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Report on the in-depth review of the second national communication of Denmark

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I. INTRODUCTION AND NATIONAL CIRCUMSTANCES

1. The secretariat received Denmark's second national communication on climate change (NC2) on 5 December 1997. An in-depth review of the NC2 was carried out between June 1998 and September 1999, including a visit to Copenhagen from 21 to 25 September 1998. The review team consisted of Dr. Park Ill Soo (Republic of Korea), Dr. Ingrida Apene (Latvia), Mr. Markus Nauser (Switzerland), Mr. Fridtjof Unander (International Energy Agency-IEA) and Dr. Katia Simeonova (UNFCCC secretariat, coordinator).

2. The Kingdom of Denmark consists of Denmark, Greenland and the Faeroe Islands, the latter two being self-governing administrative divisions. The Danish Government ratified the Convention on behalf of the Kingdom on 21 December 1993. The NC2, however, contains mainly information on Denmark, with the exception of impact assessment of climate change on the fragile ecosystems of Greenland and the Faeroe Islands.

3. Denmark's population was 5,275,121 as of 1996, and the area of the country is 43,094 km^2. Agricultural land accounts for about 64 per cent, followed by urban areas with 15 per cent, and the remaining 21 per cent is split almost equally between forests and natural areas (moors, marsh, bogs, lakes and streams). Denmark has a coastline of 7,314 km, of which 500 km is protected by dykes. The country has a relatively mild marine climate, with mild winters and cool summers, and precipitation almost evenly distributed throughout the year.

4. Economic development in Denmark during the last two decades followed a relatively steady upward trend, with gross domestic product (GDP) increasing by almost 40 per cent over the period 1980-1995. Denmark's economy was affected by recessions in the nineties, but even then it maintained a small positive growth of about 1.3 per cent over the 1990-1993 period. From 1994 to1996, annual GDP growth was 3 per cent on average, and in 1997 it reached 3.5 per cent. It was expected that this growth would pick up further in 1998 with the recovery of Denmark's main export market, Germany. With GDP per capita of $32,750 in 1995, Denmark ranks among the top income countries. The economy is open, the main trading partners being the European Community (EC), Norway, the United States of America and Japan. As far as the economic structure of the country is concerned, the service sector, including the provision of public services, is extensive accounting for 69 per cent of GDP in 1995, followed by an industrial sector dominated by light industries and food processing with 20 per cent, agriculture, forestry and fishery with 4 per cent, and others.

5. By implementing an aggressive energy efficiency policy, Denmark has had remarkable success in decoupling energy demand from economic growth. Thus, the total final energy consumption (TFC) increased by only 3 per cent in the 1980-1995 period, reaching the level of 15.56 million tonnes of oil equivalent (Mtoe) in 1995. Total primary energy supply (TPES) increased by only 2.5 per cent in the same period, reaching 20.48 Mtoe in 1995, while GDP grew by 40 per cent, reflecting a level of energy intensity that is among the lowest of countries in the Organisation for Economic Co-operation and Development (OECD). Even more indicative of energy efficiency policy was the sectoral energy consumption for the same period, with energy

demand in services and the household sector decreasing by 6.3 per cent, that of industry falling by 0.5 per cent and that of transport increasing by 27 per cent. This resulted in an energy demand pattern in 1995 in which services and households were by far the dominant sector, with 41 per cent of TFC, and the remaining part shared almost equally between the transport sector, 29 per cent, and industry, 27 per cent. Another feature of TFC in Denmark was the shift towards secondary sources, such as heat and electricity, which, together with the high level of penetration of combined heat and power (CHP) plants, has contributed to the very high efficiency of the energy transformation system.

6. In terms of total primary energy supply in 1995, oil and oil products accounted for 44 per cent, followed by coal and coke 32 per cent, natural gas 16 per cent and renewables 8 per cent. There was a steady rise in the share of natural gas and renewables in TPES over the last two decades, mainly by replacing oil used for heat and electricity production, while the share of coal remained relatively constant. Indigenous energy resources include oil and gas from the North Sea, and renewables, while all the coal is imported. In 1997, for the first time in its modern history, Denmark became self-sufficient in energy. In the light of the current state of exploration, the quantity of oil and natural gas in the Danish fields is expected to cover domestic demand for 10-15 and 20-25 years, respectively. Changes in the fuel mix and the constantly improving energy intensity of the Danish economy have resulted in a level of carbon intensity well below the OECD average.

7. The total installed capacity in the Danish electricity sector in 1996 was 10,723 MW, comprising 9,133 MW of utility capacity and 1,590 MW from autoproducers, and the amount of electricity produced was 45,387 GWh and 5,027 Gwh, respectively. The bulk of electricity, about 75 per cent, was produced by large coal-fired CHP and condensing plants, followed by small-scale district heating CHP 16 per cent, wind power 5 per cent and industrial CHP 4 per cent. In 1997, a ban on the construction of new coal-fired power plants was imposed by the Government with the consent of the parliament and two applications received from utilities after this decision were accordingly rejected. Following a 1985 decision by the parliament, no nuclear power plants have been built in Denmark and nuclear power was not considered an option in the current energy plans.

8. Denmark was among the countries which in the late eighties included climate change in their policy agendas. Since then, climate change policy has been target-oriented. The national target adopted by the parliament in 1990, which was still valid at the time of the review visit, called for a 20 per cent reduction in energy-related CO_2 emissions in 2005, compared to their 1988 level. In addition to the UNFCCC target and as a contribution to the European Union (EU) stabilization target, Denmark made a commitment to reduce CO_2 emissions by 5 per cent in 2000 compared to the 1990 level. Under the Kyoto Protocol and the EU burden-sharing agreement, Denmark accepted the target of a 21 per cent reduction in emissions of all six greenhouse gases (GHG) for the period 2008-2012 compared to 1990. Finally, the 1996 Energy 21 Plan explores options for achieving a long-term objective of reducing emissions by 50 per cent over the period

1990-2030.[1] Danish experts fully acknowledged the importance of EC legislation and policy coordination for the national climate policy process. They emphasized that policy coordination in the field of energy taxation, promotion of renewables and cogeneration, as well as measures to promote energy efficiency and especially for labelling of appliances and common minimum energy efficiency standards, would be of significance to achieve the 21 per cent reduction target.

9. With respect to the conformity of the NC2 with reporting requirements, the main conclusion of the team was that, in general, the presentation of the information in the NC2 followed the UNFCCC guidelines. Moreover, the team's impression was that, while the NC2 reflected adequately Danish climate policy, many new initiatives had been launched or considered after it had been published. During the visit, the team met with a wide spectrum of climate change experts, thus obtaining a wealth of information and background documentation which helped to afford a better understanding of contemporary Danish climate policy.

10. In the process of preparing the NC2, the Danish Environmental Protection Agency (DEPA) of the Ministry of Energy and Environment (MEE) served as the main agency to coordinate the efforts of other governmental and non-governmental institutions. The MEE and DEPA[2] have the role of coordinating the major part of climate change policies and measures at national level. As mentioned in the first in-depth review report, the combination of those two important issues, energy and environment, under the same ministry, together with the strong position of this ministry within the Government, has been an important factor in implementing Denmark's climate change policy. At the same time, the team found that it is well understood in Denmark that further strengthening of the institutional setting is required, by bringing together all major stakeholders and involving them in the process of formulating and implementing climate policy.

II. INVENTORIES OF ANTHROPOGENIC EMISSIONS AND REMOVALS

11. The review of the Danish GHG inventory is based on information presented in the NC2, the latest submission to the UNFCCC secretariat of the 1996 inventory and the 1997 report *Inventory of Emissions to the Air from Danish Sources 1972-1995*. The NC2 contains inventory data for the 1990-1995 period for the main GHGs such as CO_2, methane (CH_4) and nitrous oxide (N_2O), for precursors, such as nitrogen oxides (NO_x), carbon monoxide (CO) and non-methane volatile organic compounds (NMVOCs), for sulphur dioxide (SO_2), and for the new gases, namely hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6).

12. In general, Denmark used the 1995 *IPCC Guidelines for National Greenhouse Gas Inventories*, referred to below as the IPCC Guidelines, as a reporting framework, while the CORINAIR methodology was used to compile the major part of the inventory. In some cases,

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[1] All targets refer to adjusted emission values in 1988 and 1990. If such adjustments are not made, the 5 per cent reduction target means a 9 per cent increase in CO_2 emissions. In the context of the EC burden-sharing agreement adopted by the Council of Ministers in June 1998, Denmark made the following statement: "Denmark is able to reduce its emissions by 17 per cent in the first commitment period compared to its 1990 level of about 80 million tonnes corrected CO_2 equivalent through domestic policies and measures and present measures adopted by the EC. In making its legal commitment to a 21 per cent reduction as set out in the agreement, Denmark has assumed the further elaboration and adoption of common and coordinated policies and measures prior to the ratification of the Kyoto Protocol".

[2] As of January 1999, the Danish Energy Agency (DEA) of the MEE is the main institution coordinating climate change activities.

such as the estimates of N_2O emissions from agricultural soils, as well as emissions of HFCs, PFCs and SF_6, the 1996 revised IPCC Guidelines were used not only for reporting, but also for estimating the emissions. Moreover, the revised 1996 IPCC Guidelines were used in preparing the 1996 inventory submitted to the UNFCCC secretariat. In the NC2, Denmark provided only the IPCC summary tables while the submission for 1996 contained both summary and sectoral tables. The team was informed that the estimates of emissions using the IPCC reference approach were not available. Instead, Danish experts used the CORENBAL methodology, which is a part of CORINAIR, for verification purposes.

