Renewable Energy in Denmark

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During the 1960s only municipal solid waste was a major source of renewable energy. As in most other European countries the promotion of other sources of renewable energy was spurred by the oil crisis in 1973. The first Danish energy strategy was adopted in 1976 and assigned priority to security of energy supply. Especially small boilers and stoves for individual households and farms became widespread during the 1970's. During the 1980's the energy policy increasingly emphasised economic sustainability and saved foreign currency from declining imports of fossil fuels. The second energy strategy gave impetus to the conversion of coal and oil-based district heating to biomass-based district heating. A biomass-based programme for combined heat and power - hereafter called CHP - was also initiated; this was in the latter half of the 1980's. Wind energy also gained in importance during the 1980's. Joint projects between the Danish Energy Agency and the utility companies were carried out to prepare the expanded use of especially land-based turbines.

Following the Toronto conference in 1988 and the establishment of Intergovernmental Panel of Climate Convention (IPCC) the Danish government initiated the preparation of a new and more comprehensive plan of action for especially biomass and wind energy. The priority of environmental sustainability was added to the existing ones of security of supply and economic viability. This third energy strategy, *Energy 2000*, aimed at erecting land based windmills with a capacity 1,500 MW before year 2005. The future use of biomass was outlined in the so-called *Biomass Agreement*, which initiated the establishment of biomass-based district heating outside the collectively supplied areas. The previous use of biomass for district heating or combined heat and power production had been directed at the areas with an existing heat distribution net, and the new policy thus expanded biomass utilisation to the small urban communities outside the collectively supplied areas. An important revision of the *Biomass Agreement* took place in 1993, in which the utility companies by government decree became obliged to replace 6 pct. of the total consumption of coal with straw and wood.

In the spring 1996 the Danish government endorsed the present energy strategy, *Energy 21*. The goals of *Energy 2000* are expanded and a long-term perspective has been added on the basis of new assessments of natural resources.
Energy 21 reinforces the governments aim to reduce the national CO_2-emission by 20 pct. by year 2005 and by 50 pct. by year 2030 as compared to the 1988 level. IPCC's recommendation of a 20 and 50 pct. reduction by year 2005 and 2030 now constitutes the official benchmark. Two means are adopted to pur-

sue this. First, substantial energy savings will take place. Secondly, the consumption of natural gas and oil will remain almost the same, but the use of coal will be abolished by rapidly expanding the use of renewable energy.

Renewables shall contribute with 29 pct. of the total electricity production by 2010 and more than 2/3 by 2030 (annex 1).

Thus, the utilisation of renewable energy in Denmark will be raised from the present level of around 8 pct. to 12-14 pct. by 2005 (100 PJ) and 35 pct. by the year 2030 (235 PJ). This implies an increase in the use of renewables by 1 pct. per year up to 2030.

The types of renewables to carry through this rapid expansion of renewable energy are illustrated in below table. The present dominance of waste, wood and straw is obvious. In the next 10-20 years wind power will gain considerable in importance. In the long term the major renewable sources will still be waste, wood, straw, energy crops and wind power, with a less significant role ascribed to biogas. The technological development within other fields such as solar cells, heat pumps and wave energy etc. might gain some importance on a smaller scale. The types of renewable energy to play a major role in the long term are specified in annex 1.

PRODUCTION OF RENEWABLE ENERGY

DENMARK	1989	1990	1991	1992	1993	1994	1995	1996
TOTAL	47 992	49 127	53 214	57 041	60 530	60 442	65 612	69 314
Solar energy	91	105	125	145	166	189	219	259
Wind energy	1 542	2 197	2 664	3 295	3 723	4 093	4 238	4 381
Hydro power	82	101	91	100	99	117	109	68
Geotermi	45	48	45	45	45	35	47	32
Straw	11 659	12 481	13 306	13 880	13 366	12 395	13 051	13 723
Wood chips	1 794	1 724	1 612	1 842	1 946	2 270	2 336	2 745
Firewood	7 029	7 019	8 163	8 413	9 351	9 081	9 191	9 768
Wood pellets	928	1 575	2 118	2 450	2 044	2 229	2 376	2 702
Wood waste	5 352	4 913	4 768	5 362	6 200	5 554	4 954	5 046
Biogas	678	752	910	899	1 077	1 383	1 752	1 990
Waste comb	15 006	15 006	16 255	17 325	18 963	19 979	24 088	25 394
Fish oil	1 302	744	744	744	800	233	243	65
Heat pumps	2 484	2 462	2 412	2 542	2 750	2 885	3 009	3 141

Solar panels are eligible for receiving financial support in order to double the annual sale of solar heating from some 2,500 by 1995 to 5,000 within a few years. Initiatives will be taken to promote the use of larger solar heating units, including solar heating installations in public buildings with large water consumption. Developing collaboration with the energy supply companies on solar energy will also be sought. These initiatives do not currently contribute significantly to the renewable energy production and will not receive special attention in this paper.

Energy crops can - depending on EU's policy pertaining to set-aside land and non-food crops - be converted to other types of biomass. This decision hinges upon the results of a demonstration programme for energy crops, which commenced Spring 1997 and runs for a period of 4 years. But it remains without doubt that especially agricultural and forestry residues will be assigned high priority vis-à-vis energy crops and liquid biofuels. This is a simple choice made on the basis of available resources and an unstable economic environment for energy crops.

In short, the important Danish sources of renewable energy are biomass from residues and wind power. The policy for development of windmills will be outlined, before the development of biomass and the economic incentives applied will be elaborated upon.

WIND POWER

Energy 21 has maintained the goal of erecting 1,500 MW of land based turbines before year 2005. A new goal of installing up to 4,000 MW off-shore turbines before year 2030 has expanded the role of wind power. 9 pct. of the present Danish electricity consumption is supplied by wind power and this share will increase to 50 pct. by 2030.

