for export. Around 3 per cent of industrial workers are employed in the wind-turbine industry.

6.2 Why wind power?

Wind power is still expensive. It is now 10–30 per cent more expensive than power from fossil fuels, such as natural gas or coal. It does, however, have two significant advantages: it emits no carbon-dioxide (CO_2) and it does not require import of fossil fuels.

Import of fossil fuels is not really an economic problem for Denmark. The country is well integrated in the world economy and has large incomes from industrial and agricultural exports. The reason why Denmark is using more and more wind power is the CO_2 problem. Denmark has a national goal to reduce CO_2 emissions by 20 per cent between 1988 and 2005. This requires a lot of investment in energy efficiency and renewable energy sources. Compared with other methods, wind power is a cheap way to reduce CO_2 emissions.

For countries in a more precarious economic situation, the opportunity to reduce energy import costs may be a significant reason to develop wind power. India has a large wind-power programme, partly for this reason. The same motive might apply to the former centrally planned economies around the Baltic Sea, which possess good engineering capabilities, but have trouble earning foreign currency. If wind turbines were produced domestically in such Baltic countries (or in some kind of joint venture creating exports to balance the imports) wind power might be an attractive option, because it creates employment and saves foreign currency.

6.3 How to build a wind turbine

A modern wind turbine is quite a sophisticated piece of technology. The forces working on blades, gears and the generator are large and very irregular. Without design and components of very high quality, the parts will wear down quickly and breakdowns will be common. This was a major problem for the first generations of American and Danish wind turbines in the 1980s and in fact often spoiled their economy and gave wind power a bad reputation.

Contemporary wind turbines only lose 1–2 per cent of their production due to failures and maintenance. The maintenance costs are very low, typically 1–2 per cent of the investment cost per year. (Try to compare this with your car!). Typically, an engineer inspects the wind turbine twice a year, replaces the oil and makes small adjustments and repairs. Otherwise, a built-in computer continuously diagnoses the workings of the wind turbine. If problems arise, the computer will call the factory or a service company by telephone and make a report. Often the problems can be analyzed without any visit to the wind turbine and operating instructions can be given to the wind turbine by telephone.

Grid connection is quite simple and can be made directly to the nearest 10 or 20 kV line. The wind turbine rotates with a speed that fits the frequency of the grid. The only interface necessary is thus some kind of emergency switch, which disconnects the wind turbine when there are disturbances on the grid.

Figure 6.1 A row of wind mills outside Ebeltoft at Aarhus, Denmark (Photo: John Sommer, © The Danish Tourist Board).

6.4 The economy of windmills

Looking at the Danish landscape, you could easily imagine that wind turbines grew by themselves from seeds, like trees and flowers. They do, however, need to be planted. Some kind of entrepreneur is necessary. The entrepreneurs have typically been farmers and other people living in the countryside. Farmers and other small businessmen often like the idea of producing their own electric power. Many wind turbines have been erected by such individuals as a complement to their main business. Cooperative wind-power projects are also very common in Denmark. People living in the countryside are often fond of decentralized activities and appreciate wind turbines as a way of making money, while reducing CO_2 emissions and protecting the climate.

The initiative for a wind turbine may thus come from a single person or a few friends. They gather more local people who like the idea. Each person or family commits itself to buying a certain number of shares and pays a corresponding amount of money into a bank account. One share typically corresponds to the delivery of 1,000 kWh per year and may cost 500–800 US dollars, depending on the quality of wind. A family often buys 5–10 such shares, because this corresponds to the electric power use of a family. If a family does not have enough savings to pay such an amount at once, a local bank will often provide credit.

The role of electric power utilities has been more limited. The government has forced them to make certain investments, particularly in larger wind farms, which are beyond the financial capacity of individuals and cooperatives. Two of these wind farms have been built at sea in shallow waters. The wind blows more strongly over the sea and production thus can be raised by some 20 per cent. Unfortunately, the costs are about 50 per cent higher than on land, mainly because of the expensive foundations and grid connections. Maintenance is also difficult and costly at sea. Yet the government demands that utilities continue to develop wind power at sea.

Another important activity, which the government has imposed on utilities, has been to buy prototypes of new wind turbines developed by the wind-turbine industry. Thus, measurements, improvements and certification have often been done on turbines owned by the utilities.

6.5 Setting the rules for wind power

The Danish government has not spent much money directly to support wind power but has provided much indirect and non-economic support. Two early steps, which were quite essential for the initial development of wind power, concern the rules that allow people to build wind turbines.

Firstly, environmental restrictions were relaxed at the end of the 1970s. Normally, it is quite difficult to get permission to build any kind of structure in the Danish countryside unless the structure is a direct part of a farm development. Liberal rules were, however, created for wind turbines. In the early days of wind power, it was important that restrictions were few. Now, when wind power is well established, the rules have been made more restrictive. In Sweden, it has been more difficult for individuals and cooperatives to build a local wind turbine because of restrictive rules for protecting the landscape and because of military restrictions.