13. The team noted that the GHG inventory did not include the emissions from Greenland and the Faeroe Islands. Among the reasons was the lack of reliable activity data on energy consumption, together with the assumption of a low level of energy consumption and associated GHG emissions due to the small population of those islands. The team noted that, because of fishing, the consumption of energy could be somewhat higher than assumed. Moreover, emissions from sea and air traffic between Denmark and these islands were considered as associated with international bunkers.

14. The National Environmental Research Institute (NERI) was responsible for coordinating the preparation of the GHG inventory and compiling the first draft, based on the input from the DEA, the DEPA, the National Forest and Nature Agency and the RISØ National Research Laboratory. A national review process was set up to cross-check both the results obtained from different agencies and the activity data used to compile the GHG inventory. This process was geared towards ensuring the quality of the GHG inventory and the consistency of information reported under different international agreements. The team found that while the institutional setting seemed close to what could be called “a system in place to collect data and estimate the GHG emissions”, further efforts would be necessary to strengthen it, for example, by including some academic institutions and/or other non governmental organizations in the national review process. Additionally, such efforts need to ensure enough capacity to recalculate and update the time series, when necessary.

15. Broadly, the inventory was compiled using CORINAIR methodology, which is oriented amongst other things towards producing estimates from major emission point sources. For emissions from road transport, the COPERT model was used, which is similar to the IPCC tier 3 approach. The model requires the vehicle fleet to be split into 46 categories, by fuel, model and age, while the emissions are calculated considering also the speed of vehicles and mileage. This approach accounts for the emissions from different types of vehicles, which was important for the non-CO_2 emission estimates. Once the national GHG inventory was compiled applying the CORINAIR methodology, the data were transferred to the IPCC format using the approach for data conversion given in the IPCC Guidelines, and information on the correspondence of different source/sink categories was made available to the team after the visit. Additionally, the team learned of the difference between the transport emissions estimated according to the IPCC approach, based on fuel sold, and those obtained by the CORINAIR approach, based on fuel consumed, which ranges from 1 to 5 per cent. To account for this difference and obtain the

national emissions, the emissions related to the cross-border trade in gasoline and diesel fuel were added to the estimates obtained using CORINAIR.

16. Mostly, official statistics were used as the source of activity data for the GHG inventory. These data came from Statistics Denmark and the DEA as regards the energy data, and the National Forest and Nature Agency. Apart from the official statistics, a great deal of additional information and numerous assumptions were used to compile the GHG inventory. Statistical data for agriculture were collected on a yearly basis applying a sampling approach. Finally, for the assessment of sink capacity in the land-use change and forestry sector, activity data were based on the statistics from the forest inventories and the yield tables. The last forestry inventory took place in 1990 and the next one is due in 2000. The team found that the activity data appeared to be of a high standard and that the quality had improved since publication of the NC1.

17. With respect to emission factors, the team learned that factors recommended by CORINAIR were used mainly and the NC2 contained a list of the factors for energy-related GHG emissions. For estimates of CO_2 emissions from fossil fuel combustion, emission factors were based on calculations taking into account the fuel heat rate. As a result, the emission factors used for CO_2 estimates were close to IPCC default ones, with only the emission factors for refinery gas being about 20 per cent lower than the IPCC default. The team noted that the same factor was used for emissions from coal for the whole 1990-1995 period without allowing for the different heat content of the imported coal, which depended on the coal mix. The impact of more precise accounting of the coal mix is likely to be small. To estimate energy-related NO_x and SO_2 emissions, emission factors were obtained by measurement at the large combustion plants. As to the non-energy emissions, research was being conducted on country-specific factors for CH_4 from enteric fermentation, but so far only the IPCC default emission factors were used. In the 1996 GHG inventory, the data for the solvents sector were taken directly from industry, resulting in changes to the CO_2 and NMVOC emissions compared to the previous estimates.

18. When comparing the methodologies used for the GHG emission estimates and the results obtained in the NC1 and NC2, the major difference appeared to be in emission estimates from new sources in the NC2 using the 1996 IPCC Guidelines. These new sources included estimates of the new gases, and N_2O emissions from several activities in agriculture. In the NC2 these included emissions from fertilizer fixation, from nitrogen deposition, from nitrogen leaching, from livestock and from organic soils, in contrast to the NC1 which included only emissions from the direct application of fertilizers. Furthermore, more precise estimates of the fugitive emissions from imported coal storage were obtained. In the NC1, to calculate fugitive CH_4 emissions, equal shares of coal from underground and surface mines were assumed, while in the NC2 the estimates were based on the actual shares. A small quantity of CH_4 emissions, about 3 per cent, was also added to the total emissions to account for the effect of incomplete combustion of natural gas in small CHP plants. Further changes included allocating the emissions from CHP from the energy and transformation industry to the respective energy end-use sectors. Finally, CH_4 emissions from landfills were estimated in the NC2 using kinetic methodology, which considered the amount of emissions as a function of the time when the

waste was landfilled, in contrast to the NC1, where a basic methodology was used, assuming emissions occur in the year of landfilling.

19. As a consequence of methodological changes and data quality improvement, Denmark revised its 1990 GHG emission estimates in the NC2 compared to the NC1. The team noted that this led to an increase in N_2O emissions of 224 per cent and CH_4 emissions of 3.6 per cent, while CO_2 emissions practically did not change, the overall result being an increase of 11 per cent in the aggregate GHG emission estimates for 1990 on a global warming potential (GWP) basis.

20. Denmark used an adjustment of the GHG inventory data in both the NC1 and the NC2 to account for electricity exchanges with neighbouring countries. Moreover, Denmark added new adjustments in the NC2 to account for temperature variations. In line with the reporting requirements, the NC2 reported both adjusted and unadjusted data. The team was provided with an explanation of the methodology used for adjustment, well documented in the NC2.[3]

21. Denmark reported estimates of the emissions from international aviation and marine bunkers separately, and did not include them in the national totals as required by the IPCC Guidelines. A comprehensive model was used to assess the international aviation bunkers, which was very close to CORINAIR methodology. According to the model, the energy used for air traffic and the related emissions were split into domestic and international flights, and additionally within each group emissions from landings and take-offs, and from cruising were estimated separately. Activity data were obtained from information on fuel sales in Denmark to national and international carriers, and the number of flights.

22. The estimate of sink capacity in the land-use change and forestry sector was one of the areas where substantial methodological changes occurred in the NC1 and the NC2. A Danish carbon sequestration model was used, which closely followed the IPCC Guidelines. Thus estimates of carbon sequestered by the existing forest were produced by converting the net forest increment into CO_2 stored using 1996 IPCC Guidelines. For estimates of the carbon sequestered by new forest, the model attempts to go beyond the IPCC approach by accounting for the delay in the carbon release from wood products, given differences in their durability. The team noted that Denmark was the only country giving estimates of emissions and removals from afforestation. The explanation lay in the fact that Denmark is now implementing an ambitious afforestation policy aimed at doubling the forest area in 80-100 years. A model has therefore been developed to estimate the effect on carbon sequestration of the new forest. The estimates of activity data on afforestation were reliable, as they were linked to annual subsidies for planting.

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[3] The adjustment for electricity trade was made by multiplying the total emissions from power generation by the ratio of net imports to the total electricity generation in central power plants. It was assumed that all the electricity trade was influenced by the climate and consequently by variations in precipitation, and the average over a long time period would be zero net exchange. The team noted that the trading patterns indicated a trend towards significant shortage of generating capacity in the Swedish/Norwegian power system, resulting in net exports from Denmark even in the years with normal availability of hydropower. Since the team visit, Denmark has decided to introduce a national quota system by January 2000 in order to control commercial interests in exporting electricity produced in Denmark. Hence, the adjustment for future electricity trade will only be relevant for evaluation of trends in national consumption compared to the national target. The temperature adjustment was applied to all fuel used for district heating, all fuel used in the residential sector and 20 per cent of the oil and natural gas used in industry. Further, an assumption was made that energy consumption increases by only 0.5 per cent when the temperature correction index increases by 1 per cent, which could be interpreted as the way to account for the share of consumption for space heating used for hot water production.

23. The qualitative estimates of uncertainty of the GHG inventory were obtained using expert judgement. The CO_2 emission estimates were regarded as highly certain, while the CH_4 and N_2O emissions were estimated to have an uncertainty factor of two. The team noted that uncertainties reported for CH_4 and N_2O were somewhat higher than the average level usually reported by the Parties. The team learned of efforts to reduce uncertainties by improving the quality of activity data and emission factors, with implications for the forthcoming GHG inventories.

24. The plans for future improvement of the GHG inventory included accounting for the emissions associated with the plastics deposited and incinerated with the waste and improved estimates of industrial process emissions. Moreover, a revision of energy statistics to improve the quality of activity data is to be concluded in 1999.