The capacity reached 790 MW in 1996 and during 1998 the capacity surpassed 1,450 MW. The wind turbines nowadays need few subsidies. Capital investment subsidies are no longer applied, although some support off course is granted for development and tests of technologically more advanced wind turbines. The only financial support for standardised or commercially available wind mills is a so-called electricity production subsidy, which is really an internalisation of external environmental costs.

Five years ago the typical wind mill had a capacity of 300 kW. Today the installed size averages 750 kW and the next generation of 1.5 MW is well on the way.

Ultimo-1998 about 5,200 wind turbines were installed in Denmark, 85 pct. of which were privately owned. The power companies owned the remaining part, and this share is forecast to increase considerably with the expansion of off-shore wind mills.

Medio-September 1997 the Danish government and the utility companies entered into an agreement about instalment of the first batch of off-shore wind mills with a capacity of 750 MW. The production price for off-shore based electricity amounts to 0.35-0.38 DKK per kWh. (the price includes grid extensions, but excludes back-up capacity). Renewable energy is exempted from the CO_2-tax of 0.10 DKK per kWh, thus the end-user price for off-shore electricity is only DKK 0-0.03 per kWh more than electricity from coal fired power plants. Land-based wind mills produce electricity at an ever cheaper price than the off-shore turbines. Today a number of land-based wind mills, depending on locality, produces electricity at same cost than coal-fired power plants. The production cost of coal-based electricity from newly built power plants ranges at 0.25 DKK per kWh and a large number of wind mills in the western region of Denmark can compete with this. Typical land-based wind mills produce electricity at about 0.30 DKK per kWh.

App. 0.85 kg. CO_2 can be saved per wind-produced kWh. Thus, the first batch of off-shore wind mills will contribute with a CO_2-reduction of 2.1 mill. ton annually - or 17.5 pct. of the total Danish CO_2-reduction by year 2005. The total reduction of CO_2 from 5,500 MW by year 2030 is forecast to be app. 14 mill. ton per year - or about one-fourth of the present level.

BIOMASS

Energy 21 specifies that the utilisation of biomass shall increase from 52 PJ by year 1995 to 85 PJ and 145 PJ by year 2005 and 2030, respectively.

The increased utilisation of biomass is envisaged to lower the total CO_2-emission by approximately one-eight of Denmarks total CO_2-reduction by 2030. As a thumb of rule, the electricity production price of biomass ranges at between 0.35-0.55 DKK per kWh. Renewable energy is exempted from the CO_2-tax of 0.10 DKK per kWh, thus the extra cost ranges at 0-0.20 DKK per kWh when compared to a newly build coal fired power plants. Straw/wood incineration at large-scale CHP has the cheapest price, while small-scale biogas plants has the highest price. A significant cost price reduction is expected due to the ongoing technological progress at biomass-based CHP's.

The increase in use of biomass till year 2005 will be pursued by the following means:

1. The utility companies are obliged to incinerate 1.2 mill. ton of straw and 0.2 mill. ton of wood chips annually before year 2000. This will reduce the consumption of coal by 6 pct. Although this amount of straw and wood chips is only a minor part of the available resources, some of the power companies and district heating plants have faced problems with price hikes due to a limited market competition. The Biomass Agreement was therefore amended the 1 July 1997 leaving the utilities with greater choice in the type of biomass procured. Thus, the previously stipulated quantities of biomass are altered to min. 1.0 mill. tons of straw, min. 0.2 mill. ton of wood chips, and a free choice of min. 0.2 mill. tons of either straw, wood chips or chips from willow. The end result is the same: a total incineration of biomass of 19.5 PJ from year 2000 onwards.

2. Biogas shall increase sharply from 2 to 9 PJ within 10 years (gas from landfill, plants on individual farms or co-operatives etc.). To initiate this development the amended Biomass Agreement of 1 July this year also permitted inclusion of biogas and land fill gas in areas supplied with natural gas. The previous monopoly for natural gas has thus been broken and biogas has been secured access to larger markets.

3. Denmark has around 90 district heating plants on biomass. 40 of these will be converted to CHP on biomass before 2005, the remaining 50 after 2005. These 90 district heating plants cover 1/5 of the total Danish market for district heating and it is the only heat production that is not produced as CHP. The conversion to biomass CHP has not been as speedy as envisaged. The average plant market approximates 70 TJ and service about 6-700 houses. This size makes district heating on biomass feasible, usually not CHP based on gasification of wood and straw. In short, the technological and commercial development of small scale CHP on biomass has been slower than expected. The Biomass Agreement was therefore amended and is now stipulating that the conversions shall take place not before year 2005, but when the conversion is technologically and economically feasible.

4. 105 new district heating plants will be constructed outside the public areas. These district heating plants cater for small urban communities of maybe a few houndred houses with local community supplies of straw and wood.

5. Finally, 350 block heating units with heating requirements above 250 kW will be established. These units are typically large institutions and they are all located outside district heating and natural gas distribution zones.

The above biomass-technologies do of course not represent all types of biomass-utilisation in Denmark. In 1996 there was also 11,000 individual straw and wood pellet boilers at the farms (12 PJ), 400,000 individual wood stoves at private homes (4 PJ), the wood industry's use of waste wood (5 PJ) and more than

30 waste incinerated heat and CHP plants (25 PJ), and some 60 district heating plants (5 PJ). Most of these types of biomass utilisation have been developed during the previous energy action plans of the past 25 years and have limited possibilities for future expansion.

The biomass technologies are supported by: Research and development, electricity production subsidy, and capital investment subsidies.