Secondly, Danish utilities were forced by law to connect private wind turbines to the grid and to pay a fair price for the power. Without this law, many wind-turbine projects would surely have been sabotaged by the electric power utilities which want to dominate the power market themselves. Danish law is quite specific in the demands on utilities. The power price paid to the wind turbine owners is always 85 per cent of the price for small consumers in the local area where the wind turbine is located. The costs of grid connection to the nearest 10 or 20 kV line are paid equally by the wind turbine owners.

Any additional cost beyond that point is paid by the utility. If, for example, the nearest line does not have sufficient capacity, the utility can decide that the connection must be made somewhere else, but it must also cover the additional costs. Such transparent rules have been very important. The rules have made it possible to calculate the costs of and income from a wind-turbine project fairly accurately at the start of the project which is essential for individual and cooperative investments. Also, the rules have made it impossible for utilities to delay projects with complicated negotiations about prices and grid connection. Transparent rules have also been important for wind power in Sweden and Germany.

Income tax rules have favoured family investment in wind power. As long as the number of shares owned by a family corresponds to the family's own power consumption, there has been no tax on the shares in Denmark.

In the early days of wind power, the Danish government provided an investment subsidy for each wind power plant. This subsidy was abolished in 1989. Thus, only a small part of Danish wind power has been built with any investment subsidy. (This is the case also in Germany. In Sweden and Finland, wind power still gets substantial investment subsidies – 35–40 per cent – from government.)

To keep wind-turbine ownership local and small-scale, Denmark has quite restrictive rules. The owner has to live in the same local area where the wind turbine is located. The number of wind-turbine shares which a family may own is also limited. These rules have forced wind-turbine entrepreneurs to get in contact with new owners and have given wind power a kind of democratic profile. About 50,000 Danish families now have wind-turbine shares. Local ownership has also been good for local acceptance of the wind turbines.

On the other hand, these restrictive rules also have negative implications. Joining wind-turbine cooperatives is, in the main, not possible for people in the big cities. Thus, their capital is not made available for wind power, which must rely exclusively on the capital resources of the rural population. In some regions with good wind and sparse population, finding owners for new wind turbines is now very difficult – simply because local people tend to have as many shares as they are allowed. Sweden and Germany are much more liberal than Denmark in these respects.

6.6 Hydro power

(6.6–6.7 by Jürgen Salay is based on J Ramage, "Hydroelectricity" in Boyle, G., Ed. 1996. Renewable Energy: Power for a Sustainable Future)

Like almost all other renewable energy sources, hydro power is indirect solar energy. But unlike renewables such as wind power, solar thermal and photovoltaic energy, hydro power is already a major contributor to world energy supplies. Hydro power plants have been producing electricity at competitive prices for about a century. Hydro power is the principal source of electric power in some 30 countries, and provides about a fifth of the world's annual electricity production.

In contrast to many of the other renewables, hydro power is a very well-established technology. The production costs of hydroelectricity depend on the geographical conditions at the site of the plant which determines the construction or capital

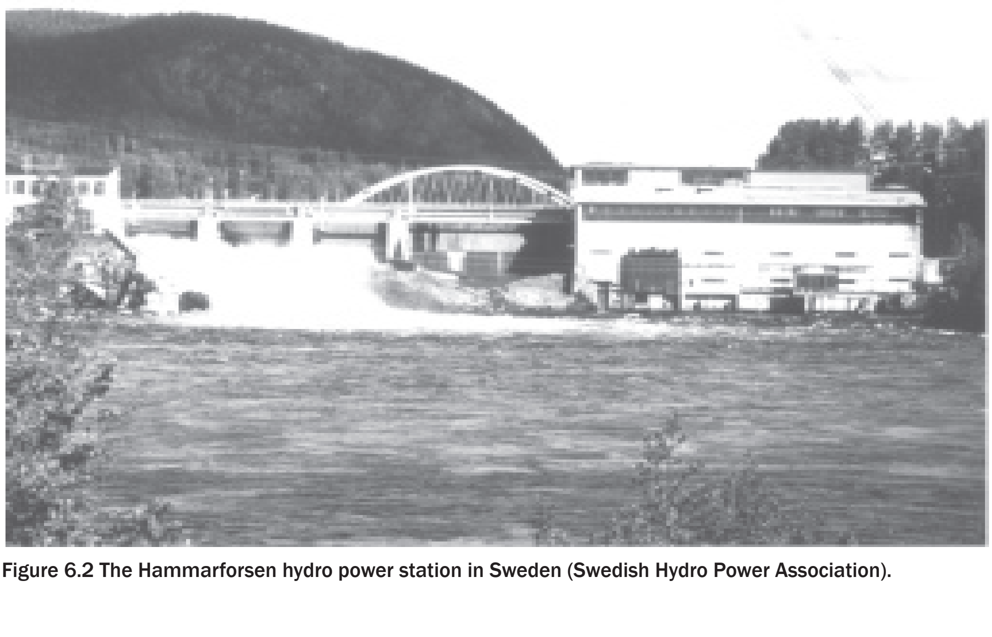


Figure 6.2 The Hammarforsen hydro power station in Sweden (Swedish Hydro Power Association).

costs. They are also dependent on the plant's load factor, i.e. how it is utilized in the integrated power system. At favourable conditions, i.e. low capital costs and high load factor, hydro power is one of the cheapest ways to produce electricity. It is also one of the most efficient; at optimal conditions efficiencies of 95 percent can be achieved.