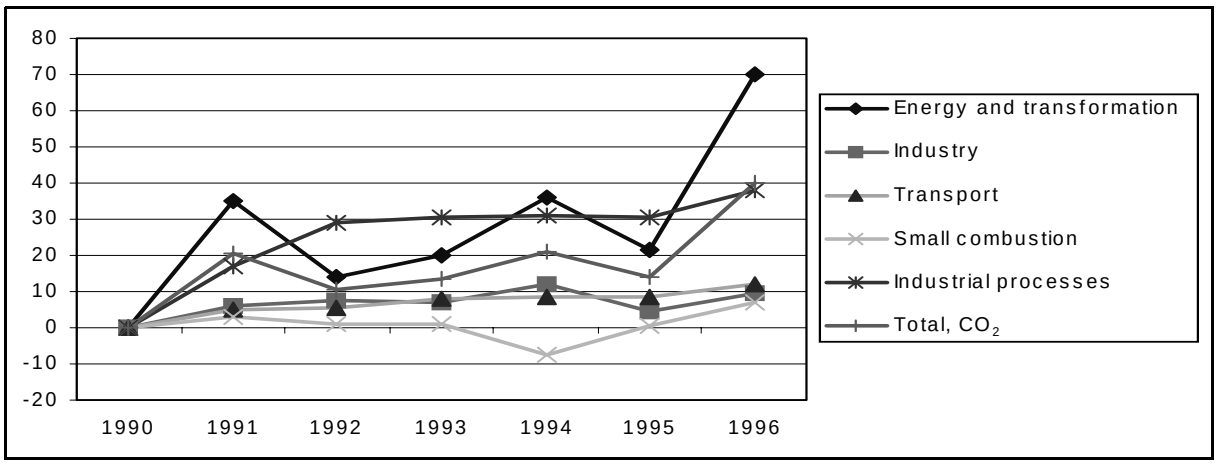
25. The results of the 1996 GHG inventory indicated that the GHG emission pattern of Denmark did not change noticeably over the 1990-1996 period. CO_2 remained by far the most important GHG, with a share of 79 per cent of the total GHG emissions expressed by their GWP. The second most important gas was N_2O, accounting for 11 per cent of the emissions, followed by CH_4 with 10 per cent. The total emissions grew by 29 per cent between1990 and 1996.

26. Total CO_2 emissions increased from 52,277 Gg in 1990 to 73,236 Gg in 1996, a 40 per cent growth, primarily attributed to the growth of emissions from the energy and transformation sector (table 1 and figure I). If adjusted data are considered, emissions decreased from 60,233 Gg to 58,736 Gg, or by 2.5 per cent for the same period of time. In 1996, Denmark exported 14.4 TWh of electricity to the Nordic countries, which corresponded to 50 per cent of the domestic consumption, in contrast to 1990, when 7.05 TWh of electricity was imported. Analysis of the emissions trend from other sectors showed that transport emissions grew by 12 per cent and those from industrial processes grew by 38 per cent over the same period. The growth in transport emissions was linked to the increased number of cars and increased mileage, while the growth in emissions from industrial processes was attributed to the increase in output of the building materials industry.

Table 1. Carbon dioxide emissions by sector, 1990-1996 (Gg)

	1990	1991	1992	1993	1994	1995	1996
Energy and transformation	25 865	34 864	29 540	31 028	35 213	31 482	44 020
Industry	5	6 114	6 218	6 168	6 481	6 039	6 312
Transport	10 474	10 976	11 072	11 301	11 345	11 370	11 748
Small combustion	8 664	8 925	8 740	8 738	8 020	8 718	9 273
Industrial processes	1 006	1 178	1 300	1 311	1 318	1 311	1 388
Others	492	913	782	810	967	612	495
Total	**52 277**	**62 970**	**57 652**	**59 356**	**63 344**	**59 532**	**73 236**
Land-use change and forestry	-924	-932	-940	-948	-956	-964	-981

Figure I. Carbon dioxide emissions, percentage change by sector, 1990-1996

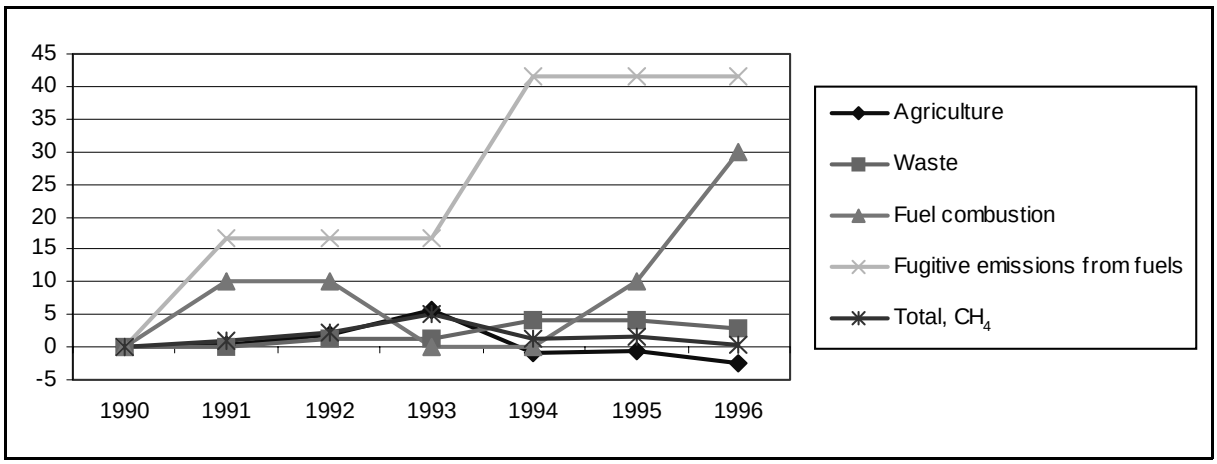


27. With respect to CH_4 emissions, agriculture remained the most important source, accounting for 75 per cent of total CH_4 emissions in 1996, followed by waste 17 per cent and energy 8 per cent. The trend of CH_4 emissions for the 1990-1996 period was upward until 1993, followed by a decline thereafter (table 2 and figure II). The trend of total emissions was linked with the emissions from agriculture, which also peaked in 1993 in line with the world demand for pork.

Table 2. Methane emissions by sector, 1990-1996 (Gg)

	1990	1991	1992	1993	1994	1995	1996
Agriculture	329	330	335	348	326	327	321
Waste	71	71	72	72	74	74	73
Fossil fuel combustion	10	11	11	10	10	11	13
Fugitive emissions from fuels	12	14	14	14	17	17	17
Total	**422**	**426**	**432**	**444**	**427**	**429**	**424**

Figure 2. Methane emissions, percentage change by sector,1990-1996

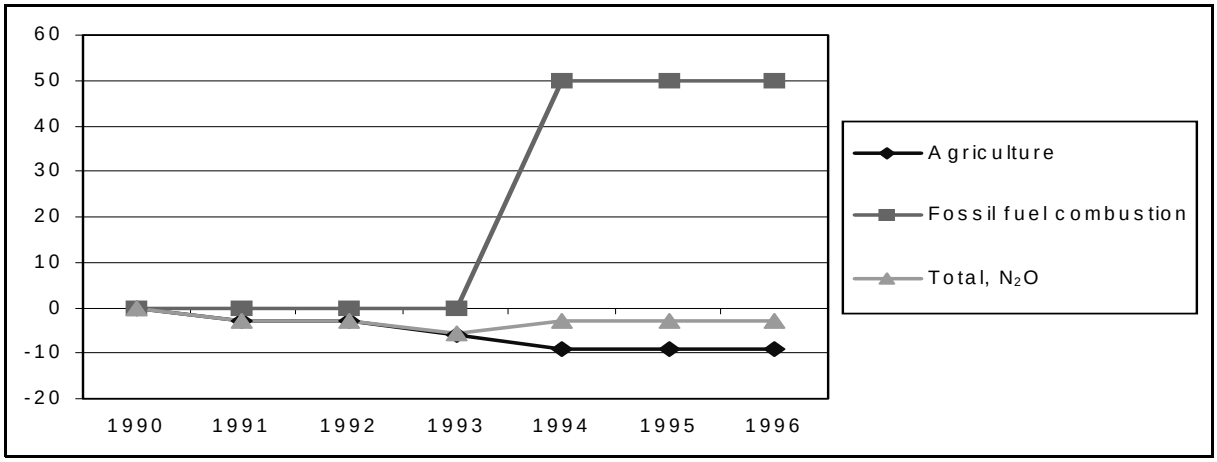


28. As a result of implementation of the 1996 IPCC Guidelines and the inclusion of new sources, the estimates of the 1990 N_2O emissions were revised upwards by 224 per cent, but the level of emissions remained relatively stable over the 1990-1996 period (table 3 and figure III).

Table 3. Nitrous oxide emissions by sector, 1990-1996 (Gg)

	1990	1991	1992	1993	1994	1995	1996
Agriculture	33	32	32	31	30	30	30
Fossil fuel combustion	2	2	2	2	3	3	3
Land-use change and forestry	0	0	0	0	1	1	1
Total	**35**	**34**	**34**	**33**	**34**	**34**	**34**

Figure 3. Nitrous oxide emissions, percentage change by sector, 1990-1996



29. As of 1996, practically the whole Danish forest was managed and forest cover accounted for 10 per cent of the land area, or 4,170 km^2 out of a total of 43,000 km^2. The area of annual afforestation was 2,300 ha. The team noted that in the 1996 GHG inventory, the estimate of the forest sink amounted to 24 Gg CO_2, which included only the fraction of the sink attributable to afforestation, while the total sink was about 981 Gg. In the NC2, the reporting covered both the CO_2 uptake from the existing forest, which amounted to 916 Gg and the CO_2 uptake from afforestation, which steadily increased from 8 Gg in 1990 to 48 Gg in 1995.

30. The team noted with appreciation that Denmark was among the few countries to provide estimates for both the actual and potential emissions of the new gases as required by the 1996 IPCC Guidelines. The methodology used for these estimates followed the IPCC tier 1 and tier 2 approach. Since Denmark was not a producer of these gases, the information on the import, export and consumption was used as a source of activity data, while the emission factors were taken from IPCC. The team noted the trend of a steep increase in HFC emissions in the 1990-1995 period, HFCs being used as a substitute for substances controlled by the Montreal Protocol.

