A Review of Bioenergy Use in Some European Countries

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ABSTRACT

This paper is a brief review of the current bioenergy utilization scenario in five European countries, namely Denmark, Finland, Sweden, Austria and the Netherlands. The level of bioenergy utilization varies from around 3% to slightly more than 20% of their total energy consumption. Straw; forestry thinnings and residues; peat; animal, industrial and municipal organic wastes as well as landfill gas form the main sources of the bioenergy used. These bioenergy sources are used mainly for heat production while some electrical power are also generated. Wherever feasible combined heat and power (CHP) systems are adopted. The concept of energy crops is also being pursued in all of these countries but at different levels of enthusiasm.

1. INTRODUCTION

The practice of using biomass for energy purposes has traditionally been associated with the so called third world countries. However the oil crises in 1973/74 and 1979/80 have caused many developed or first world countries to rethink their energy supply and utilization strategies. As a result biomass utilization was included in the energy agenda of a number of these countries. The utilization of biomass in these countries was given further impetus after the United Nations Framework Convention on Climate Change was signed by the Heads of States in Rio de Janeiro, Brazil in June 1992 and the Kyoto Protocol of December 1997.

Thus to provide a better perspective of what is happening in some parts of the developed world as far as bioenergy utilization is concerned, this paper outlines a quick review and summary of the current bioenergy scenario in five European countries, i.e. Denmark, Finland, Sweden, Austria and the Netherlands as these countries are rather committed to the use of bioenergy.

2. BIOENERGY IN DENMARK

Denmark with a population of a little over 5 million [1] is an agricultural country. As such, large quantities of agricultural wastes in the form of straw and animal wastes are produced. It has been estimated that currently 3 billion kg of dry animal wastes are produced annually and if these wastes were to be converted to biogas, an amount of 26 PJ can be obtained [2]. Presently straw production averages 2.3 billion kg per year with an energy equivalent of 46 PJ [2]. In addition the country also produces substantial quantities of industrial as well as solid municipal wastes. The energy content of these two sources is in the region of 4 PJ/y [2].

Even though only 12% of Denmark (total area 43 094 km^2) is covered by woods and forests, the forestry and wood industries also produce a fair amount of forest wood (200 million kg/y to 300 million kg/y) and waste wood which can be utilized for energy purposes [2]. Forest wood chips are produced from forest thinnings which have to be carried out while industrial wood wastes are produced by the wood industry. The energy available from these two sources are respectively 7.6 PJ/y and 13.2 PJ/y [2].

Thus in total the energy that is potentially available from the above biomass is about 120 PJ/y. However not all of these potential are harnessed. Presently Denmark utilizes only about 50 PJ/y of energy from biomass. Most of these are used for the production of heat, but more recently biomass is also utilized for power production as well, especially in combined heat and power (CHP) production plants. In this paper power means electrical power. The 1996 and 1997 figures indicate that 6% of Denmark's total energy consumption (of about 800 PJ/y) come from biomass while 2% are from other forms of renewable energy [2].

The 1996 Danish Governments' Action Plan for Energy (Energy 21) envisages that the contribution of renewables to the total Danish energy consumption will increase to 12% to 14% by 2005 and 35% by 2030 [1, 3, 4]. Biomass is expected to play a significant role in this action plan. By the year 2005 biomass is projected to supply 85 PJ/y as Danish power plants (currently mostly coal-based) have been committed to use straw and wood in their operations in the years to come either as the principal fuel or as a co-fuel. It is also envisaged that biomass from energy crops/plantations will be used to supplement biomass from agriculture, forestry and industrial wastes after 2005.

In the current biomass utilization scenario, animal wastes are used mainly for the production of biogas which is then used for heating and power generation. Both single-farm biogas plants as well as centralized biogas plants are in operation. In June 1996, there were 18 of the latter and 15 of the former [2]. Biogas is also generated using organic wastes from the municipalities and industries as well as in land fills and sewage treatment plants. In all a total of 2 PJ/y are produced. This figure is projected to increase to 4 PJ/y by 2000 and 6 PJ/y by 2005 [2]. Table 1 shows three examples of centralized biogas plants that are in operation in Denmark. All the plants operate at a temperature of 53°C and a digestion period of 11 to 16 days [2]. An example of a on-farm biogas plant is the Sindrup "Smedemester" plant, commissioned in 1988, producing 60 kW of electricity and 180 kW of heat from a biogas production of 800 m^3 per day. The annual raw material input is 3.5 million kg to 4 million kg of liquid animal wastes and 60 000 kg to 70 000 kg of industrial wastes [2].