An important advantage of hydro power plants is that they can be used to store energy. Water is stored in dams as a reserve energy source to meet sudden changes in demand. In northern Europe water is typically stored during spring and summer, when electricity demand tends to be lower, and is used to produce power later in the winter when electricity demand is high.

Another way to store energy is pumped storage systems. In pumped storage systems electrical energy is converted into gravitational potential energy by utiliszing the surplus power from a thermal or a nuclear power station at low demand to drive a pump which raises water into a reservoir. The water in the reservoir can then be used to produce electricity in a hydro power station at times of peak demand. At present, pumped storage systems are the only practicable solution to store electrical energy in large quantities.

Although hydroelectricity has important environmental benefits (e.g. no or little air pollution), large-scale hydropower plants can have negative hydrological, ecological and social effects. The first type of impacts are related to changes in water flows and groundwater level that may occur from the diversion of streams and rivers. Such changes affect the local conditions for water supply and irrigation. The construction of large dams in connection with hydropower plants have other significant consequences for the local environment. Valuable farm and forest land is lost because of the water reservoirs that are blocked by the dams. Sometimes whole valleys are put under water and homes and even entire villages have to be relocated. These effects have to be compared to the benefits the hydro power plant brings, such as electrification and regulation of the river flow to protect from devastating floods.

Because of the negative effects of large-scale hydropower, it has become less viable as an energy source in our part of the world. Moreover, the best sites for hydro power in the Baltic region, which are found in the mountainous northern parts of the Baltic region, are already exploited. The landscape where we find the large rivers in the three Baltic states and in Poland is in comparison very flat. Earlier plans to build power plants, e.g. in upper Daugava in Latvia, are now abandoned. Some undeveloped rivers remain in the northern parts of Finland, Norway and Sweden, but there is a strong public opinion against using these rivers for hydro power.

Figure 6.3 Solar collectors are especially suitable for central heating. The installation at Särö, south of Göteborg in Sweden, serves a small residential area of 48 apartments with 740 m^2 of roof integrated collectors in combination with 640 m^3 of water in an insulated steel tank placed in a rock pit. The installation, in operation since 1989, covers 35 % of annual load and 400 Mwh/y. It would cover 65 % if the storage was enlarged. (Source: Dalenbäck, J-O, 1996) (Photo Alpo Winberg).

6.7 Small scale hydro power plants

Small-scale hydro power, i.e. power plants with a capacity below 5 MW, is a more promising alternative. There is still a significant potential for small hydro power stations in the Baltic region. In the past 50 years or so, the number of small scale hydro power plants in industrialized countries has declined as power companies have invested in larger, more profitable electricity production systems. However, the conditions for small-scale electricity generation are slowly improving again in Europe. One reason for this change is the deregulation of the electricity market which in some countries includes better provisions for independent producers. Another reason is a revived interest in developing domestic energy sources in order to reduce the dependence on electricity imports. In Latvia and Poland, small hydro power stations that have been idle since the Second World War are now being put into operation again.

6.8 Solar-heating and heat storage

(6.8 – 6.9 by Tomas Kåberger)

Direct conversion of solar energy into heat or electricity are increasingly important technologies. With improving performance and decreasing costs, the use of solar energy will increase.

During a cold winter night we need heat, but the sun is not shining then. When the sun does shine on a summer day, we do not need heating. Therefore, to use solar heating extensively, heat storage is necessary.

When solar-heating panels are installed on single-family houses, solar-heating is not the only source of heat. Solar-heating is used to produce hot water during the summer and also some room-heating in spring and autumn. The heat storage capacity is normally a water tank of a couple of cubic metres, storing heat from day to night or from one day to the next. Technically, it is easy to increase the storage capacity but, as long there are other cheap sources of energy available, larger storage devices are not considered economically justified.

Solar-heating systems are installed in hundreds of single-family houses in Sweden every year, sometimes the complementary heat source is biomass, which is conveniently used with the same accumulation tank as the solar-heating panels.

In addition to these small systems, some larger systems, with heat-storage capacity to store heat from summer to winter, have been built in Sweden. In these systems, solar-heating panels, mounted on roofs or as stand-alone units on the ground, all feed heat to a large volume of water in a tank or in an underground cavity containing up to ten thousand cubic metres of water. During the winter, the stored hot water is used to heat houses and water; sometimes the stored heat in the storage device is fed via a heat pump to use energy when the temperature of the storage device is below the desired temperature. For every new system of this kind that has been built, costs have decreased making the technology almost competitive with conventional heat sources.

A small, but economically very interesting, use of solar-heating technology is summer camping sites and outdoor swimming pools where heat is used when the sun is shining.