III. POLICIES AND MEASURES

31. The Danish NC2 contains an overview of policies and measures, organized by gas and by sector in line with the UNFCCC guidelines. In addition, two annexes provide more detail on the legal foundation and policies in the energy sector, as well as the Danish energy, fuel and vehicle taxation system. Information on the type and objective of measures, implementation status, expected mitigation impact and progress indicators was not available in the tabular format required by the guidelines.

32. In general, Danish climate policy centred on the extensive use of economic instruments, applied in the context of sectoral action plans, which served as the main policy instruments to pursue the goal of sustainable development. Regular follow-up of these plans made it possible to react flexibly to new developments and to ensure that the instruments applied were on track to deliver the necessary effects. The team noted that, while no formal integrated monitoring procedure was in place at national level to provide detailed assessment of the effectiveness of individual policies and measures and their quantitative impact on emissions, in the energy sector a yearly assessment was used to assess the progress in the implementation of measures. The team acknowledged that, while rigorous monitoring was in place on the effects of policy to promote renewables, there were no mechanisms to monitor the effect of energy efficiency policy. Consequently, the NC2 contains little information on the actual effects of implemented policies, and the team was told that little analysis had been done to quantify them. In June 1999, after the team visit, the DEA launched a project to improve the monitoring of policies and measures.

A. Carbon dioxide

33. The 1990 Energy 2000 Action Plan, the 1990 Transport Action Plan and their 1993 follow-up were the main policy documents to introduce the goal of sustainable development in the energy sector and to build the foundations of contemporary Danish climate policy. In 1996, the Energy 21 plan was adopted, which outlined policy initiatives to achieve the national target of a 20 per cent reduction in adjusted energy-related CO_2 emissions by 2005 compared to the 1988 level. Increased use of natural gas and biomass in place of coal, further promotion of CHP, a shift from electricity and oil to district heating and natural gas in the end-use sectors, and improvements in energy efficiency are the core components of the strategy to achieve the reduction. Denmark has thus chosen a fairly comprehensive approach to exploiting the emission reduction potentials in all sectors, other than transport, requiring coordination of policies, which had usually been quite independent. Nevertheless, coordination of policies will still deserve enhanced attention in the future, as the various trade-offs between agricultural, forestry and renewable energy policy will require careful monitoring.

34. The NC2 contains a detailed and informative description of the taxation system in the energy and transport sectors up to 1996. Taxes on energy consumption have been applied in Denmark since 1977, exclusively targeting private households. In 1992, Denmark introduced a carbon tax of DKr 100 per tonne of CO_2 on fuels, complementing the energy tax, with the explicit aim of reducing the consumption of emission-intensive fuels. Households and public

sector consumers paid the full tax, while industry and the commercial sector paid half, and heavy industry was exempt, which altogether resulted in an effective level of tax for industry of 35 per cent of that for households. In 1995, a "green" tax reform was initiated, with the objective of shifting the balance in the tax system away from labour taxation towards natural resource taxation, and to extend the coverage of taxation. Another objective of the reform was to increase gradually the combined energy/carbon tax level for household heating up to the equivalent of DKr 600 per tonne of CO_2. In 1996, this reform was extended to industry. The energy component of the combined energy/carbon tax was most significant, but the trend was towards a gradual increase in the weight of the CO_2 component. Hence, from 1996 to 1998, the revenue from the energy tax increased from DKr 20,006 million to DKr 23,475 million, while that from the carbon tax increased from DKr 3,693 million to DKr 4,550 million.

1. Energy and transformation sector

35. Even after the 1995 "green" tax reform, electricity taxation continued to be directed exclusively at consumption, with no distinction between the electricity produced from renewables and natural gas and that produced from coal, in contrast to heat production, where fuel inputs were subject to energy and carbon taxation. To compensate for this, the approach was to focus on subsidies and investment grants. Thus, a subsidy of 0.10 DKr/kWh was provided for electricity generated by decentralized CHP plants, from natural gas or from renewables, while an additional subsidy of 0.17 DKr/kWh was granted for electricity generated from wind and biomass. As to the investment grants, in 1997 for example, for CHP plants in industry they amounted to DKr 87 million, with a total of DKr 532 million spent over the period 1993-1997. Investment grants for renewables reached DKr 192 million in 1996.

36. The Danish electricity sector is organized in two vertically integrated power pools, ELSAM and ELKRAFT, which interestingly do not have an electric connection between them, eight major power companies, several hundred small producers and approximately 100 distribution companies. As of 1997, 75 per cent of electricity was produced on utility power plants, 20 per cent as CHP (16 per cent district heating and 4 per cent industrial CHP) and 5 per cent as wind power. The high share of the decentralized power plants, including CHP, which helped to restrain the growth of energy supply during the last 25 years despite the economic growth, was an indicator of the success of the Danish energy policy.

37. The 1996 Electricity Supply Act, which came into force in early 1998, opened the Danish electricity and gas markets to competition. Key elements of the Act were partial opening of the electricity market by giving distributors and consumers above 100 GWh/year free access to the market, introducing provisions on public service obligations and regulations regarding the system operator. ELSAM has already taken the first steps towards restructuring to meet the market conditions by splitting into three parts, namely, power generation, system operator and distribution association. A similar process with some lag is taking place at ELKRAFT. Market liberalization was expected to have a considerable impact on the taxation and subsidy scheme. Hence, investment subsidies were likely to continue to play a central role in achieving the goal of

1 per cent annual growth in renewable energy, while production subsidies were expected to become less important.

38. At the end of 1998, a proposal was under preparation by the MEE for legislative reform of the electricity, heating and gas sectors to secure environmental objectives, consumer protection, security of supply and a high degree of cost effectiveness, under energy market liberalization. At that time, a decision on legislation for opening of the market to third parties was yet to be taken. According to information provided during the review, non-discriminatory environmental criteria for the construction of new power plants, the introduction of CO_2 quotas to avoid production in old emission-intensive power plants, and the establishment of a "green" electricity market will be given special consideration in the context of the energy market liberalization in Denmark. In May, 1999, the Danish parliament adopted this new legislation.

39. Utilization of renewable energy resulted in it gaining an 8 per cent share of TPES in 1997, mainly due to the target-oriented policy and implementation of subsidy and grant schemes. The Energy 21 plan established an ambitious target of expanding the use of renewable energy at an annual rate of approximately 1 per cent and assumed that renewables would contribute 12-14 per cent to TPES in 2005 and 35 per cent in 2030. One of the ways to achieve this target was to use for renewable energy projects 40 per cent of the total amount of DKr 100 million spent annually on energy-related research under the Energy Research Programme.

40. Within the Danish energy policy, biomass-based CHP played an important role. The 1993 biomass agreement required the replacement of 6 per cent of total coal consumption in power plants by prescribed amounts of straw and wood. Development was slower than expected due to the cost involved. Following an adjustment of this agreement, in 1997 the amount and type of biomass to be used in power plants was handled in a more flexible way.

41. Wind power capacity on land exceeded 1,000 MW in 1997, contributing about 7 per cent of the electricity consumed. The Energy 21 plan established a target of 1,500 MW of installed wind power capacity in 2005, to be achieved by having new wind turbines built by utilities and private owners. To achieve this target, it was planned to develop about 100 MW of wind power capacity annually. Given current trends, it is likely that the target will be reached ahead of time. Capital investment subsidies are no longer necessary while there remains an electricity production subsidy. Expansion of wind power is shifting somewhat to offshore installations, with a first phase of 150 MW to be constructed by 2002, followed by around 150 MW installed annually thereafter with the aim to have 750 MW installed by 2008. By 2030, wind turbines are expected to cover 50 per cent of Danish electricity consumption, while reducing CO_2 emissions by 14,000 Gg per year. The team considered the promotion of wind energy in Denmark as a remarkable example of an efficient policy to promote environment-friendly technology. The Danish wind turbine industry, which is a world leader in technical innovation, achieved a turnover of DKr 7 billion for 1998, almost double that of 1994. Additional benefits were the exports, amounting to DKr 5 billion, and over 12,000 jobs created in this sector.

42. Subsidies and the inclusion of external costs in the price level were considered essential to promote renewables. The team was informed that, from experience in Denmark, the correct level of subsidy is difficult to assess and there has been a tendency to oversubsidize wind energy and undersubsidize biomass. In fact, some of the wind farms which were best situated did not need subsidies at all, as the cost of electricity was comparable to the long-run marginal cost of coal-based electricity. This issue was addressed in the new energy legislation adopted in May 1999.

43. The promotion of CHP is central to the Danish strategy to achieve the GHG reduction targets and the team noted the good tradition of district heating in Denmark. As of 1998, about 50 per cent of space heating demand was met by district heating and about 70 per cent of its production came from CHP. In large cities, heat was produced in large coal-fired CHP plants, while in small cities heat came from small heat plants and CHP plants burning natural gas and waste. The existing electricity law gives priority to CHP through production subsidies, power purchase obligations and guaranteed premium buy-back rates based on the concept of avoided cost. With respect to small-scale CHP, the main efforts were geared to converting the district heating plants to natural-gas-based CHP. As of 1998, this conversion was almost completed, with an installed capacity of 1,300 MW and approximately 20 per cent of district heating coming from small-scale CHP. The policy of actively promoting CHP resulted in a transformation of the energy market, where large CHP plants were competitive but small CHP plants still needed support.