AGENDA 21 AND FUTURE BIOMASS UTILISATION

	<--- 1995 ----->	<---------- 1995-2005 ---------->	
(Rounded figures)	ACTUAL USE	PLANNED GROWTH	CO_2-REDUCTION
- 32 waste incineration plants	24 PJ		
- 12,000 farm straw & wood boilers	7 -		
- 500,000 individual wood stoves	7 -		
- 90 District Heating plants	6 -		
- Wood industry's use of waste wood	5 -		
- Other biomass utilisation	4 -		
- Utility companies	2 -	17 PJ by 2005	1.1 mill ton by 2005
- Biogas	2 -	7 - - -	0.4 - - - -
- 40 DH plants converted to CHP		3 - - -	0.3 - - - -
- 105 new DH plants		3 - - -	0.3 - - - -
- 350 institutions to central heating		1 - - -	0.2 - - - -
Total	57 PJ	31 PJ by 2005	2.4 mill ton by 2005

In the long-term a major increase is forecasted in the following use of biomass:

- More than 80 PJ by year 2030 shall be incinerated by the utilities at large-scale CHP's.
- 30 PJ of biogas shall be produced.

As biomass has not yet reached the same level of commercial sustainability as wind mills, some economic incentives are needed. These economic means will be elaborated upon in the following.

ECONOMIC INCENTIVES FOR PROMOTION OF BIOMASS

There are several types of economic incentives. Taxes and fees are used to affect the consumption of fossil fuels and renewables, and subsidies are used to increase the biomass-utilisation for electricity production and heat. The taxes will be outlined first, and their actual use will be described afterwards.

A host of energy taxes has been applied during the last 25 years. An important one is the 'energy tax' from 1986, which serves the purpose of maintaining a stable price relation between fossil fuels and renewables. In the latter half of the 80's the international price level of oil decreased considerably. In order to protect the domestic market for natural gas and renewable energy, a fossil energy tax was introduced to maintain the fairly high price level of oil.

The CO_2-tax from 1992 extends the taxation of fossil fuels, and for the first time the private sector enterprise sector is imposed an energy tax. The so-called green taxes from 1995 increase the CO_2-tax and energy tax, and comprise an additional SO_2-tax; see figure below. The total state revenue from all types of energy taxes and fees amounted to 24,5 bill. DKK last year. More than 4 bill. DKK was collected from CO_2- and SO_2-taxes.

'GREEN' TAXES TO SUPPORT RENEWABLE ENERGY

Per ton CO_2/year	Space heating: Housing, industry, trade & commerce	Light industry, trade & service	Heavy industrial production	SO_2-fee(*)
CO_2-tax (1992)	100 DKK	50 DKK	>50 DKK	-
Green taxes (1995)(#)	600 DKK by 2000	>90 DKK by 2000	>25 DKK by 2000	10 DKK by 2000

(*): Per kg. SO_2

(#): Gradual increase from 1996 to 2000. In industry, commerce and trade, the green taxes will be reduced according to documented energy savings.

A minor part of the taxes and fees is used for promotion of renewable energy in a number of ways.

1. Energy research:

The *energy research programme* commenced in 1991. Funds are granted for research in development of new RES technologies. In 1996 the research support for RES amounted 40 mill. DKK.

2. Running cost subsidies:

A major economic incentive for renewable energy takes form of *support to electricity production (Law No. 944 of 27 December 1991)*, which is the only scheme providing a subsidy for running costs. This subsidy consists of two grants. The first (0.17 DKK/kWh) is a general incentive to expand electricity produce from renewables. The other grant (0.10 DKK/kWh) serves to internalise part of the external costs of fossil fuels. The said amount constitutes compensation for the automatic levying of the CO_2-tax on all electricity at a rate corresponding to the CO_2 emitted during the coal-fired generation. The total electricity production subsidy amounts 0.27 DKK per kWh. For the utility companies only 0.10 DKK per kWh. is granted. From 1 January 1997 the CO_2-subsidy for waste incinerated CHP plants was reduced to 0.07 DKK per kWh.

In 1997 the total electricity production subsidy amounted to 404 mill. DKK, 275 mill DKK of which is subsidies for wind-based electricity. Due to the rapid expansion of wind turbines, this subsidy is expected to range DKK 745 mill. by 1998.

ELECTRICITY PRODUCTION SUBSIDY

	Private & decentralised electricity producers	Utility companies
Support for renewable energy (wind, hydro & biomass)	0.17 DKK/kWh	-
CO_2-tax (*)	0.10 DKK/kWh	0.10 DKK/kWh

TOTAL SUBSIDY	0.27 DKK/KWH	0.10 DKK/KWH

(*): Based on an estimated shadow price = 100 DKK per ton CO_2 (1992).

The electricity subsidy has made biomass-based **electricity** somewhat competitive vis-à-vis fossil fuels. Biomass-based **heat** production is also made competitive. This is, however, not reached by direct subsidies but by tax exemption.

3. Capital investment subsidies:

Investment subsidy is another economic means to promote biomass and other types of RES. Investment subsidies are granted via two programmes: The so-called CHP-fund (Combined Heat and Power-fund) and the so-called 'Development and Demonstration Programme for Renewable Energy'.

1) The so-called CHP-fund was set up in 1992 to support the conversion from biomass-based district heating to CHP (*Law No. 3 of 3 January 1992*). The programme was supposed to last till 1997 but has been extended till 2002. Most projects receive a support of 10 to 35 pct. The upper ceiling for support is 50 pct. and applies for the most risky or development-oriented projects. In 1996 this type of support amounted to 21 mill. DKK.

2) The so-called 'Development and Demonstration Programme for Renewable Energy' began in 1992 (*Law No. 837 of 7 October 1992*). The duration has not been decided upon but the programme is supposed to cease its activities in accordance with the commercialisation of RES technologies. Investment subsidies are offered to spur the dissemination of *commercially available technologies*, such as solar panels, heat pumps, small scale biogas plants, straw and wood based boilers etc. The subsidy varies between 15 and 30 pct. of the construction costs. No subsidies are given to purchase of wood stoves, which are commonly used in privates homes and subsidies are not necessary for this widely adopted technology. In 1996 a total of 71 mill. DKK was spent on investment subsidies.