In 1990, 1 800 kg of industrial and municipal wastes were combusted in 38 district heating plants to produce 10 PJ of energy which is about 13% of total district heating sales [2]. The plan in Denmark is to use all combustibles in these wastes in combined heat and power plants by 2000. By then it is projected that 2.5 billion kg/y of combustible wastes would be produced [2].

Straw is mainly used for the production of heat and in some cases power in on-farm plants, district heating plants and combined heat and power plants. The straw used are usually in the form of bales (called Hesston bales). Some of the older coal-fired power plants are gradually being converted to using straw as fuel or co-fuel. In Denmark straw is presently traded commercially at 400-500 DKK per 1000 kg [2].

Forest wood (in the form of wood chips) and industrial waste wood (sometimes in the form of pellets) are presently used in the heating of individual dwellings, in district heating plants and in combined heat and power plants. In fact, in the current scenario, these plants use more of wood than straw. Industrial wood wastes are also used by the wood industry itself for its own heat and power requirements. Many coal-fired boilers are also committed to convert to use wood as fuel or co-fuel.

In the foregoing account, CHP plants are mentioned in many situations. This is because these plants (both big and small) are very much encouraged by the Danish Government. Many of the traditional heating plants are being converted to CHP types. The current total installed capacity of CHP plants in Denmark is about 1150 MW. In fact 70% of district heating plants are now of the CHP type [2]. Though natural gas is widely used in these plants, biomass in the form of straw and wood are also being used. However it must be admitted that presently it is more expensive to install straw-fired than gas-fired plants. CHP plants that use biomas as fuel or co-fuel are now commercially available in the kW to about 100 MW (total) range. Some examples of such plants in Denmark are listed in Table 2 [2]. Thus one can conclude that CHP plants are fairly well developed in that country.

Table 1 Examples of Centralized Biogas Plants Operating in Denmark

Name	Year commissioned	Annual material input (1000 kg)		Electricity output	Heat output
		Animal wastes	Other organic wastes		
Ribe	1990	110 000	30 000	1 MW	3 MW
Thorso	1994	80 000	25 000	1.3 MW	2 MW
Sinding-Orre	1988	33 000	14 000	1 MW	3 MW

Table 2 Some Examples of CHP Plants Using Biomass as Fuel or Co-fuel

Year commissioned	Name	Annual fuel input (1000 kg)	Heat produced (MJ/s)	Power produced (MW)	Technology
1992	Grenaa	Straw = 70 000 Coal = 38 000	61	19.6	CFB combustion
1993	Maabjerg	Wastes = 150 000 Straw = 50 000 Wood = 30 000 Natural gas = 4 million m^3 (for superheaters)	68	28	Grate-fired boiler
1995	Masnedo	Straw = 43 000 (some straw can be replaced by woodchips)	20.3	8.3	Grate-fired boiler

When compared to the utilization of agricultural and forestry biomass, biomass from energy crops/plantations are less well developed in Denmark. The concept of energy crops/plantations is still in the R&D stage and in small scale field trials. All aspects of an energy crop system are still being evaluated; from cultivation to final utilization of the biomass as well as the economics and impact on the environment. Several plant species are being evaluated and they include buchina, sunflower, knotweed, Jerusalam artichoke, false flax, reed canary grass, corn cockle, willow, miscanthus, rape and energy grain crops [4, 5]. Of these the last four have seen the most progress. It has been projected that by the year 2030, 2 billion m² to 3 billion m² of energy crops are expected to contribute 45 PJ annually to Denmark's energy requirements [4].

The above discussion clearly shows that Denmark is very much into the utilization of biomass as a source of energy. The policies adopted by the Government of Denmark have contributed greatly towards this commitment. For example a policy is in place that sets a target of a 20% reduction of carbon dioxide emission before 2005 [1, 3]. This is in reference to the 1988 levels. Wide ranging policy initiatives are also in place that encourage the greater use of biomass; from CO_2 tax to direct financial support/subsidy. As a result of these policy initiatives various technologies associated with the use of biomass as a source of energy have been developed to a fair degree of sophistication. These technologies are also exported [3]. Most of the technologies are developed in cooperation with Danish industry, R & D institutions and public authorities at both the national and municipal levels. Among them are wood stoves and small boiler technology with high efficiencies (>90%) and low emissions, biogas plants, district heating plants, combined heat and power technology as well as large scale power plants all using biomass as fuel or co-fuel.