44. The integrated resource planning (IRP) approach launched in Denmark in 1995 in response to the 1994 Electricity Act required utilities to prepare 15-year plans, considering options in energy demand and supply in an integrated manner. Furthermore, the Act required these plans to be updated every two years and the most recent IRP was published by the two pools ELKRAFT and ELSAM in 1997. In conditions of a liberalized market, the role of IRP was seen as a basis for dialogue between electric companies and authorities on the one hand, taking into account the distribution between the production, transmission and distribution, and gas and district heating companies on the other. Additionally, the Energy Supply Act introduced licensing for operators of power stations of more than 25 MW as well as for the building of new plants, which in turn implied an obligation for the operators to supply certain regions in cooperation with other companies laid down in an IRP.

2. Industry

45. As of 1998, in line with the “green” tax reform, the maximum rates of the combined energy/carbon tax, formerly applied only to the residential sector, were extended to space heating in industry and in the commercial and institutional sectors, but at reduced levels for enterprises involved in light and heavy processing, and the possibility of tax exemption was envisaged. For heavy processes, the tax was set at DKr 5 per tonne of CO_2, with the objective of increasing it gradually to DKr 25 per tonne of CO_2 in 2000. For light processes, the tax was set at DKr 50 per tonne of CO_2, with the prospect of increasing it to DKr 90 per tonne of CO_2 in 2000. For space

heating in industry, the initial tax in 1996 amounted to DKr 200 per tonne of CO_2, and in 1998 it reached the same level as the tax for households, i.e. DKr 600 per tonne of CO_2.

46. In the industrial (including commercial and institutional) sector, revenue from the energy/carbon tax was fully recycled within the sector, mainly through investment grants for energy-saving measures and the lowering of social security contributions. The tax increase was introduced gradually and the full effect will be achieved only after 2000, when the tax is fully phased in. After five years of "green" tax implementation, i.e. in 2000, tax revenue will have risen to over DKr 2 billion, with the major part of revenue directed at lowering social security contributions. By that time, investment grants will remain at a level of DKr 235 million annually.

47. The 400 most energy-intensive enterprises were offered tax exemptions if they would conclude three-year voluntary agreements with the Government based on energy audits and action plans to improve energy efficiency, with an obligation to implement measures with payback periods of less than four years. In 1996, 20 enterprises, representing 13 per cent of industrial energy use, signed such agreements, which gave them a tax deduction of approximately 70 per cent. In 1998, 129 enterprises, accounting for 21 per cent of industrial energy end-use, were already covered by such voluntary agreements. The team noted that a process had been set up to review the voluntary agreements on an annual basis and to monitor the effect achieved. However, it seemed difficult to ascertain whether genuine progress in implementing energy efficiency measures had been made.[4]

48. As of 1997, the installed capacity of industrial CHP was 300 MW. This capacity was less than expected due to a reduction in the production subsidy from 0.10 DKr/kWh to 0.07 DKr/kWh, fluctuations between the relative cost of natural gas and electricity, and high production cost. The potential for new gas-fired CHP in industry was estimated at 450 MW. A revival of the interest of industry in new CHP and of creating additional incentives was expected along with the revision of the "green" tax package.

3. Residential, commercial and institutional sector

49. Electricity consumption in the residential, commercial and institutional sector was subject to taxation, which constituted up to 70 per cent of the price to the consumer. In 1998, the five components of tax on electricity were: (a) an energy tax of 0.47 DKr/kWh, which was to increase to 0.54 DKr/kWh in 2002; (b) a CO_2 tax of DKr 100 per tonne of CO_2 paid at the end-use at a rate of 0.1 DKr/kWh with reimbursement for consumers with voluntary agreements; (c) a 25 per cent value added tax (VAT), which was reimbursed to VAT-registered consumers; (d) a SO_2 tax of 0.09 DKr/kWh, which was to rise to 0.13 DKr/kWh in 2000; and (d) a tax earmarked for the Electricity Saving Trust of 0.006 DKr/kWh. The high price of electricity, one of the highest in

[4] In May 1999, the DEA published the results of an evaluation carried out in 1998. Due to the positive effect found, it is estimated that, by continuing the agreement system, a decrease in CO_2 emissions corresponding to 6 per cent of the total emissions from trade, industry and services could be achieved by 2005, compared to a situation without agreement. However, the positive effects of energy management are based on the assumption that companies will continue to work on improving their systems.

Europe, acted as an effective incentive for consumers to shift away from electricity for space and water heating. Along with the application of maximum carbon/energy tax rates for industry, in 1998 such rates were introduced for space heating in the commercial and institutional sectors as part of the "green" tax reform.

50. The 1992 Act on Conversion of Older Dwellings to CHP, with a financial commitment of DKr 1.5 billion for 10 years, was intended to convert the heating systems of the residential buildings constructed before 1950 from electricity, coal or oil to CHP-based district heating. By 1997, 31,000 out of 66,000 eligible building owners had applied for grants and the associated saving of CO_2 was estimated at 120 Gg.

51. In 1997, the Electricity Saving Trust was set up to promote further the switch from individual electrical heating to district heating. The trust was financed by a 0.006 DKr/kWh tax levied on electricity consumption in the residential, commercial and public sectors and was to provide funds of DKr 1 billion over a 10-year period. In 1997, the trust's budget was DKr 50 million. As some of the funds available were not used, they were transferred to the following year, 1998, making a total of DKr 90 million. In addition to that, state subsidies of DKr 47 million were made available for improving energy efficiency in housing for the elderly, with a ceiling of DKr 24,000 for individual projects.

52. As part of the Energy 21 plan, the Energy Management Act entered into force at the beginning of 1997, requiring house owners to establish energy labelling, energy rating and energy plans. Small buildings (up to 1,500 m^2) have to be assessed before they are sold, while larger buildings have to be assessed annually. An information campaign was launched to increase awareness of the Act's requirements. This measure was seen by the Danish authorities as a promising one in the residential sector, with an expected annual CO_2 reduction of 600-800 Gg in 2005, or about 5-7 per cent of the 12,000 Gg CO_2 reduction target in 2005 compared to 1988.

53. New building codes were introduced in Denmark in 1995, with the objective of reducing the heat demand for new buildings to 70 kWh/m^2 annually, which means a 25 per cent reduction from the current level. Strengthening of the codes was envisaged to reduce the heat demand to 45 kWh/m^2 annually. Use of passive solar heating, insulation and coated glazing were some of the technical solutions chosen by the building companies to meet the new standards.

54. Minimum energy efficiency standards were considered a key component of the 1993 Energy 2000 follow-up, with an effect estimated at 1,100 Gg of CO_2 saved annually. Standards for refrigerators and freezers were to be enforced in 1995, for washing machines and dishwashers in 1996 and for the other appliances in 1996, with further strengthening of all standards in the 1999-2002 period. However, due to the lack of agreement at EC level on coordinated policy with respect to these standards, they were not enforced as of 1998. Instead, the Government stimulated demand for energy-efficient products by voluntary energy labelling, innovative procurement strategies, and voluntary agreements and schemes.

55. As of 1992, mandatory implementation of energy management measures and purchase of energy-efficient equipment was introduced in the public sector, with the aim of achieving a 10 per cent reduction in energy use. This measure was backed by an information campaign. The actual reduction achieved was about 6 per cent. In government buildings, a total amount of DKr 9.4 million was spent on energy efficiency improvement. Another grant scheme available for energy efficiency investment in the public sector was based on a special 10 per cent tax levied on energy consumption, and the annual revenue from this tax was approximately Dkr 114 million.

4. Transport

56. Transport policy in Denmark was founded on the 1990 Transport Action Plan and its 1994 follow-up Transport 2005, which, together with the Energy 2000 programme, set the target for the transport sector to contribute to the 2005 reduction target by stabilizing emissions at the 1988 level. Recent developments indicated that this target would not be attained, as transport emissions have been increasing constantly, with an overall growth of 12 per cent for the period 1990-1996.

57. As reported in the NC2, achieving the transport target was always based on assumptions on coordinated measures at the EC level, in particular agreements with the automobile industry on the reduction of average fuel consumption of new cars. In this context, Danish experts noted that the agreement concluded in 1998 would lead to higher-than-expected emissions from transport. However, it was estimated that a further increase in gasoline prices would affect car use in Denmark as a 1 per cent rise in fuel prices in the past induced a 0.6 per cent improvement in car fuel economy. Danish officials expressed concern that such a rise could not be made without the cooperation of the other EC countries. Another measure to improve car fuel efficiency was the voluntary agreement with car companies to include information on fuel economy when selling cars. The most recent development in this sector was the 1997 parliamentary decision to introduce changes in the taxation of fuels and vehicles. The most important elements of this decision with implications for climate change were: (a) the change from a weight basis to a fuel consumption basis for the yearly tax on vehicles; (b) differentiation of the tax on gasoline depending on its benzene content; (c) the provision of incentives for light commercial vehicles to meet the proposed EC standards and the intention to extend this incentive to passenger cars.

58. In spite of the Government's attempt to control traffic expansion by keeping the taxes on car purchase at a high level compared to the other EC countries, Denmark has experienced very strong growth in both car numbers and miles driven, starting, however, from a lower level than the other EC countries. Data available indicated that fuel efficiency gains were offset by the growing number and use of cars, thus leading to an emissions growth.

59. The funds of the Ministry of Transport for road and rail infrastructure development were allocated in a ratio of 4:1 in 1996. In the same year, DKr 7.4 billion was spent on improving the road infrastructure, but only 10 per cent of that was government expenditure, as most of the road

network came under the responsibility of regional and local authorities rather than the national government. As of 1998, several large infrastructure projects to improve public transport were being realized or planned. Approximately DKr 22 billion was to be spent on such projects by 2005, focusing mainly on the Copenhagen area and on inter-city transport. Moreover, the public transport price dropped by 10 per cent in 1997, thus creating an incentive for more extensive use. In 1997 (rail) and 1998 (road), the first phase of the "fixed links" transit project connecting Fyn Island to Seeland Island was opened to traffic. This led to a drop in travel cost for cars formerly transported by ferry. The team was informed that new financial incentives to reduce emissions from road transport were under discussion at the time of the team's visit.