Besides supporting the commercially available technologies, the 'Development and Demonstration Programme' also offers subsidies for *demonstration projects*. Especially decentralised CHP, biogas, new straw and wood-based boilers, new types of wind mills and solar panels are found eligible for support. The subsidy rate typically ranges between 20 and 40 pct. 50 pct. is maximum. A few RES technologies at the development stage, i.e. *pre-commercial technologies*, receive support above 50 pct. 56 mill DKK was

granted for demonstration (and development) of RES-technologies in 1996. Another 37 mill. DKK was spent by test-stations for dissemination of knowledge, information and advice to overcome special trade barriers. Although the latter type of grant cannot be categorised as a capital subsidy, the budget item is included in the capital investment support programme.

The above two RES programmes are summarised in the table below (next page).

The above table lists the economic support granted in 1996 only. In 1997 two new sub-programmes for promotion of renewable energy were launched to intensify the development of renewable energy in Denmark:

- A renewable energy island: The island of Samsoe with 4,400 inhabitants has been selected to demonstrate the possibilities of a small community to base its entire energy supply on renewable energy, including the transport sector. The total investment amounts to 600 mill. DKK, 70 mill. of which constitutes the need for investment support from the Danish government, EU etc. This programme will be financed from the existing grant schemes described above.

- Development of new renewable energy technologies: The programme aims to contribute to the development of new technologies, which could supplement the ongoing efforts to attain the long term targets of *Energy 21*. From 1997 till 2000 a total of 100 mill. DKK can be granted to the development and testing of wave power, seasonal heat storage from solar energy, privately owned off-shore wind turbines, and hydrogen technology. An additional grant scheme has been established for this programme, which is administered as part of and in accordance with the rules of above mentioned 'Development and Demonstration Programme for Renewable Energy' (*Law No. 837 of 7 October 1992*).

INVESTMENT SUBSIDIES FOR RES

(1996)	TOTAL SUBSIDY (MILL. DKK)	PURPOSE	SUBSIDY RANGE
CHP FUND	20.9	Conversion of biomass DH to CHP	10-50 %
DEVELOPMENT &			

DEMO. PROGRAMME:			
- Purchase of equipment	71.4	Small scale boilers (not stoves), biogas plants, solar panels, heat pumps etc.	15-30 %
- Demo projects	55.6	RES in general	10-50 %
- Test stations etc.	36.6	RES in general	10-100 %

FUTURE FINANCIAL SUPPORT FOR RENEWABLE ENERGY

The above description of financial support to renewable energy outlines the actual disbursement of 1996. The future support schemes for RES technologies will be sketched in the following.

As shown in the table below, the financial support to renewable energy increases from the present disbursement level of app. 600 mill. DKK to maybe 1400 mill. DKK by year 2001 (a support for information campaigns etc. has been included in category of capital investment subsidy). Indeed the electricity production subsidy constitutes the bulk of financial support. The capital investment subsidies are presumed to stagnate at the present level till year 2001 and to decline from 2002 onwards, as the market matures and the technologies becomes more commercially available.

FUTURE GRANT DISBURSEMENT FOR RENEWABLE ENERGY

(Mill. DKK)	1997	1998	1999	2000	2001
Capital investment subsidies:					
- Devel. & demo. programme	153	143	124	123	119
- CHP fund	13	25	24	25	25
- New RES technologies	2	25	25	25	(23)
Electricity production subsidy(est.)	404	744	888	1042	1206
Research	40	40	40	40	40

TOTAL	**612**	**977**	**1101**	**1255**	**1413**

There are no official estimates of the amount of private investments for RES installations brought about by the above support schemes. However, a thumb of rule can be applied: The total private investments are estimated at 3-4 fold the total amount of capital investment subsidies.

The above outline of future financial support is based on the assumption that the present support schemes continue. However, national and/or EU reforms may substantially alter this forecast. Feed-in tariffs and subsidy schemes for RES will be streamlined in the near future. During 1999 a law on the so-called green certificate market is expected to be approved by the parliament, and the entire energy sector will be re-structured and reformed in the coming years. Some substantial reform measures have already been adopted by the parliament.

REFORM OF FEED-IN TARIFFS AND RULES FOR RES-ELECTRICITY

By 3 March 1999 a large majority of Danish Parliament entered into an agreement on a comprehensive electricity reform. Part of the Agreement concerns electricity produced from renewable energy sources. A competition-based green market shall be introduced.

The tables in annex 3 summarise the transitional scheme for existing RES-plants and the introduction of semi-green market conditions for the new RES-plants erected before the end of 2002. 2003 will have established a fully functional green marked.

The green market for RES-electricity from 2003 onwards will be designed after consultation with relevant parties in the area, including professional experts and various organisations in the field. Before the end of 1999, a report with recommendations on the specific organisation of the green market will be submitted. Some of the green market components to be considered are sketched below.

FORTHCOMING MARKET REFORMS OF THE RES-BASED ELECTRICITY

The specific means adopted to achieve the development of RE in Denmark are presently being reconsidered in relation to the EU-liberalisation of the internal market and the use of market instruments in a harmonised EU-framework. In line with other EU-members Denmark aims at extending the role of the market while, at the same time, ensuring the development of renewable energy by indirect state guidance.

Annual quotas

Within the framework of liberalisation of energy markets annual quotas for development of RE will exert an active government policy. The annual quotas are compulsory and constitute a demand guarantee. The distribution companies are obliged to pay a fee, if the annual quota is not fulfilled. This purchase guarantee is a confidence building measure for the manufacturers of RE equipment in order to bring about increased investments into renewable energy technologies. A stable commercial infrastructure is an important precondition.