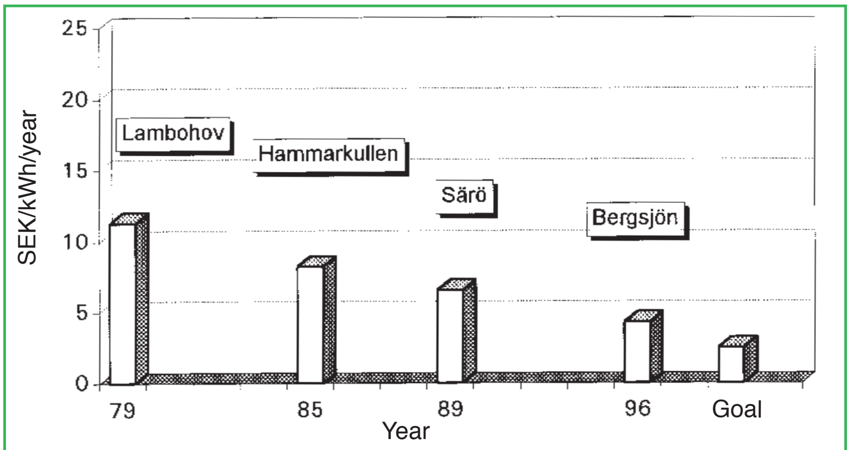


Figure 6.4 The total costs for roof-integrated solar collectors expressed as SEK/ kWh/y has fallen from 12 to 4 over a 17-year period, 1979-96. The expected possible goal is 2.5. (1 SEK=0.14 USD), the same for ground-mounted collectors. The investment costs for large-scale solar collectors is today typically 210–350 USD per m^2. For an installation, the costs for heat stores should be added. (Source: Dalenbäck, J-O, 1996)

6. 9 Solar electricity

Production of electricity directly from light is now a standard technology used in a growing number of applications. In most parts of the world the cost per kWh is still in the order of five times the cost from conventional power plants. But photovoltaics are competitive when they can deliver electricity where it is needed without expensive cables from the electricity grid. This is the case with electronic devices such at watches and calculators, where they also have won the competition with batteries. Photovoltaics have been competitive as sources of electricity for lighthouses or isolated houses in mountain regions. Recently, photovoltaics have proved to be competitive as a source of electricity for electronic parking meters and for powering lights in bus stops in the middle of cities, where connecting to the grid would require the expensive breaking-up of street surfaces.

As with solar-heating, storing energy from moments of sunshine until dark periods is necessary if a continuous electricity supply is desired. In the applications mentioned above, this is done using accumulators.

The production costs for photovoltaics have decreased considerably over the years and the trend of decreasing costs and increasing production is likely to continue. Recently, photovoltaics have become commercial for grid supply in parts of the world where there is a lot of solar radiation and where demand for electricity is highest when the sun is shining the most. On Hawaii, a MW solar power contract costs two USD per peak watt.

When the prices of photovoltaics reach levels at which solar electricity is competitive for grid supply, the intermittent character of solar power becomes even more important. In electricity systems with a significant amount of hydroelectricity, solar power is easily integrated into the system because the variation in production is compensated by controlling the hydro generators. Hydroelectric dams may serve as accumulators of energy by saving water for periods when little sun or wind power is available. As mentioned earlier there are even hydro plants that can be reversed so that electricity is used to pump water up to the dam when there is a power surplus and then to produce electricity using the same water when there is excess power demand.

At present, many different photovoltaic technologies have been developed. However, only a few of these are likely to be competitive in a long-term scenario where solar electricity becomes a main source of world energy supply. The reason is that some of the technologies rely on chemical elements that are scarce in the Earth's crust. Photovoltaics based on pure silicon will not encounter such resource constraints as silicon is one of the Earth's most abundant elements.

The costs of technologies for direct conversion of solar energy are continuously decreasing and there are no reasons why that process should not continue. Therefore one may expect that these technologies will increasingly contribute to the societal energy supply in the Baltic region also; possibly supplying in the order of 10 per cent of electricity and heat within 20 years.