60. The impression of the team was that the options for further progress in mitigating transport emissions by domestic measures alone were limited in Denmark. Hence, the issues related to the integrated transport planning, physical planning and other tools to ensure backing of the financial instruments used, did not receive enough attention. The team emphasized that, given the importance of stabilizing CO_2 emissions in the transport sector, new and innovative ways of influencing transport modes and efficiency need to be explored.

5. Land-use change and forestry

61. As of 1998, 11-12 per cent of the Danish territory was covered by forests. A parliamentary decision taken in 1989 and reiterated in 1996 set the target of doubling the forested area within 80-100 years, which would require an afforestation rate of 5,000 ha annually. The main intent was to improve self-sufficiency in wood supplies and to increase the areas of forest for recreational purposes. Thus far, the majority of afforestation has taken place on state-owned land, with a smaller part on marginal farmland. To promote afforestation on private land, the Government offers a subsidy for a 20-year period but landowners have been reluctant to use this option, as inflation was not considered when disbursing subsidies. As of 1998, only approximately 2,300 ha were planted per year. Additional funds of DKr 120 million annually have been made available for afforestation in 1998 and it was expected that this supplementary action would also help reduce the impact of nitrogen leakage on groundwater.

62. The present afforestation policy implies a considerable trade-off between agricultural and forest land, with agricultural land decreasing from 65 per cent to 55 per cent of the total area of Denmark. In light of information provided by Danish experts, the team gained an understanding that full implementation of the parliamentary decision was quite uncertain, given that farmers face a choice between EC subsidies or afforestation grants.

B. Methane

63. Danish agricultural policy depended strongly on EC agricultural policy. The quota for milk production has led to a reduction in the number of cattle and associated CH_4 emissions, while increasing productivity at a rate of about 1.5-2 per cent annually. As no quota system existed for pigs, the second most important source of CH_4 emissions from agriculture, emission reductions from dairy cows at times offset the increases in the pig sector, depending on market.

64. In the context of the Energy 2000 programme, the 1993 biomass agreement required that, by the year 2000, 75 per cent of the CH_4 emitted by liquid manure tanks be used for energy. Until 1997, actual development was slower than expected. However, the recent development of a new and simple technology to recover CH_4 greatly improved cost efficiency and bettered the prospects of reaching the target.

65. The main policy instrument to reduce waste and waste-related emissions was the 1993 Action Plan on Waste. Denmark has been very successful in making the best possible use of waste according to its properties. In 1996, 60 per cent of waste (including construction waste) was recycled, 20 per cent consisting of inorganic waste fractions was landfilled and 18 per cent was incinerated in plants with energy recovery. These results were achieved mainly by providing subsidies for generating electricity from waste. Since 1997, landfilling of biodegradable waste has been prohibited. Consequently, CH_4 emissions were expected to decrease, with the gradual decomposition of formerly landfilled organic waste and the increased recovery of CH_4 from landfills for energy purposes.

C. Nitrous oxide

66. With respect to N_2O, Danish policy, as laid down in the 1987 Action Plan on the Protection of the Aquatic Environment and Groundwater and the 1991 Action Plan for Sustainable Agricultural Development, was geared to reducing nitrogen losses in aquatic ecosystems and groundwaters. Between 1991 and 1997, a decrease of 23 per cent in commercial nitrogenous fertilizer consumption was achieved, through regulation of the amount of fertilizer used by type of crop. During the last 10 years, N_2O emissions from agriculture decreased by 15 per cent. In 1998, the policy to limit N_2O emissions was strengthened further along with an update of the 1987 Action Plan, by requiring the norms for application of nitrogenous fertilizers to be reduced by 10 per cent in 1999 compared to 1998. The team learned that enforcement of measures was monitored and sanctions were provided. The EC also offered financial incentives for environment-friendly and organic farming, but the effect was limited.

D. New gases

67. As of 1998, there was no regulation in Denmark on the use of HFCs, PFCs and SF_6, with the exception of the prohibition, adopted already in 1977, of the use of selected HFCs in spray cans and fire extinguishers. The team was informed of intended legislation to phase out by 2006, at the latest, all the new gases for which alternatives exist and to prepare an action plan. The DEPA has prepared a report backing its intended strategy and plans to consult industry and non-governmental organizations on the subject. Amongst the options considered were taxes based on CO_2-equivalent as well as financial support for the development of technology alternatives.

IV. PROJECTIONS AND EFFECTS OF POLICIES AND MEASURES

68. The projections in the NC2 covered the direct GHGs (CO_2, CH_4, N_2O), as well as precursors (NO_x, CO, NMVOCs) and SO_2, and were presented by sector and by gas in line with

the guidelines, including the separation of emissions from bunker fuels. Projections for PFCs (insignificant in Denmark), HFCs and SF_6 were not included, given the plan under development to phase out the use of these gases within 10 years. Emissions and sinks of CO_2 and the indirect GHGs were presented for the years 2000, 2005, 2010, 2020 and 2030, while emissions of CH_4 and N_2O were presented for 2000, 2005 and 2010.

69. The projection of energy use and CO_2 emissions is based on projections included in the Energy 21 plan, with 1993 taken as the base year. Two scenarios were reported in Energy 21, the reference, or business-as-usual, scenario and the energy plan scenario. Only the latter was given in the NC2 as a "with measures" scenario, since the reference scenario already included all policies implemented in the 1990-1996 period and can thus not be regarded as a baseline. Instead, Danish experts suggested that the team consider the reference scenario from the 1990 Energy 2000 plan as a more relevant baseline to reflect the development without all measures launched after 1990. Figure 4 presents projections of energy-related CO_2 emissions for four scenarios, including the reference and plan scenarios from the Energy 2000 and Energy 21 plans, and the actual development of emissions adjusted for electricity exchange and temperature variations.[5]

70. The methodology used for projections presented in the NC2 was based on a combination of bottom-up and top-down approaches and included the use of several sub-models, covering energy end-use, transport, energy supply. The energy end-use model consisted of a top-down element, in which a projection of economic activity, prepared by the Ministry of Finance, was combined with energy and income elasticities, to obtain a first order estimation of future demand. This demand was corrected thereafter to account for changes in behaviour, technology and fuel switching at a detailed end-use level. Since these changes were estimated outside the model, it can be classified as an accounting model, in contrast to optimization models, where the model itself chooses a cost-effective set of options. To counter this effect, an expert panel was used to assess a wide range of measures, given information on a variety of energy-demand technologies. Price elasticities were not included in the model and the effects on the economy of the policies and measures, including taxes, were not assessed. The model for the transport projections was similar to the stationary energy end-use model, although little information about this model was provided to the team. The supply model calculated the quantity of different fuels needed for electricity and heat production in order to meet the demand estimated by the end-use model. It contained a description of a large number of existing and planned power, district heat and CHP stations, and provided the possibility of optimizing the supply system to obtain minimum overall cost.

71. Denmark had chosen the modelling approach for the NC2 primarily for historical reasons, as the same approach had been applied in a number of energy plans, as well as the NC1. The Danish experts believed that, through the extensive use of expert judgements, their approach

[5] The projections are taken from the energy plans and match Denmark's national target. However, the emission sources covered by the national target differ somewhat from the emissions reported in the NC2, based on the IPCC Guidelines. The main difference is that the national target covers international aviation, but not flaring from offshore oil production. In line with the IPCC Guidelines, in the NC2 emissions from flaring are accounted for, while international aviation is excluded. Statistical data shown on the figure and base year emissions were adjusted for variations in climate and trade patterns in electricity.

isolated overlapping effects among different policies and measures. For future analysis Denmark has recently developed a macroeconomic top-down model, with which the macroeconomic implications of various measures can be assessed and sensitivity analysis conducted.

72. Key variables for fuel price and activity development were summarized in the NC2 in a table, in line with the guidelines. The team was informed that, in general, fuel prices had been lower and economic growth somewhat higher than assumed, with implications on the baseline. It was assumed that some 5 per cent of the electricity produced in 2005 could be exported due to the expected 2 to 7 per cent surplus from CHP and wind power production. The effects of liberalization of the electricity markets were not considered in the analyses presented, but assessments of price effects have been undertaken. No sensitivity analysis was performed to assess effects of changes in key assumptions.

73. The results obtained from the "with measures" scenario indicated that the national target of a 20 per cent reduction in energy-related CO_2 emissions from the1988 level by 2005 could be reached through a series of measures, resulting in fuel switching and improved energy efficiency on both the supply and the demand side. The implementation of these measures was expected to result in a decline in TPES from 779 PJ in 1990 to 773 PJ in 2005, despite the average annual GDP growth of 2.2 per cent for that period. In the longer term, more use of biomass, geothermal and solar heat, and wind energy, together with further improvements in energy efficiency, would allow the goal of a 50 per cent CO_2 emission reduction over 1988 to 2030 to be achieved. Over the same period, TPES was expected to decrease by 25 per cent to 578 PJ. The share of renewable energy in primary energy supply was expected to increase significantly, from 7 per cent in 1990 to 13 per cent in 2005 and 35 per cent in 2030, in line with the Danish goal of a 1 per cent annual increase in the share of renewables.