It is considered to be a PSO-obligation to issue quotas of RE-electricity, to certify and monitor the certificate market, to provide net services, to balance demand and supply and voltage regulation (individual connection to the nearest feed-in point of the grid will be paid by the individual producer). The PSO-agency will be empowered to impose upon the energy distributors the obligation to provide and sell a certain share of energy from renewable sources.

Green certificate market

The national government defines the norms for green electricity, i.e. electricity from renewables produced on approved and certified, environmentally friendly, equipment. Electricity from nuclear power and large hydro power plants (above 10 MW) will not be defined as 'green electricity' in Denmark. The producer of green electricity receives so-called green certificates according to actual amount of green electricity delivered to the grid. The electricity is sold to the distribution companies on the same terms and conditions as conventional generators. This means that the owner or operator of a sustainable energy plant actually has two products: electricity and green certificates.

The financial market for the green certificates can be a national stock exchange or similar financial market. A green certificate exchange has several advantages: The transaction costs are lowered, as a cumbersome process of commercial bargaining with a host of potential buyers is replaced by a single, independent market operator with simple procedures; the small-scale producers have the same bargaining position as large-scale producers; the additional costs of RE are represented by the value of the green certificates and cost transparency is thus ensured; the producers can at their own discretion choose between more stable long-term contracts or the potentially high-value spot market contracts. Furthermore, a national green stock exchange enables international trade, as the certificates are financial vouchers which can be traded in an internal EU-market.

The consumer/distribution companies fulfil their quota by purchasing certificates at the national stock exchange for green certificates. This enables a free market for green certificates, and supply and demand sets

the price. If the consumer/distribution companies do not fulfil their quota, they are imposed a fee of DKK 0.27/kWh, which is *de-facto* a price ceiling for the green certificates. Thus, production and distribution of RE shall take place on market conditions; increased efficiency shall be pursued by controlled commercial incentives. The producers and distributors offering the most competitive prices for green electricity will automatically be awarded.

This guidance of the market for renewables represents a more cost-effective means of producing green electricity. Today the Danish green electricity producers receive a fixed price subsidy, but the base price varies according to locality and distorts a unified market. Profitability partly depends on locality and the national and international comparative advantages are not exploited. A harmonised EU-market structure for RE could enhance efficiency to the benefit of the producers and end-users.

Fixed settlement price

Fixed feed-in tariffs will still exist till year 2003. The tariff will enable the wind mill owners and local biomass plants to obtain bank loans on commercial terms. The size of the tariff ensures that the loan can be repaid on normal terms. The tariff is not high enough to ensure a profit. The size of the profit depends entirely on the value of the green certificate, which is decided on the green market. Thus, fixed feed-in tariffs enable also small-scale producers to obtain commercial loans, but the achievement of a profit depends on supply and demand on the green market.

The report with recommendations on the specific organisation of the green market from 2003 onwards will consider, if the above combination of a guaranteed settlement price and a market set price of the green certificate shall be continued.

Flexibility to provide different levels of support to different renewables

Market penetration of a host of renewable energies must be enhanced in order to ensure both an immediate and long-term development. Some less matured technologies are needed to fulfil the long-term targets for RE. Renewable technologies are at different stages of maturity and the support needed for e.g. wind is much lower than the support needed for biomass gasification. Other biomass technologies, photovoltaic panels and wave energy hinges upon either further research and development or additional financial support for market penetration.

Various support measures are at hand to ensure a continuous development of also less mature technologies. Green certificates of higher value can be issued, running cost subsidies and capital investment subsidies can be applied in accordance with EU rules, and research and development can be supported.

Extra green certificates to less matured technologies

An administratively simple means to support the less matured technologies is to grant extra green certificates. Electricity from biomass could be awarded e.g. 150 kWh-certificates for each 100 kWh delivered to the grid. Electricity from photo voltaics could be remunerated e.g. 300 kWh-certificates for each 100 kWh delivered. This 100-150-300 ratio between wind-biomass-PV certificates shall be determined on the basis of actual production costs, in order to establish an equal level of competitiveness between the differently matured technologies. This ratio shall be in force for (maybe)15 years for all RE-equipment erected by year 'X'. This set-up of creating a more equal competition between unequally matured technologies shall be a temporary measure.

The ratio will be adjusted for new equipment in accordance with the technological progress. When biomass gasification and photo voltaics reach a higher degree of commercialisation in the following years, the ratio could be altered to, e.g., 100-140-285 by year 'X+2'. This ratio is guaranteed for the established equipment by year 'X+2' for a period of 15 years.

The certificate-ratio system has the advantage that the green market contains several types of commercial RE-equipment, and a competition between the various technologies can bring about a decrease in costs. Oversubsidiation is avoided by the fine-tuning of the certificate-ratio on an annual basis. The ratio shall be defined as a common ratio for all EU-member states in order to avoid an unequal national competition. This ratio should be a minimum-ratio, i.e. the ratio creating equal competition between wind power and the most competitive biomass technology and the most competitive PV etc. Other types of important but less matured biomass and PV technology can be supported by an additional capital investment subsidy in compliance with EU rules. Such a double-track support system can enforce market competition on both matured and less matured technologies - thereby creating incentives for all technologies to increase efficiency and lower costs.

Another measure could be to grant an electricity production subsidy to the less competitive biomass and PV technologies.

Research and development

Denmark shares the opinion that research and development activities will continue to have a major impact on new or presently less viable RE-technologies. The R&D activities shall be as cost-effective as possible and be subject for open tendering at the internal market. The PSO-operator could be assigned the responsibility to undertake the R&D procedures of large-scale activities for the utilities.

A supplementary tendering model

A tendering model, like the NFFO in England, could be used as a supplement to the green certificate market. Some RE-technologies are large-scale, require capital and equity availability, and have only few potential developers.