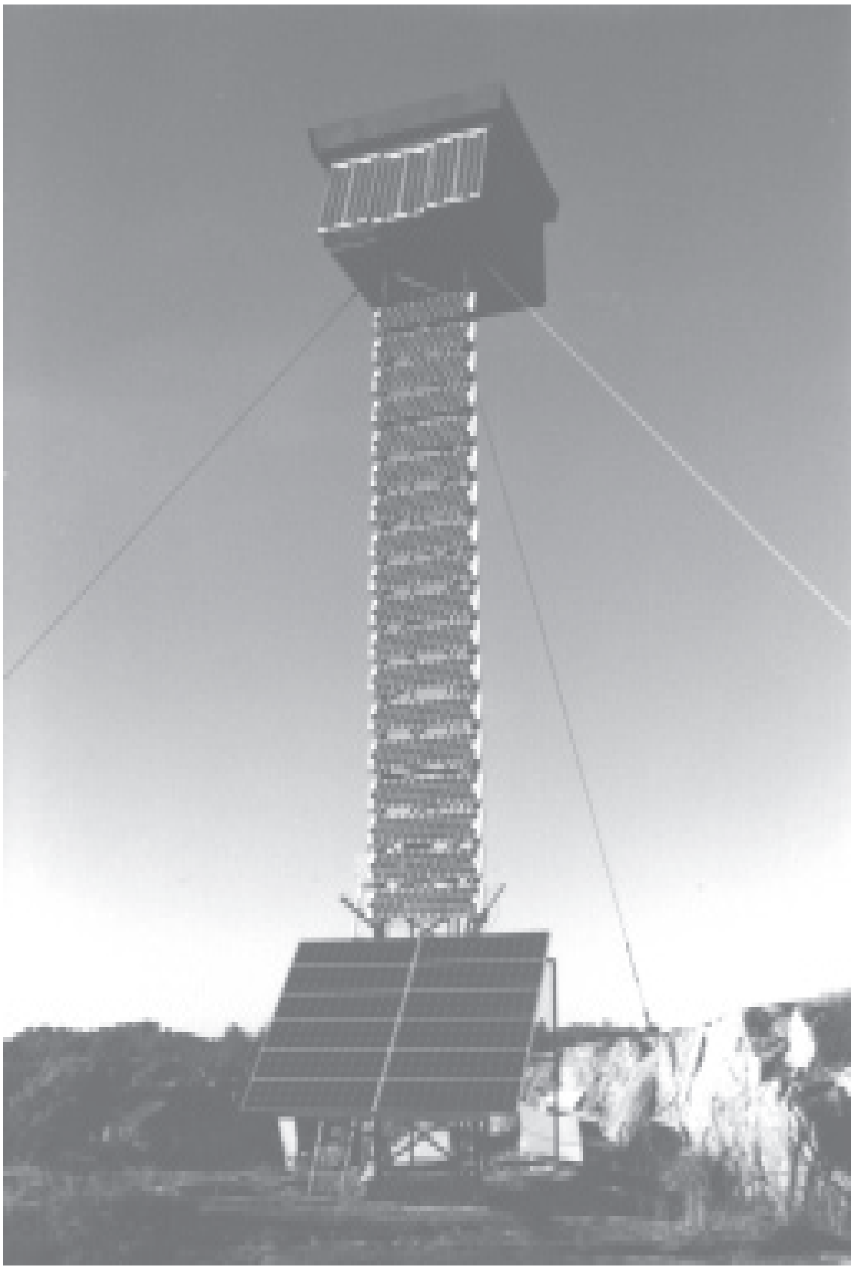


Figure 6.5 The photovoltaic installation on the island of Bullerö in the Stockholm archipelago provides all power needed for one household – lighting, refrigerator, radio, TV etc – and simple machinery. The upper parts are 33 W modules of 1980 design and the lower parts are 55 W modules of 1996 design. The system is used for 48 V voltage and is coupled to a battery aggregate of 750 Ah. Peak effect is 1.45 kW. Transformation to 220 V AC is provided. The total cost is about 20,000 USD. A small wind power station helps during winter and back up is provided by an ordinary petrol motor. (Photo Mats Andersson, who also installed the equipment).

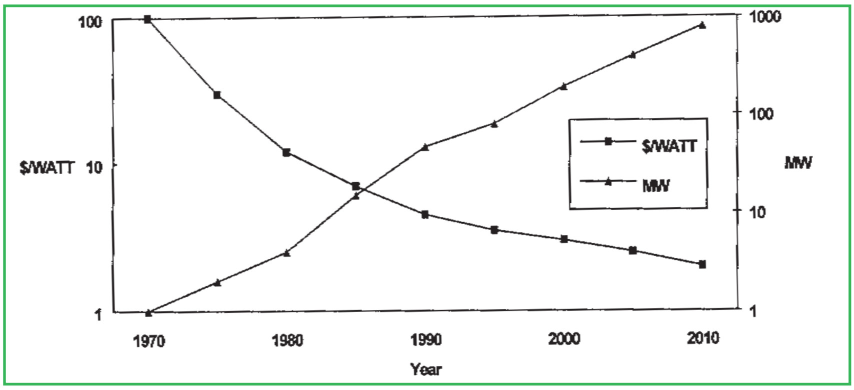


Figure 6.6 Photovoltaic technology, price and market forecast to 2010. After 20 years of development the major PV module providers have recently started to make profits and the long-term prospects for the industry seem very good (Source: Maycock, 1995).

7.

Towards a sustainable energy system in the Baltic region

by Jürgen Salay and Lars Kristoferson

The way energy is produced and consumed in the Baltic region today is not sustainable. It is wasteful, costly and harmful to the environment. In this concluding chapter we review the main arguments for a shift towards a sustainable energy system and discuss how the environmental and social costs of energy use can be reduced. We discuss the potentials for renewable energy sources and improved energy efficiency, identify barriers that obstruct their implementation and suggest possible ways to overcome these barriers.