In spite of the successes achieved thus far, Denmark continues to be active in bioenergy R&D [2, 4, 6, 7]. The areas that are still being given attention include:

- further optimization of the combustion process;
- fluidized bed combustion using biomass;
- gasification of biomass for CHP plants;
- fuel characteristics and preparation;
- microbiological development and further optimization of biogas plants;
- liquid fuels from biomass, e.g. bioethanol; and
- energy crops/plantations

Compared to other countries, the Danish budget for R&D on biomass is rather impressive as depicted in Fig. 1.

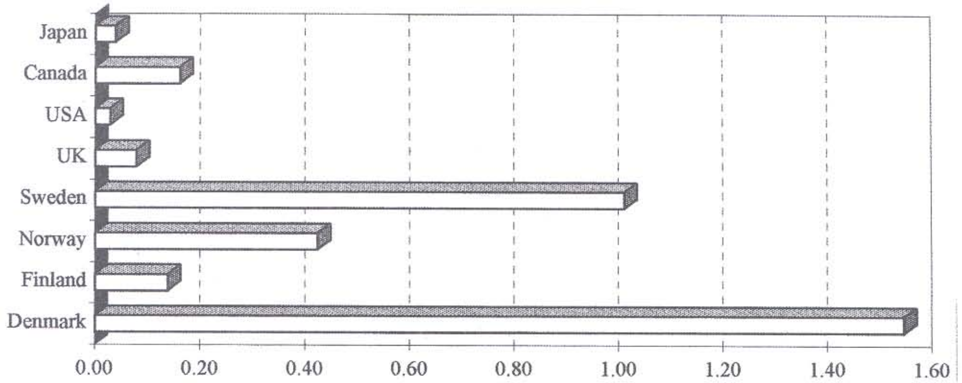


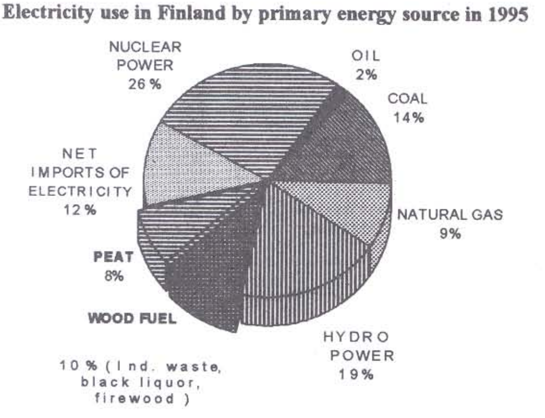
Fig. 1. Public R&D expenses in biomass ($ per capita in 1994).

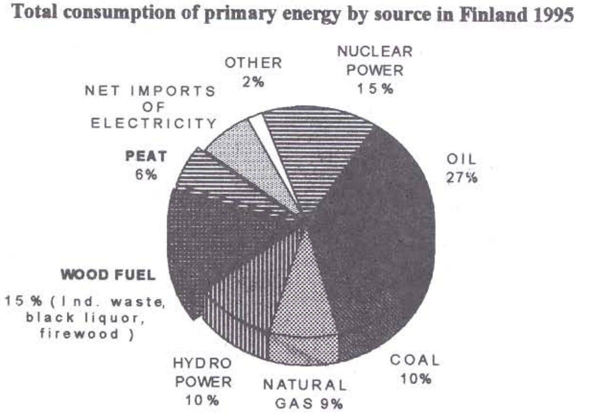
3. BIOENERGY IN FINLAND

In Finland peat is regarded as a source of biomass energy. In 1995 bioenergy accounted for slightly more than 20% of the total energy consumption in Finland [8, 9]. This is shown in Fig. 2. In that same year, about 18% of the electricity generated is from biomass (wood fuel contributed 10% and peat 8%) [8]. Thus most of the bioenergy used in Finland comes from peat and wood which is obtained from thinnings of commercial forests, logging residues and wastes of the timber and pulp and paper industries. Finland's area of productive forests is 200 billion m² and annually 1% of this needs first commercial thinning [9]. Finland is not much into energy plantations though reed canary grass has been cultivated experimentally. The yield of grass is reported to be 0.5 to 0.7 dry kg/m²/y [8].