74. The results for TFC, reported in the appendix to the NC2, show a slight increase from 560 PJ in 1990 to 570 PJ in 2005. The share of district heat and heat from CHP plants was to increase from 15 per cent to 22 per cent over that period, with the share of renewable energy remaining fairly constant at just below 4 per cent, reflecting the Danish strategy to use renewable energy primarily on the supply side, for electricity and district heat production. In 2030, TFC was expected to be reduced by almost 100 PJ from the 2005 level to 474 PJ, with fossil fuels accounting for only 42 per cent. A further increase was envisaged in the share of district heat and heat from CHP to 28 per cent, and in renewables to almost 8 per cent. Emissions from the transport sector were expected in the NC2 to grow slightly by the year 2000 and decrease thereafter, reaching the stabilization target set for this sector in 2005, in contrast to the NC1, where they were expected to grow by 11 per cent over the same period.

75. The above-described changes to the Danish energy system were assumed to be achieved through an extensive list of policy initiatives launched in the energy and transport plans since 1990. The main initiatives were: (a) increasing the efficiency of electric appliances and other energy equipment, which would lead to15-78 per cent CO_2 savings by the year 2030 compared to 1995; (b) demand-side fuel switching and increased use of natural gas and renewables for heat and power generation, which would have the effect of reducing the CO_2 content of the overall fuel mix by 20 per cent from 1990 to 2005 and by 50 per cent from 1990 to 2030; the main driver

of this change was expected to be the CO_2 tax and grants, which altogether contributed to about 50 per cent of the CO_2 reductions in 2005; (c) increasing the use of CHP, which was assumed to affect emissions substantially; (d) in the transport sector, applying measures that were assumed to result in stabilization of emissions at the 1988 level by 2005, about 10 per cent of the necessary reduction being expected from measures coordinated internationally. It was estimated that the 'green' tax reform in industry would increase the wage bill by about 0.1 per cent and would create a modest positive effect on employment after 2000.[6]

76. Table 4 and figure 4 summarize the information on the effect of measures included in the three energy plans launched since 1990, together with information on the Energy 2000 reference scenario and Energy 21 plan scenario.[7] About 55 per cent of the expected mitigation effect in 2005 will be the result of measures launched in Energy 2000, an additional one quarter from Energy 2000 follow-up, while the remaining 20 per cent is expected to be achieved through the additional measures suggested in the Energy 21 plan and internationally coordinated transport measures suggested in 1997.[8] The actual development of emissions showed that since 1993 the emission trend has been above even the Energy 21 reference scenario, primarily because of higher-than-expected economic growth, lower-than-expected energy prices, and slower progress in reduction of final energy use to GDP. The effect of demand-side fuel switching was in line with the plan, while both supply-side fuel switching and improvements in energy efficiency were more effective than projected in the plan. A comparison of the actual emission trend with the Energy 21 scenario suggests that the target of a 20 per cent emission reduction will be difficult to achieve and CO_2 emissions in 2000 are likely to be 2 to 4 per cent higher than the 1990 unadjusted emissions.

77. Developments in the transport sector give cause for concern because actual emissions in that sector are higher than forecast in both the NC1 and the NC2. What is more, according to the most recent document, 1998 *Environmental Evaluation of Budget Law for 1999,* prepared by the Ministry of Finance, these emissions are expected to be 25 per cent higher in 2005 than in 1988, far beyond the stabilization target. Denmark pointed out that implementing stricter measures in the transport sector may prove difficult, given the long time required for car stock replacement and given that raising fuel taxes unilaterally would result in extensive cross-border trade in gasoline.

78. Denmark's national target in 2005 was based mainly on emissions from domestic sources. This means that emissions related to electricity exports affected by hydroelectricity availability in Sweden and Norway were excluded, while emissions associated with the expected

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6 According to the 1999 DEA report *Follow-up of Energy 21 - Status of Energy Planning*, the new projections of energy consumption and CO_2 emissions show that there is a deficit of some 3.5 per cent in the national target of a 20 per cent reduction of CO_2 emissions in 2005 in relation to 1988 levels. Developments in the energy sector are progressing better than expected, while things are going in the wrong direction in the transport sector. Therefore, to achieve the target in 2005 it appears necessary to implement new initiatives.

7 The slight difference between the emission levels of the curves in figure 4 and the results reported in table 4 is partly explained by footnote 5, and partly by the fact that the numbers in the table are adjusted for the changes in energy prices and GDP growth that have taken place since Energy 2000 was established.

8 The team was informed that implementation of some measures like taxation of domestic flights and standards for appliances and electric equipment have been decided nationally, but have not been implemented due to lack of consensus within the EC.

export due to surplus from the CHP system were included in projections. There has been a tendency in recent years to export electricity to Norway and Sweden over and above that attributed to the fluctuations of hydrological conditions, and it is likely this trend will continue. To control these emissions, as of 1998 the Danish Government was considering introducing emission quotas.[9]

79. The methodology to project the carbon sink was similar to the approach used for the inventory. The team was informed that the projections were based on the parliament's decision to double Denmark's forest area within the next 80-100 years. The existing forest covered 417,000 ha in 1990, while the cumulative figures for the new area under afforestation in the NC2, assuming annual afforestation of 4,000 ha, were 31,628 ha in 2000, 51,628 ha in 2005, and 151,628 ha in 2030. The average CO_2 sequestration per hectare for projections was estimated at 0.004 Gg. Emissions of CH_4 were expected to decrease somewhat, mainly due to a fall in livestock numbers and a decline in emissions from landfills, as the landfilling of combustible waste was prohibited in 1997. However, CH_4 emissions from manufacturing industries and from the building sector were projected to grow, as a result of increased use of natural gas. Emissions of N_2O were projected to decrease by 2000 and stabilize thereafter, mainly driven by the actions to protect ground- and sea-water. Projections of SO_2 and NO_x emissions were also available.

Figure 4. CO_2 emissions in Energy 2000 and Energy 21 scenarios, and actual emissions trend

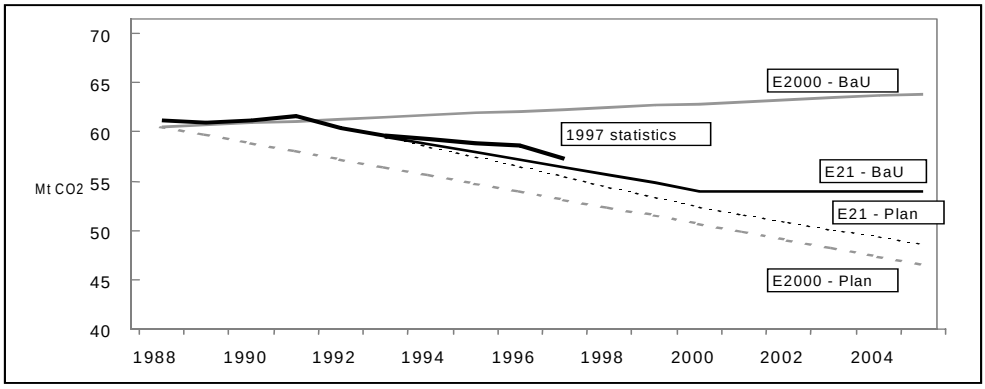

Table 4. CO_2 emissions for baseline and "with measures" scenarios, and effects of measures (Gg)

	1990	2000	2005	2010
1. Scenarios with emissions corrected for net				
Baseline scenario	57 250	64 800	68 300	71 100
Energy 21 plan scenario ("with measures")	57 250	50 800	46 600	42 500
Total reduction		14 000	21 700	28 600
2. Reductions due to measures at national level		13 300	19 800	20 400
3. Reductions dependent on international coordination		700	1 900	8 200

[9] The new energy legislation, adopted in 1999, envisaged introduction of such emission quotas.

V. VULNERABILITY ASSESSMENT AND ADAPTATION MEASURES

80. The work on climate change modelling, vulnerability assessment and adaptation was substantially extended after publication of the NC1, and the presentation of the information on these issues in the NC2 followed the guidelines. The Danish Meteorological Institute (DMI) was the main institution to work on the climate scenarios and was responsible for providing the results to other institutions involved in impacts assessment, such as the Botanical Institute of Copenhagen University, the Danish Coastal Authority and the NERI.

81. In both the NC1 and the NC2, general circulation models (GCM) applying the most probable IPCC "business-as-usual" scenario (IS92a), with subsequent statistical downscaling for temperature and precipitation, were used for the climate scenarios. According to the scenarios in both communications, an increase in temperature, precipitation and sea level was expected in Denmark. An increase in temperature and precipitation was also expected in most of Greenland and the Faeroe Islands. However, the temperature may decrease in southernmost parts of Greenland. The difference in the results reported in the NC1 and NC2 was a slight reduction in the estimates of temperature and precipitation changes, due to the fact that the results in the NC1 were based on a transient coupled atmosphere/ocean GCM greenhouse simulation from the Max Planck Institute (Germany), whereas the NC2 results were based on a similar GCM simulation from the Hadley Centre (United Kingdom), which included also the impact of aerosols. The scenarios for Denmark were based on statistical downscaling of the GCM results. Recently, this method has been replaced by a nested approach, which was believed to provide more accurate results.