These types of RE, i.e. off-shore wind farms, may benefit from an open tender procedure, where the limited number of interested investors can bid at the same time and submit comparable offers according to pre-defined conditions.

TOTAL ECONOMIC COSTS OF RENEWABLE ENERGY

In comparison with the total cost of the Danish energy sector (renewables and fossil fuels as well as all types of investments in energy plants), the costs for renewable energy are not sizeable.

The costs of fuel, operations and maintenance, as well as investments and reinvestments in supply facilities and consumers installations - for renewable energy as well as fossile fules - comprise DKK 28 billion annually in 1995-2005. This figure will increase to DKK 41 billion annually from 2020-30. The bulk of investments and purchase of fuel etc. is due to renovation of excisting CHP's, construction of new natural gas-fired CHP's etc.

The extra costs of renewable energy are estimated to range between DKK 1 and 1½ billion per year. Thus, 4-5 pct. of the Denmark's total costs of the energy sector ensures the fulfilment of Energy 21's policy target for renewable energy. Technological development and improved cost-efficiency due to the increased market incentives and an internal EU-market has not been taken into consideration in the above cost-estimates.

The direct additional employment as a consequence of the present energy action plan is estimated to be 3,000 - 5,000 man-years/annually during the whole period. The staff in the conventional energy sector may stagnate or decline, and the net-expansion of employment is largely carried through by the employment in the renewable energy sector. Thus, the wind mill manufacturers has provided direct and indirect employment for 10,000, and the biomass sector has an estimated 3-5,000 people on their payroll.

In 1997 the Danish export of renewable energy technology approximated DKK 5 billion, or half of the total Danish energy technology export. Wind turbines contributes most to Danish export, but the biomass equipment to large-scale CHP's and small-scale heating furnaces are envisaged to capture an important share of the growing market for RES technologies.

SOCIO-ECONOMIC COSTS FOR CO_2-ABATEMENT

The financial support for RE appears to be large but that is only due to the fact that external costs of using coal have not been internalised. The external costs of environmental restoration, costs for additional health services, loss of agricultural produce and trade etc. are sizeable. Such costs can be added by a so-called life-cycle analysis. If these costs are included, several renewable energy technologies are able to compete on equal terms with fossil fuels without any subsidies at all.

SOCIO-ECONOMIC COSTS PER SAVED TON CO_2 IN DENMARK

RE-SOURCE	SOCIO-ECONOMIC COSTS
Biogas	- 50 DKK/ton CO_2
Woodpills in small boiler	0 - - -
Large wind mills	110 - - -
Woodchips	195 - - -
Heat pumps	345 - - -
Solar heating	2360 - - -
Solar cells	8700 - - -

(Data from 1993)

As shown in the figure above, reducing CO_2 can save costs by biogas and small woodpill boilers. The socio-economic cost of producing electricity by wind mills is neglectable. The figures stem from 1993 and the technological development has in the meantime made the actual costs even more favourable.

More recent figures show that the socio-economic costs, or shadow costs, are even lower for other types of renewable energy technologies. As mentioned previously, the energy taxes from private enterprises are channelled back to the sector in the form of subsidies to energy saving, purchase of renewable energy technologies etc. The actual investments and CO_2-reducing measures have demonstrated *de-facto* that the socio-economic costs of industrial CHP range from -200 to 0 DKK per ton CO_2. Thus the typically heavy energy consuming industries can reap direct and tangible financial benefits from renewable energy technolo-

gies. The same applies for newly deployed power and CHP plants based on natural gas. Entirely straw-based power plants showed to have a shadow price of only 300 DKK per ton CO_2.

Nevertheless, the direct support for renewable energy amount to less than 1 bill. DKK which is much less than the 5 bill. DKK collected in CO_2 and SO_2-taxes in 1997. But the availability of resources must also be taken into consideration. In a few decades the market prices for fossil fuels will increase sharply and it is thus a matter of time before alternative, i.e. renewable fuels constitute a precondition for future development. The present energy policy is but obliged to pave the way for renewable energy.

PROSPECTS FOR ACHIEVING THE MEDIUM TERM GOALS OF ENERGY 21

As mentioned above, wind mills and especially offshore-based wind mills are being erected at a speed surpassing the targets of *Energy 21*. The technologies are commercially viable and no financial supports except electricity production subsidies are given. Due to the success of wind mills, the electricity subsidies may be reduced in the near future, and the medium and long term goals seem to be achieved ahead of schedule. The most recent estimate from the Danish Wind Turbine Manufacturers Association expects that some 2500 MW of wind power will be installed by year 2005 - 1000 MW more than planned in *Energy 21*.

The achievement of the *Biomass Agreement* is slightly delayed. More than half of the biomass utilisation is expected to come from the utility companies' use of straw and chips from wood and willow. The utilities have constructed or decided to construct power plants with a capacity of 10 PJ biomass. That corresponds to app. 55 pct. of the stipulated goal, and even if there are 2 more years to reach the goal of 19.5 PJ by year 2000, the construction period of - say 3 or 4 years - will make a timely conversion less realistic. The more flexible choice of biomass fuel is definitely to the benefit of a speedy development in the coming years. But a few years delay is to be expected.

The amended Biomass Agreement has also made possible the exploitation of biogas and landfill gas in the areas already supplied with natural gas. This is an important factor for the development of decentralised CHP and to the achievement of *Energy 21*. Biogas is expected to support one-sixth of the increased biomass utilisation. The technological development seems able to cater this development. The number of new biogas plants in 1996 was less than expected, but 1997 seems to have surpassed the annual target.