The main sectors using bioenergy are the pulp and paper industry and district as well as local heating facilities. Bioenergy use in Finland is the highest among industrialized countries (in terms of percentage of total energy consumed). Compared to most other European Union countries which use agrowastes as biofuels Finland uses more of wood and peat as bioenergy. As such technologies for harvesting, handling, processing, drying and combustion of wood fuels are fairly well developed in Finland [8, 9]. Finish companies have developed various types of machinery for the harvesting and chipping of wood at the logging site. For example, for efficiency logging is mechanized with harvesters and forwarders. A mobile chipper operating on the logging site and equipped with a tippable chip bin is one cost cutting measure that is under evaluation in Finland.

Since Finland generates both heat and power from biomass, the country is the trend setter in combined heat and power production. Over 30% of the total installed power capacity comes from combined heat and power systems [8]. Finland uses mostly fluidized bed combustion (FBC) for the country's cogeneration systems that use biomass as fuel [8]. Multifuel boilers fired with biomass and fossil fuels are also widely used in Finland. FBC boilers can combust moist biomass and mixed fuels with high efficiency. Systems that generate power in the capacity range of kW_e to over 100 MW_e using biomass as fuel are readily available in Finland. Finland has also successfully converted small oil fired heating boilers to biomass fired heating systems by retrofitting the boiler with a fixed bed gasifier or with a special burner.





(Note : 1 TWh = 3.597 PJ ; 1 million toe = 42 PJ)

Fig. 2. Electricity use in Finland by primary energy source in 1995.

In spite of the country's successes in many areas of biomass technology Finland is still actively involved in bioenergy R&D [8, 9, 10]. Some of the areas that are actively being pursued include:

- Production and utilization of pyrolysis oils. Wood pyrolysis oil is very corrosive (pH ≈3), has a low calorific value and a high particle content. Its viscosity increases if the oil is in contact with air. It also cannot be stored at temperatures of more than 50 °C. As such the oil is difficult to use.
- Advanced combustion technologies including further improvements on the circulating fluidized bed combustion systems.
- Biomass gasification technology is being developed with a view to utilizing the gasified fuel in a combined cycle gas turbine plant or a diesel plant that can achieve a higher power-to-heat ratio. Power generation by means of conventional steam cycle offers a rather low power to heat ratio. A simplified IGCC process under development for systems of 30 MW_e to 150 MW_e is based on pressurized fluidized bed gasification of biomass and high-temperature cleaning of the fuel gas.

4. BIOENERGY IN SWEDEN

Sweden with a population of about 8.8 million started replacing her fossil fuel consumption with biomass (bioenergy) more than 20 years ago [11]. In Sweden peat is considered as a source of bioenergy. Besides peat the other sources of bioenergy include forest wood; residues of the logging, wood and pulp and paper industries; agricultural residues; household and industrial wastes; and grass and fast growing trees from energy crops/plantations. In addition gas from 55 landfill sites is also extracted for use as a source of bioenergy [11].

In 1994, Sweden's energy supply was 461 TWh while the final use was 383 TWh [11, 12]. The difference in the above two figures is attributed to production and transmission losses, foreign shipping and use for non-energy purposes. Fig. 3 shows that roughly 17% of this total energy supply, i.e. about 79 TWh come from bioenergy sources [7, 11]. The contribution of the various bioenergy sources to the above 79 TWh is as shown in Table 3.

Table 3 Utilization of Bioenergy in Sweden in 1994

No.	Source	TWh
1	Forest wood, residues from the logging, wood and pulp and paper industries	70
2	Agricultural residues	0.03
3	Household solid wastes	3.8
4	Industrial wastes	1.5
5	Peat	4
6	Landfill gas	0.004
7	Energy crops/plantations	Minimal

Crude oil and oil products (204)	Natural Gas (9)	Coal (28)	Biofuels, peat etc. (79)	Hydro power (59)	Nuclear Power (73)	Waste heat etc. (8)
Total energy supply 1994 (461 TWh)						

Fig. 3. Total Energy Supply and Use in Sweden in 1994 (1 TWh = 3.597 PJ)

Table 3 indicates that Sweden's bioenergy resource consists mainly of forest wood, and residues from the wood and pulp and paper industries. In 1994 about 30 TWh of spent liquor were produced by the pulp and paper industry and these were utilized as fuel within the industry itself, while roughly 40 TWh of wood fuel were used in private houses for heating (12 TWh), district heating (8 TWh), and within the wood industry [11, 12].