7.1 The negative impact of present energy systems

There are several arguments for a sustainable energy system in the Baltic region. One of the strongest arguments is the need to reduce the environmental impact of energy use. As described in chapter four, air pollution from combustion of fossil fuels in power plants, industry and transportation is still a serious environmental problem in the Baltic region despite improvements in pollution abatement in the past decade. In Poland, the Baltic states and Russia, power plants and heat boilers burning fossil fuels are the main emittors of air pollution. Many power plants are old and inefficient and lack adequate equipment for pollution abatement. In Germany, Scandinavia and Finland emissions from stationary sources are less of a problem. In these countries, transportation is the dominating source of air pollution. Other significant problems related to the use of fossil fuels are land degradation and water pollution from coal and oil-shale mining, as well as oil spills from ships at sea and in ports.

Since the 1980s, governments have become increasingly aware of the negative environmental effects of electricity and heat production based on fossil fuels. These effects are both local, regional and global. Emissions of particulates and gases from power plants contain hazardous substances that can cause respiratory diseases and other health problems among the local population. An example of regional effects of burning fossil fuels is the emissions of sulphur dioxide and other acidifying pollutants that form acid rain which can damage plant life, forests and even buildings. A much discussed global effect is the gradual increase in the average air temperature at the earth's surface, also called global warming, which is caused by emissions of carbon dioxide and other so-called greenhouse gases released by the burning of fossil fuels.

In order to curb emissions of sulphur dioxide and other acidifying pollutants, taxes on polluting energy sources are now wide-ly used in Europe. In some countries, including Sweden, Finland and Poland, large emittors also have to pay charges for their emissions of carbon dioxide. In Poland, the Baltic states and Russia, environmental fees and fines are

Table 7.1 A comparison of environmental impact of electric power generation technologies. Emissions of pollutants from electric power generation[1] (in tons per GWh).

	CO_2	NO_2	SO_2	*Nuclear waste*
Coal	1,058	3.00	3.00	na
Natural gas	824	0.25	0.34	na
Nuclear	9	0.03	0.03	3.6
Photovoltaic	6	0.01	0.02	na
Biomass	0[2]	0.61	0.15	na
Geothermal	57	tr	tr	na
Wind	7	tr	tr	na
Solar thermal	4	tr	tr	na
Hydropower	7	tr	tr	na

[1] Emissions from the total fuel cycle, i.e. including fuel extraction, facility construction and plant operation.
[2] With biomass fuel regrowth programme
na: not applicable
tr: trace elements

Source: Adapted from G. Boyle (Ed.), *Renewable Energy: Power for a Sustainable Future*, The Open University and Oxford University Press, Oxford, 1996, p. 420.

collected in special funds which have become the main source for financing investments in environmental protection.

Renewable energy sources have much smaller environmental impact than fossil fuels. As demonstrated in Table 7.1, electricity generated from wind or hydropower produces almost no air pollution at all. Electric power from biomass is also less pollution-intensive compared to electricity produced from fossil fuels.

Nuclear power produces only small amounts of air pollution. But the use of nuclear energy poses other environmental risks such as radioactive emissions from accidents at nuclear power plants or leakages of radioactive material from the transportation and storage of nuclear waste. In the Baltic region, the safety of the Chornobyl-type, graphite-modulated nuclear reactors in the former USSR is a matter of concern. Such concerns make the future of nuclear power uncertain. In Western Europe, although the main argument against nuclear power is not its economic costs, a nuclear power plant is more expensive, and takes longer time, to build than a thermal power plants burning coal or gas. In the 1990s, almost no new nuclear reactors have been commissioned in Western Europe.

7.2 Arguments of self-sufficiency

Beside the environmental benefits, there are also other factors that make renewable energy sources increasingly interesting. Fossil fuels are becoming more expensive to utilise not only because of environmental reasons. The world's demand for fossil fuels is growing steadily which is likely to raise the price of oil and gas in the next 5–10 years. As the prices of coal, oil and gas increase, alternative energy sources, such as biofuels and wind power, will become more attractive.

Another important effect of the growing fuel prices is that the costs of producing electricity and heat from coal, oil and gas will increase, too. Growing electricity and heat prices have become a serious social problem in many eastern European countries where energy used to be cheap because of state subsidies. Although still subsidised by the state, heat and electricity prices have increased rapidly since the early 1990s. Because energy prices generally have risen faster than real income, many households find it difficult to pay their energy bills. The social dimension of rising energy costs is an urgent but complicated task to solve for many governments in eastern Europe. Energy efficiency will be an important tool to ease the economic burden of households and other energy consumers.

Yet another factor that makes renewable energy sources more interesting for some governments is the objective to reduce energy imports. This goal is particularly evident in the case of the Baltic states, which are dependent on Russia for their supply of oil and gas.