Another one-sixth of the increased biomass-utilisation is expected from decentralised CHP and new local districts heating plants outside the collective distribution zone. The gasification technology is not yet commercially viable, and the technological development has not progressed at the speed envisaged. The pres-

ent district heating plants are economically viable, but a conversion to CHP is not. Therefore, an evaluation of the 7 pilot- and demonstration projects is currently undertaken in order to outline future priorities. The most promising results are achieved with a 35 kW Stirling-engine, where the technology seems to face a break-through as regards decentralised CHP - depending on the price reductions after establishment of a serial production.

In sum, the outlined goals for development of renewable energy and CO_2-reduction are very ambitious. Although Danish GDP has risen by 15 pct. from 1988 till 1996, the consumption of fossil fuels increased by only 3 pct. The CO_2-emission has declined by 7 pct. from 1988 till 1997. The benchmark for year 2000 is, however, less likely to be achieved within the remaining years and will be reached a few years later due to the positive impact from energy savings, increased energy intensity and expansion of renewable energy production. The benchmark of 29 pct. green electricity by 2010 seems to be achieved as planned. This trend is the result of Denmark's sizeable investments in the development of renewable energy technologies and the economic incentives applied to mature the market.

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ANNEX 1

DEVELOPMENT OF RENEWABLE ENERGY

According to the Danish energy plan of action, *Energy 21*, the performance of various types of renewables till year 2030 is expected as follows:

(PJ)	***ENERGY 21***				
	1996	**2000**	**2005**	**2010**	**2030**
WIND POWER	**4.4**	**8.6**	**13.8**	**22.7**	**59.8**
- of which electricity	4.4	8.6	13.8	22.7	59.8
PHOTOVOLTAICS	**0.0**	**0.6**	**1.0**	**1.4**	**3.0**
- of which electricity	0.0	0.6	1.0	1.4	3.0
BIOMASS	**61.4**	**73.4**	**84.9**	**95.9**	**145.7**
- of which electricity	6.5	11.5	15.5	18.0	31.3
- Municipality solid waste	25.4	22.7	22.6	22.6	22.1
of which electricity	3.9	5.0	5.8	5.8	6.1
- Straw	13.7	24.8	26.7	27.7	33.6
of which electricity	1.5	4.0	6.1	5.4	6.1
- Wood	20.3	23.8	26.5	26.5	24.3
of which electricity	0.4	0.7	1.4	1.4	1.8
- Energy crops or other biomass	0	0.1	0.1	5.9	45.7
of which electricity	0	0	0	1.1	11.9
- Biogas	2.0	5.2	9.0	13.2	20.0
of which electricity	0.7	1.8	3.2	4.3	5.4
OTHER (geothermal, hydro power)	**3.5**	**0.7**	**1.9**	**2.8**	**26.4**
- of which electricity	0.1	0.1	0.2	0.3	1.0
TOTAL RES - incl. MSW	**69.3**	**86.4**	**101.6**	**122.8**	**234.7**
- of which electricity	11.0	20.8	30.5	42.4	95.1
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Contrib. total primary energy consum.	7 %	10-11%	12-14%	17-19%	35 %
Contrib. total electricity consumption	9 %	17 %	25 %	34 %	73 %
TOTAL RES - excl. MSW	**43.9**	**63.7**	**79.0**	**100.2**	**212.6**
- of which electricity	7.1	15.8	24.7	36.6	89.0
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Contrib. total primary energy consum.	5 %	7-8%	10-11%	14-15%	32 %
Contrib. total electricity consumption	6 %	13 %	20 %	29 %	68 %

1996: De-facto.

2000-30: According to national energy plan of action, *Energy 21*.

Figures for total RES constitute the policy target, the contributions by each RES source are indicative.

Summary of Danish plan of action for renewable energy

In 1996 Denmark elaborated an Energy Action Plan "*Energy 21*" including medium and long-term scenarios 2030. In the medium term, the development of renewable energy is expected to take place primarily by means of increasing the use of bioenergy (especially agricultural and forestry residues) and wind power, which are also expected to provide the largest contribution in the longer term.

As a consequence of technological developments within individual fields, other renewable energy technologies such as solar cells, heat pumps, and vawe energy will become increasingly important.

By 2005 the utilities are presumed to incinerate at least 19.5 PJ of straw and wood chips, and up to 40 of some 90 districts heating plants on biomass shall be converted to CHP on biomass. 105 new district heating plants and 350 block heating units (< 250 kW) are expected to be constructed outside the collectively supplied distribution net. Landfill gas and biogas are expected to increase from 2 to 9 PJ annually.

In the long term especially large-scale CHP's and biogas shall constitute the major sources of biomass consumers. The utilities' use of biomass shall top 80 PJ by 2030 and biogas shall range 20 PJ. The total bioenergy production is envisaged to increase from 85 PJ by 2005 till 145 PJ by 2030.

The total capacity of wind mills is presumed to be at least 1,500 MW by year 2005 and 5,500 by 2030, which shall increase the total wind production from 14 PJ by 2005 till 60 PJ by 2030. The off-shore wind mills constitute 4,000 of the 5,500 MW by year 2030.

By 2010 RES shall contribute to 14-15 pct. of the *total primary energy consumption* (17-19 pct. if MSW is included). This share is forecasted to rise to app. one-third by 2030.

The RES-contribution to the *total electricity consumption* shall increase from the present level of 10 pct. to 25 pct. by 2010 (or 12 pct. till 29 pct. by 2010 if MSW is categorised as a source of renewable energy). By 2030 as much as 68 pct. of the Danish electricity consumption shall derive from RES, if internationally concerted actions have been enforced.