Agricultural residue which is mainly straw is currently being used in three district heating plants [11]. Though household and industrial wastes are mainly used for heat production some electricity are also being produced. In fact most of the bioenergy in Sweden is used for heat production. In total, only about 2.5 TWh/y to 2.7 TWh/y of biomass (principally wood) are used for the generation of electricity [12]. Wherever possible the installation of combined heat and power plants is encouraged. In addition a small amount of ethanol is being experimentally utilized on some inner city buses [12].

From 1970 to 1994, bioenergy utilization in Sweden increased from 43 TWh per year to 79 TWh/y [11]. Even so not all the bioenergy potential have been harnessed for utilization. For example only 50% of household wastes are being utilized for fuel while the major part of industrial wastes are not used although 50% of such wastes can be used as fuel. Thus there is still some room for a further increase in bioenergy utilization [11].

Sweden has also embarked on an energy crop/plantation program. In this program reed canary grass as well as different species of the fast growing willow tree (salix) have been cultivated. The current experimental cultivation of the former is on 40 billion peep of land and the latter on 150 million m^2 [12]. To date the results indicate that the dry matter yield of reed canary grass is 0.5 to 0.7 dry kg/m^2/y while the yield for willows is about 1.2 kg dry matter/m^2/y [11, 12]. However it must be pointed out that bioenergy from energy crops/plantations is still under development and evaluation and hence its exploitation is still minimal. Nevertheless it has been projected that by the year 2010, 3 billion m^2 of fast growing trees would have been cultivated in Sweden and the biomass from them would contribute 15 TWh/y to 20 TWh/y to the nation's energy requirements [11].

To encourage the greater use of bioenergy Sweden has introduced taxes for the emission of carbon dioxide, sulphur dioxide and oxides of nitrogen. The country therefore practises the "Polluters Pay Principle" [11]. Like many other European countries, inspite of the nation's fairly successful program in bioenergy utilization, Sweden continues to be active in bioenergy R&D [11, 12]. The following are some of the areas that are still being actively studied:

- technologies for improved combustion (FBC) and gasification of biomass that will result in an increase in efficiency and a reduction of emissions;

- biofuel production;
- energy technologies for transport (i.e. biogas as motor fuel and ethanol from woody biomass) & industry; and
- all aspects of energy crops/plantations.

5. BIOENERGY IN AUSTRIA

Austria (population of about 8 million) requires 1200 PJ of energy per year [13]. Since her local energy production is only 350 PJ/y Austria is forced to import the remaining amount [13]. As Austria is not in favor of nuclear energy, she has turned to bioenergy as an alternative.

In 1993 biomass contributes about 134 PJ, i.e., about 13%, to Austria's total primary energy requirements [13, 14]. The biomass used is primarily forest wood, forest residues and wood wastes from the timber industry with straw playing a very minor role (contributing roughly 1 PJ/y) [14]. Wood and wood wastes are readily available since about 40% to 46% of Austria is still under forest cover [13, 14]. In addition to wood and straw, rapeseed oil is also used as a source of bioenergy.

In total, about 93% of the biomass goes into the production of heat, roughly 6% to the production of electricity and 0.8% (i.e., the rape seed oil) goes into use as motor fuels [13]. Of the total amount of solid biomass consumed, 60% is used in wood stoves and a large proportion of the remaining is used in district heating plants of which there are now 160 of them in operation [14]. Most of these district heating plants are small to medium scale.

Rapeseed oil on the other hand is converted to its methylester for use in conventional diesel engines as motor fuel (biodiesel) [14]. Two large commercial plants of capacity 10 million kg/y and 15 million kg/y have been constructed to produce the biodiesel [13, 14]. In addition there are also several small plants of capacity 50 million to 200 kg/y in operation [14]. Thus Austria is quite into the production of biodiesel though as mentioned above, biodiesel presently accounts for only 0.8% of the total amount of bioenergy used in that country.