On the long-term perspective, another strong argument for renewable energy sources and energy efficiency is the simple fact that the world's resources of fossil fuels and uranium are finite. As oil, gas, coal and uranium become more scarce, the price of these energy sources will increase and the interest in other energy sources will be stronger. However, at current technologies and extraction rates, the world's reserves of oil and gas are sufficient to last at least another 50 years and in the case of coal perhaps even 200 years. Thus, a complete transition to an energy system based on renewable energy sources is likely to take long time.

As we have shown, the growing environmental and social costs of an energy system based on fossil fuels and nuclear power, and the desire to become less dependent on imported fuels, are strong arguments for an increased use of renewable energy sources and promotion of energy efficiency in the Baltic region. Today, environmental concerns appears to be a stronger driving force in western than in eastern Europe. In most east European countries, governments are more concerned with issues such as securing energy supply, diversifying energy imports and reducing the economic burden of households and other energy consumers due to increasing energy prices.

7.3 The potential for renewables

How much can the use of renewable energy sources increase? Theoretically, renewables combined with more efficient energy use could replace most, if not all, energy produced by fossil fuels and nuclear power within the next 50–100 years. In the Baltic region, hydropower, biomass and wind power seem to be the most promising renewable energy sources.

The best sites for hydropower stations in the Baltic region are already exploited. Some undeveloped rivers remain in the northern parts of Finland, Norway and Sweden. But these rivers are not likely to be used for hydro power because of environmental and aesthetical concerns with respect to the dams that would have to be constructed in connection with the power stations. However, there is still a significant potential for smaller hydro power stations in the Baltic region. In Latvia and Poland, small hydro power stations that have been idle since the Second World War are now being rebuilt.

Beside hydro power, the renewables that have the largest development potential in the Baltic region are wind power and biomass. Both biomass and wind power are interesting energy sources for countries wanting to reduce the consumption of fossil fuels. They can easily be applied for small-scale energy production and are thus well suited for local needs. As demonstrated in the preceding chapters, the technologies for wind and biomass are modern and mature. According to official estimates, the energy production potential in Sweden for biomass is 130–170 TWh per year and for wind power 55–90 TWh per year. This is equivalent to 40–60 percent of Sweden's total energy use in 1994. Estimates for Lithuania indicate that biomass from forests and agriculture could provide up to 50 percent of the country's present annual electricity consumption or up to 35 percent of its heat consumption.

As for other renewable energy sources, such as photovoltaic, solar thermal and geothermal energy, the development potential appears to be less favourable in the Baltic region because of limited solar and geothermal resources in this part of the worldKåberger estimates that solar energy may eventually supply in the order of 10 per cent of the region's electricity and heat production (p, 46)..

7.4 Energy efficiency: a win-win solution

The easiest, fastest and cheapest way to make more energy available with the least environmental impact is to reduce energy waste. There are two principal ways to achieve this goal: to reduce energy consumption and to improve energy efficiency. Simple ways to reduce energy consumption are, for example, to walk or bike for short trips (instead of going by car) or putting on warmer clothes rather than increasing the heating of an apartment. The technical potential for more energy-efficient buildings, cars, appliances, lights etc is far from fully utilised.

Given the substantial energy price increases in central and eastern Europe in recent years, the inefficient energy use, and the need for affordable pollution abatement, energy efficiency should be a key policy for improving the energy situation in these countries. Energy efficiency is a win-win solution in the sense that it provides benefits both for energy producers and consumers:

- it saves money for the customer;
- it improves the comfort and thus the value of the customer;
- it saves money for the producer; and
- it reduces pollution.

Improved energy efficiency would help households in the Baltic states and Russia to lower their energy costs so they could afford to pay their bills and thus improve the financial situation of energy companies. If implemented on a large scale, energy efficiency can even be a cheaper alternative for energy companies than investing in a new power plant or heat boiler.

Energy savings can often be achieved with the help of relatively simple measures and uncomplicated equipment. As demonstrated in chapter 5, there is a huge potential for improved energy efficiency in district heating networks and residential buildings in the Baltic states, Belarus and Russia. The situation is similar in Poland.

7.5 Barriers – and how to overcome them

As pointed out earlier, there are several barriers that make large-scale implementation of

renewable energy sources and energy efficiency difficult. The most important barrier is that the price of energy produced by fossil fuels typically excludes the environmental costs of using these fuels.

There are also institutional barriers that complicate the implementation of energy efficiency. With respect to renewables, an important barrier is the difficulty for small, independent energy producers to compete with the established energy companies. There are several issues that have to be resolved in order to give independent producers a strong and secure position in relation to larger producers so they can compete on equal terms. One issue is how the prices of electricity and heat are regulated. Other crucial questions are that the independent producers have free or cheap access to power grids, and that they have the same tax benefits as other producers of energy.

For example, small district heat producers in Estonia and Latvia have recently faced increased competition from their national gas companies, which offer imported gas for heating to households at cheaper rates than the heat produced locally by the district heat companies. In those cases where the district heat is produced from biomass, a switch to gas would be against the interest of the Estonian and Latvian governments, which want to reduce the dependence on imported fuels. Paradoxically, the same governments are owners in the national gas companies.