ANNEX 2
PREVIOUS FEED-IN TARIFFS FOR RES ELECTRICITY

There are no legal restrictions for private power generators. If the power generating capacity is higher than 25 MW, the Department of Energy shall issue a licence. Energy utilities are obliged to allow private producers access to the grid. The feed-in tariffs in Denmark are based on the principle of avoided cost and include the costs for fuel, operation, maintenance and long run capital costs. The private supplier of electricity is obliged to pay the costs for the connection to the nearest feed-in point of the grid. Any costs necessary to enhance the grid shall be paid by the utility. Access to the grid is not subject for payment in the form of a fee, as this service is indirectly taken into account when setting the tariffs and the payment pr. kWh is estimated to be 0.07 DKK lower due to this indirect fee. This indirect fee is subject to regional variations and depends on the voltage level fed into the grid. The below listed tariffs will no longer be valid, when the liberalised green electricity market enter into force.

Electricity generated from biomass

If electricity from biomass is fed into the grid, the utilities pay on the basis of avoided cost. Thus, the price depends on the specific time at which the electricity is supplied. The private producer receives between 0.14 – 0.98 DKK/kWh from the utility. The average payment ranges at approx. 0.32 DKK/kWh. Added to this is the afore-mentioned electricity production subsidy (reimbursement for energy/carbon tax) of 0.10 DKK/kWh and (support for RES) of 0.17 DKK/kWh. Thus the total price varies between 0.41 – 1.25 DKK/kWh. The average price approximates 0.54 DKK/kWh.

Electricity generated from wind power

The price for electricity from land-based wind power systems constitutes 85% of the net price of a consumer of more than 20,000 kWh per year (minus costs for using the grid). The price paid by the electricity utility depends on the area, and varies between 0.25 – 0.39 DKK/kWh. An electricity production subsidy is also granted for wind power (0.27 DKK/kWh). Thus the total feed-in tariffs ranges between 0.52 – 0.66 DKK/kWh. The annual average throughout Denmark approximates 0.59 DKK/kWh.

ANNEX 3
NEW FEED-IN TARIFFS FOR RES ELECTRICITY FOR EXISTING AND NEW RES-PLANTS TIL THE START OF COMPREHENSIVE REFORMS, PRIMO-2003

The investments already made by wind mill owners, district heating and CHP plants etc. are based on existing regulations and a transitional phase should therefore be established for these investors. The amendments in feed-in tariffs will improve the economic conditions for biomass plants and shorten the subsidy period for wind mills in the transitional period.

1. WIND MILLS

Type	Fixed price (DKK/kWh)	CO_2-tax exemption (0.10 DKK/kWh)	RES subsidy (0.17 DKK/kWh)
EXISTING WIND MILLS			
Private wind mills below 100 kW *) **)	0.33 DKK/kWh for 10 years	YES	For 25,000 full-load hours
Private wind mills at 100–200 kW *)	0.33 DKK/kWh for 10 years	YES	For 25,000 full-load hours
Private wind mills at 201-599 kW *)	0.33 DKK/kWh for 10 years	YES	For 15,000 full-load hours
Private wind mills at 600 kW and above *)	0.33 DKK/kWh for 10 years	YES	For 12,000 full-load hours, starting 1 January 2000
Utility owned wind mills, financed by allocations under previous rules	NO	NO	NO
NEW WIND MILLS ***)			
Private wind mills erected during 2000, 2001 and 2002	0.33 DKK/kWh for 10 years	NO	Replaced by green certificate with a value of max.0.27 DKK/kWh
Utility owned land-based wind mills erected during 2000, 2001 and 2002 by government decree	NO	NO	NO
Utility owned off-shore wind mills erected during 2000, 2001 and 2002	0.33 DKK/kWh for 10 years	NO	Replaced by green certificate with a value of max.0.27 DKK/kWh

*) Should these changes in the price subsidy for wind turbines result in the owner of the wind turbine not

being able to meet unpaid debts for the investment in the wind turbine, upon request from the owner of the wind turbine the State will guarantee that the system responsible company can take over the wind turbine and the payment of loans outstanding which were taken out to finance the purchase of the wind turbine before the Bill was presented.

The guaranteed settlement price of DKK 0.33/kWh is expected for a period of 10 years from the time of erection of the wind mill. This awaits approval of the Parliament.

**) Special rules are to be established to promote the replacement of old wind turbines under 100 kW. Under the precondition that the existing wind turbine is decommissioned, the turbine owner can instead acquire wind turbine shares in a new, jointly owned wind turbine for electricity production corresponding to the triple of the electricity production at the decommissioned wind turbine for a guaranteed settlement price of DKK 0.60/kWh for production corresponding to 12,000 full-load hours. After this, the wind turbine is ensured a settlement similar to other new wind turbines established during the period.

***) Private wind turbines, purchased on binding, unconditional contract before the end of 1999, and which have the necessary permits, will be regarded as existing wind turbines. If the above contracts and permits are achieved after 1 January 2000, the wind mills will be regarded as new.

Special rules will apply for small domestic turbines.

2. BIOMASS

Type	**Fixed price (DKK/kWh)**	**CO_2-tax exemption (0.10 DKK/kWh)**	**RES subsidy (0.17 DKK/kWh)**
EXISTING BIOMASS PLANTS *)			
Biogas plants	0.33 DKK/kWh	YES	YES
Local biomass plants **)	0.27-0.33 DKK/kWh (specified during 1999)	YES	YES
NEW BIOMASS PLANTS ***)			
Biogas plants erected during 2000, 2001 and 2002	0.50 DKK/kWh for 10 years	NO	Replaced by green certificate with a value of max.0.27 DKK/kWh
Local biomass plants **) erected during 2000, 2001 and 2002	0.50 DKK/kWh for 10 years	NO	Replaced by green certificate with a value of max.0.27 DKK/kWh

*) The economic conditions for the utility owned biomass plants will be defined during 1999.

**) Excluding utility owned biomass plants

***) Local biomass plants purchased on binding, unconditional contract before the end of 1999, and which

have the necessary permits, will be regarded as existing plants. If the above contracts and permits are achieved after 1 January 2000, the biomass plant will be regarded as new.
The economic conditions for the utility owned biomass plants will be defined during 1999.