Besides cultivating rapeseed for its oil, Austria has also ventured into the cultivation of energy crops since the early 1980's [14]. Annual plants such as sugar beet, sweet sorghum and topinambur as well as short rotation crops such as poplars, willows and miscanthus are currently being evaluated [13, 14]. It has been estimated that at least 1.7 m^2 of land in Austria can be allocated for energy crop cultivation (13). This is surplus land for food and feed crops. It must however be pointed out that no commercial production of biomass from energy crops/plantation has started [14]. Their cultivation is still under development and evaluation. Even so it is projected that by the year 2000 to 2005, bioenergy use in Austria will increase to about 220 PJ/r [13].

The above account indicates that Austria is very much committed to bioenergy use and development. In fact the government provides subsidies for its utilization. Currently the total annual public subsidy for bioenergy utilization amounts to ATS 40 (~ US$3.50) per person [13]. It has also been estimated that in Austria, for each MW of installed capacity of energy from biomass, two to three new jobs are created in the rural areas [13].

The greatest success in biomass R&D in Austria is the progress made in combustion technology. Within 10 years the emission of pollutants for a given amount of energy from biomass combustion was reduced to less than 10% of the initial values [14]. Combustion efficiencies have been improved to more than 80% for all ranges of boilers [14]. Even so further technology developoment in production, harvesting, transport, storage, processing and utilization of biomass is required. Research and development projects [13, 14] that are currently being undertaken include:

- reduction of nitrogen oxide emissions from biomass combustion;
- cogeneration systems;
- biomass gasification via anaerobic and thermal processes; and
- non-technical questions.

6. BIOENERGY IN THE NETHERLANDS

Like many other European nations, the Netherlands (population, slighty over 15 million) is also into the utilization of bioenergy. The bioenergy used comes from three sources viz, wastes, biomass and landfill gas [15, 16]. In the Netherlands, municipal solid wastes, sewage sludge, industrial waste, scrap wood, plastic wastes, paper sludge and shredder waste are considered as wastes while biomass encompasses forestry thinnings, cuttings from parks and gardens, residues from the wood processing industry, agricultural residues and biomass from energy crops/plantations [15].

It has been projected that by the year 2000, 54 PJ/y will be available for utilization from both the above wastes and biomass categories. This will represent 3% of the total Dutch energy consumption then [15]. For the near future, biomass contribution from energy crops is deemed to be minimal though studies have been initiated on the cultivation of poplars, willows and miscanthus [15].

The Netherlands has wide experience in tapping landfill gas which is claimed to be cost effective. Extraction of the gas started in the 1980's. In 1993, of the 760 million m^3 of gas formed, only 123 million m^3 were extracted and 85 million m^3 (i.e.~ 2 PJ) utilized. Of the 85 million m^3, 51% is used in CHP plants, 39% upgraded to natural gas quality and 10% combusted directly by industrial consumers for heating or use in some other industrial processes. Since only 50% of the gas formed are extractable, the Netherlands predicts that in the years to come about 200 million m^3 to 265 million m^3 of landfill gas can be extracted annually [16]. Thus compared to solid wastes and biomass the contribution from landfill gas to the total amount of bioenergy used is small.

Most of the wastes and biomass utilized in the Netherlands is combusted to produce heat and electricity and wherever feasible CHP systems are encouraged. In fact the government even grants subsidies for CHP installations. In some installations co-combustion with coal is also practised [15]. The technologies for biomass and waste combustion are fairly well established though improvements are constantly being made to increase efficiency and reduce pollutants. It has been projected that by the year 2000, 15% of power generated in the Netherlands will use wastes and biomass as fuel [15].

Like many other European countries financial support from the Dutch Government for the development and utilization of bioenergy is available. As such R&D activities on bioenergy are still being pursued [15, 16] and these include:

- anaerobic digestion technology though the Netherlands is one of the leading countries in this area;
- gasification of biomass, both fixed bed and fluidized bed gasification;
- liquid fuels production via pyrolysis and liquefaction; and
- use of landfill gas in gas engines.

7. CONCLUSIONS

The above short account of the bioenergy utilization scenario for five European countries indicates that governments in that part of the world are serious in their efforts at reducing their dependence on fossil fuels and at the same time contribute towards the abatement of global warming.

Though currently the level of bioenergy utilization may differ, efforts in all these countries are directed towards a further increase in bioenergy utilization. As such R&D activities in this area have also been given emphasis.

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