In the case of energy efficiency, mixed ownership and unclear responsibilities for the maintenance of residential buildings often discourage the residents from investing in energy saving equipment. There is also an information problem. Energy consumers are often not aware of the possibilities for making their energy use more efficient. Information campaigns in school and at work could be helpful in presenting what options are available for reducing energy costs at home. Local demonstration projects, such as the renovation of Estonian residential buildings described in Chapter 5, are also important in order to explain the benefits of energy efficiency to the local population.

A large-scale implementation of renewable energy sources in the Baltic region requires that the external costs of environmental impact be included in the price of fossil fuels. In Scandinavia, the cost of producing a unit of electricity or heat using imported coal is about half of the production cost if biomass is used. Environmental taxes on emissions of carbon dioxide or acidifying air pollutants will therefore be important to promote the utilization of renewables.

8.

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A Sustainable Baltic Region

ENERGY
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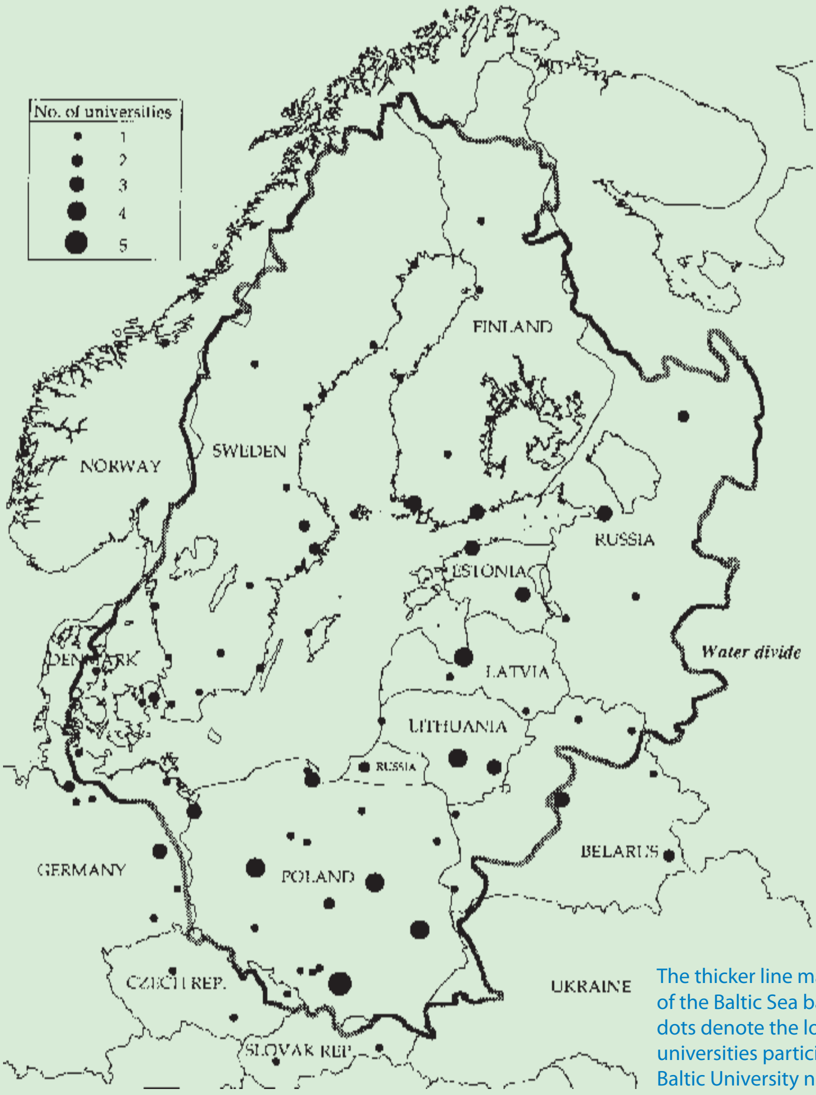

The thicker line marks the limits of the Baltic Sea basin, and dots denote the locations of universities participating in the Baltic University network.

A SUSTAINABLE BALTIC REGION is a series of well-illustrated booklets introducing the concept of sustainable development, in particular with reference to the area around the Baltic Sea, the Baltic Region. It deals with issues of sustainable use and management of natural resources, the long-term protection of our environment and the sustainable organization of human societies from the level of households to those of municipalities, cities and countries.

The booklet series constitutes the main reading in a university credit course, produced by the Baltic University Programme, and offered by the universities in the region. The other main component of the course is a TV series of ten programmes, produced in cooperation by a consortium of national TV companies in the region, broadcast over satellite TV and national TV channels. The TV series contains a wide variety of reportages from all count-ries in the region. In addition, the course contains a database on natural resources and environmental impact in the region available over the Internet. The booklet series is available in English, Polish and Russian, while the TV series is produced in English and in several national languages.

The Baltic University Programme is a network of international cooperation among some 150 universities in the 14 countries that are wholly or in part within the Baltic Sea basin. The Programme is coordinated by Uppsala University.

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