82. The team was provided with a wealth of information on climate change impacts on human health and well-being, energy, industry and transport, water resources, agriculture, forestry and terrestrial, freshwater and marine ecosystems and coastal areas, and possibilities for adaptation in Denmark, Greenland and the Faeroe Islands. No serious direct physical impact was expected in Denmark except for some sectors, such as agriculture, forestry and coastal zones. The main concern remained sea-level rise and problems connected with land movement and erosion. Climate change impact on the cultivated landscape was expected to be minimal, but natural terrestrial and freshwater ecosystems would suffer, as they were found more vulnerable. Special attention was given to the climate impacts on the fragile ecosystems of Greenland and the Faeroe Islands. According to estimates, based mainly on expert assessment, the slow changes in plant species are expected to result in more visible changes in animal species. The negative impact on the marine ecosystem would come from additional freshwater input from melting ice and a rise in the sea surface temperature. The Faeroe Islands in the next 40-50 years will be less affected than Greenland, except for marine ecosystems whose species would be more vulnerable.

83. At the time of the team visit, Denmark was considering the feasibility of implementing the following adaptation measures: coastal protection, change of agricultural crops, and afforestation by mixed forest or deciduous trees, replacing the Norway spruce by a more stable mixture of oak and beech. Programmes in place were related to coastal zone management and

especially to dyke maintenance, including a security system financed by both the Government and municipalities in line with Energy 21 and the five-year plan for coastal protection. Financing of these programmes amounted to DKr 145 million annually.

VI. FINANCIAL ASSISTANCE AND TECHNOLOGY TRANSFER

84. In general, Denmark has followed the guidelines in reporting on financial assistance and technology transfer. Four governmental institutions were involved in financial assistance and technology transfer in Denmark, namely, the Ministry of Foreign Affairs, coordinator of these activities, the Danish International Development Assistance, which is part of the same ministry, the DEA and the DEPA.

85. Denmark has to be commended for being among the few industrialized countries whose official development assistance (ODA) amounts to 1 per cent of GNP. Moreover, after the United Nations Conference on Environment and Development, it was decided to allocate an additional 0.5 per cent of GNP to support environmental projects and projects to mitigate the effects of natural disasters. Thus, the Environmental and Disaster Relief Facility (EDRF) was established to manage the additional funds, split equally between environmental and disaster mitigation projects. Denmark considered the funds provided under the EDRF as "new and additional" as they come on top of the standard amount of ODA. In absolute terms, the amount of ODA increased from DKr 7,850 billion in 1990 to DKr 10,750 billion in 1997. With respect to the Danish contribution to bilateral and multilateral entities, the team was informed that is was linked to the extent to which these entities' efforts correspond to Danish policy objectives. So far, Denmark did not have projects relating to activities implemented jointly, but at the time of the visit, options to launch such projects were being considered in view of the interest of industry in participating in such projects.

86. International cooperation focused on middle-income countries of central and eastern Europe and the poorest countries. The choice of countries was recipient-driven, but the main focus was on the countries of the Baltic region. Since 1993, the cooperation with countries of eastern and central Europe has mainly been in the field of air and water protection, energy efficiency and renewables. It was estimated that each year DKr 134 million was spent on such projects and savings of CO_2 emissions of about 1,000 Gg realized. In 1998, for example, half of the EDRF funds, amounting to DKr 670 million, was spent on projects in those countries, of which DKr 67 million was for energy efficiency projects. The most successful projects were in the field of CHP, landfill gas use, geothermal energy and energy efficiency. A pilot project for a geothermal plant was successfully carried out in Poland and, as of 1998, in other countries of eastern and central Europe. Danish officials emphasized that addressing climate change on a global scale would depend on the success achieved in mobilizing private sector investment for development and transfer of new technologies, such as renewables and CHP. This is why the Danish Government established options to obtain mixed credits and soft loans to promote the export of wind turbines, to China for example. Additionally, a new facility set up in 1998 in the Ministry of Industry provided soft loans, especially for CHP technologies.

VII. RESEARCH AND SYSTEMATIC OBSERVATION

87. Denmark has in place a number of programmes for climate-related research and systematic observation, as well as for energy technology research. Denmark has a long history of climate- related systematic observation and it was the responsibility of DMI to provide Denmark, Greenland and the Faeroe Islands with meteorological services. To achieve this goal, DMI has been using a set of models, including the operational regional weather forecasting model DMI-HIRLAM (High Resolution Limited Area Model) and the regional climate model HIRHAM. DMI also monitored weather, sea conditions, climate, and related environmental conditions in the atmosphere, on land and in the sea, as well as carrying out environmental and climate research and development. Research activities of DMI were in the areas of weather and climate modelling, atmospheric chemistry relating to monitoring and modelling of stratospheric and tropospheric ozone, impact of changes of radiative forcing in the troposphere and impact of tropospheric ozone changes on climate. Research activities also include oceanographic modelling, solar terrestrial physics and remote sensing of the atmosphere and oceans. In recent years, a research programme on climate change was launched in Greenland by the Danish Polar Centre, where two stations for biological observations were set up to create a database, study the impacts of CO_2 and CH_4 emissions on ecosystems, and study the carbon cycle, temperature changes and water run-off. The funding for climate-related studies amounted to DKr 200 million annually.

88. DMI served as the Nordic focal point for climate modelling and, as such, was involved in a number of domestic and international studies on severe storms, surges and waves, net fluxes of carbon and freshwater from an Arctic catchment, and in modelling the interactions between land surface and atmosphere. Assessment of the anticipated changes in climate after a doubling of the concentration of CO_2 in the atmosphere, using an atmospheric general circulation model (AGCM), was under way at the time of the team visit. Other research programmes for 1996-2001 were on the atmospheric circulation, climate variability and prediction of wind energy production. DMI contributed to international climate research programmes, such as the World Climate Research Programme, climate monitoring programmes, such as the World Weather Watch and the World Climate Data Programme, and the European Climate Support Network.

89. Denmark is one of the leading countries in the development of environmentally sound technologies and equipment for biomass combustion, wind energy production, marine windmill parks and efficient heating, ventilation and air-conditioning. Furthermore, according to the 1996 Energy 21 plan, renewable energy technologies, energy efficient technologies and integrated energy technologies were considered as priority areas for energy research and development. The team was informed that the total amount spent on research was about DKr 800 million annually, with the major part, DKr 540-625 million, going to energy research in both public and private sectors and universities.

VIII. EDUCATION, TRAINING AND PUBLIC AWARENESS

90. The team formed the opinion that Denmark had a comprehensive approach to raising public awareness of climate change and to including climate change topics in education curricula. Among a number of publications related to the scientific and social aspects of climate change, the 1992 report *The Greenhouse Effect and Climate Change - Implications for Denmark*, and the 1996 report *Greenhouse Effect and Climate Change - Implications for Denmark in the Light of the 1996 IPCC Reports* are worth mentioning. Non-governmental organizations also contributed to the dissemination of information on climate change. The team found the level of public interest in climate change to be high, thanks to the proactive policy of the Government and the excellent work of the non-governmental organizations. Information campaigns on radio, television, newspapers and the Internet concerning energy saving were launched periodically and a number of publications were issued on renewables and especially on wind energy by government agencies and non-governmental organizations. The team felt, however, that more focused campaigns may increase public acceptance of measures to mitigate the growth of GHG emissions from private cars. The team was informed about the environmental subjects and lessons on energy saving taught in the secondary and high schools. The Danish industrial and "green" non-governmental organizations have been involved in the formulation of climate change policy and in the preparation of the NC2 to a different extent.

IX. CONCLUSIONS

91. In general, the impression of the team was that Denmark has in place a comprehensive climate policy, in which the combined energy/CO_2 tax has an important role. The 1998 decision of the parliament to increase the tax gradually until 2002, with the intention of extending the coverage for industry and increasing the CO_2 component of the tax, clearly demonstrates the firm commitment of Denmark to attain the targets adopted. In addition to substantial taxes, Denmark has in place a wide range of regulatory and voluntary measures geared to increasing the share of CHP and renewables, and to improving energy efficiency, which confirms the commitment of the Government to maintain and develop its leading role in the achievement of sustainable development.

92. A distinctive feature of the contemporary Danish climate policy is the integration of the climate change issues within the sectoral policies and plans, and the Energy 21 plan is an excellent example in this regard. The next step in the formulation and implementation of the climate change policy is seen to be the integration of the sectoral policies into a national strategy, which would undoubtedly give further impetus to the implementation process. Such a step towards integrated climate policy could be very important also in view of the difficulty of achieving further reductions in GHG emissions in Denmark, given the results obtained so far in promoting CHP, energy efficiency and renewables. Finally, the historical and projected growth of emissions from transport suggests that this sector deserves much attention in the integrated climate strategy.

93. The team acknowledged the steps taken to improve the GHG emission inventory. While, broadly, the same CORINAIR methodology was used in both the NC1 and the NC2, the coverage of the GHG inventory was extended to include new sources of emissions in agriculture and emissions of new gases. Moreover, the quality of activity data and emission factors was improved. Information provided to the team during and after the visit confirms the improvement of transparency, comparability and compatibility of the GHG inventory results. Last but not least, information on the1990-1996 GHG inventory, in terms of activity data, emission factors and results, was made available on the Internet at the instigation of the team.

94. The review of the key data points, assumptions, methodologies and results of the projection exercise suggests that the national target of a 20 per cent reduction in CO_2 emissions from the1988 level by 2005 can be achieved with the additional measures suggested in Energy 21 and internationally coordinated traffic measures. The actual trend of emissions, however, was somewhat higher than that in the “with measures” scenario, owing to a change in the baseline emissions, the lower-than-expected effect of some measures, and slow international coordination of measures in transport, energy labelling and appliance standards. This was especially true for emissions from the transport sector, which, according to the recent projections, were expected in 2005 to be well above their 1988 level, instead of being stabilized according to the target. Hence, in light of the short time left before 2005, Denmark may have to seek more reductions from other sectors, by pursuing even tougher measures than those envisaged in the NC2.

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