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Lead Study 2008

Further development of the "Strategy to increase the use of renewable energies" within the context of the current climate protection goals of Germany and Europe

– Key findings for decision-makers –

Study commissioned by the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU)

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Lead Study 2008 – Key findings for decision-makers

A **Lead Scenario 2008** and five further scenarios ("Efficiency": E1, E2 and E3 and "Shortfalls" (*Defizite*): D1 and D2) explore the probable future **development corridors** of the energy supply system and explain the structural and economic effects that are to be expected in the energy sector. The study sets out in detail how the goals of the German federal government can be attained to expand renewable energy production and improve energy efficiency by 2020. It also shows how the long-term targets of reducing greenhouse gas emissions by 2050 to approx. 20% of the 1990 level and boosting the contribution of renewables to overall energy supply to 50% can be achieved. A number of matching **sub-strategies** are examined as key elements, and are implemented in all branches of the energy sector with their reciprocal structural interactions modelled over time. These sub-strategies are: *"Substantial expansion of renewable energies (EE)", "Significantly improved efficiency of use in all sectors (EFF)"* and *"Improved efficiency of conversion by means of expansion of cogeneration (KWK)"*. The key findings of this analysis are:

1. According to the Lead Scenario 2008, the combination of **continuous expansion of renewable energy production and substantial efficiency improvements** leads **by the year 2020** to a reduction in primary energy consumption by 17% from the 2005 level. The average rate of growth of primary energy productivity is 3%/yr. The corresponding target of the federal government is thus achieved. The share of renewables in final energy consumption rises to about 18%, and that of combined heat and power (CHP) production to almost 21%. This delivers a reduction in **CO_2 emissions of 36% from the 1990 baseline**. **By 2050** primary energy consumption according to the Lead Scenario 2008 is 55% that of 2005, renewables meeting almost 50% of the remaining primary energy demand. Only 37% of the fossil energy deployed today is required; energy import requirements figure 40% of the presently imported quantity. The targeted 80% reduction in CO_2 emissions is just achieved.

2. A **40% reduction in energy-related CO_2 emissions by 2020**, as modelled according to Scenario E1, succeeds if – in accordance with the goal set by the federal government – an additional significant increase in electricity efficiency is achieved, and the share of CHP is raised to 25%. To achieve this, the average rate of increase of electricity productivity needs to average 2.1%/yr instead of the 1.8%/yr assumed in the lead scenario. The targeted addition of CHP capacity will require great efforts to substantially expand the use of central and local district heating while heat demand in the building stock drops.

3. According to the Lead Scenario 2008 the contribution of **renewables to electricity supply** by 2020 grows to just under 180 TWh/yr, which is **30%** of gross electricity consumption. In **2030** renewables already cover **50%** of gross electricity consumption. Renewable generating capacity installed totals 70 GW in 2020, twice the figure of 2007. The figure rises to about 100 GW by 2030. Renewable generating capacity newly installed since 2000 produces more electricity in each year than the quantity lost due to the phase-out of nuclear power up to the respective year.

4. Under the precondition that 28 GW of existing fossil generating capacity is decommissioned between 2005 and 2020, new fossil-fired power plants with a total capacity of 29 GW can be installed according to the lead scenario. Of that capacity, 9 GW should **not be exceeded** in coal-fired power plants, the remaining 20 GW to be operated with natural gas, if the CO_2 reduction of 36% that follows from the Lead Scenario 2008 is not to be jeopardised. European emissions trading, including the flexible mechanisms CDM and JI, provide minor additional margin. At least 12 GW of the new **fossil generating capacity**

must take the form of CHP facilities, of which almost 3 GW must be in the form of small CHP units. The increased consumption of natural gas for energy supply that this leads to can be offset by natural gas savings in the space heating sector. Demand for natural gas drops substantially after 2020.

5. The **heat sector** must undergo major structural change by 2050. Demand for heat drops to 82% of its present level by 2020 and to 50% by 2050. The contribution made by renewables rises to 14% by 2020. In 2050 half of the remaining demand for heat energy can be met from renewable sources. In 2050, 25% of the present quantity of fossil energies consumed is still required.

6. CHP penetration and renewables expansion require considerable conversion of individual on-site heating systems to **grid-connected heat supply systems**. According to the Lead Scenario 2008 their share rises from its present level of 12% to 65% in 2050. The structural changes in the heat market required by the climate policy goals of the federal government call for very precise monitoring of the effects of the present energy policy tools, and rapid adjustments where required.

7. Because a strong growth trend persists in freight transport, the efficiency strategy only deploys limited effect over the medium term in the **transport sector**. The reduction in mean specific fuel consumption of the entire car fleet by 25% and of road freight by 20% according to the Lead Scenario 2008 only leads to a reduction in overall consumption by 10% by 2020. By 2050, total energy demand in the transport sector drops to 73% of the 2005 level. In terms of fossil energy, then only 50% of the presently required quantity of fossil fuel is consumed.

8. Under the precondition that fuels will be used much more efficiently, a measured introduction of **biogenic fuels** is a recommendable transitional strategy if the sustainability criteria set out in, among other things, the biomass strategy of the BMU are complied with. A contribution to total fuel consumption of 12% in energy terms (and of about 15% to consumption for road transport) is achieved by 2020. The share of biofuels in fuel consumption achievable in the long term figures 17% (20%).

9. There are highly attractive options to deploy cost-effective **renewable electricity** on a relevant scale **in the transport sector**. Electric traction and hydrogen engines are already available. Scenario E3 shows that if these options are deployed, by 2030 almost 25% of the final energy requirement of the transport sector can be met by biofuels, renewable electricity and renewable hydrogen. **This share can rise to 56% by 2050.** By then only 30% of the presently deployed quantity of fossil fuel is required.

10. The expansion of renewables in accordance with the Lead Scenario 2008 continuously maintains an **investment volume** of approximately 12 billions €$_{2005}$/a. This improves the prospects of maintaining technology leadership in many renewable energy technologies and of further developing export markets. Annual investments rise to more than 15 billions €$_{2005}$/yr after 2020. Cumulative investments in renewable energy facilities between 2008 and 2020 figure 160 billions €$_{2005}$. Under favourable conditions (Scenario E2) cumulative investment can grow to 190 billions €$_{2005}$ by 2020.

11. With realistic energy price developments (Price Path A) the production costs of the renewable electricity mix according to the Lead Scenario 2008 are lower in 2020 than those of fossil electricity supply. If photovoltaic production is excluded from the calculation, that point is already reached by 2015. Further expansion of renewable generation leads to a **stabilisation of electricity production costs** at approximately 8.5–9 ct$_{2005}$/kWh (me-

dium-voltage level) with a trend towards further long-term cost reduction in accordance with the further cost degression potential of renewables.

12. The annual **additional costs of the entire expansion of renewable production** based on production costs figured 6.7 billions €$_{2005}$/yr in 2007. Of this, 57% were attributable to electricity supply. These costs rise (based on Price Path A) to 8.5 billions €$_{2005}$/yr in 2010, dropping markedly thereafter. No additional costs arise any longer around **2022**. By that time renewables cover 20% of total final energy consumption and already avoid 200 millions t CO_2/a.

13. The mean **CO_2 avoidance costs** are currently 55 €/t CO_2 for the renewable electricity mix according to the Lead Scenario 2008. These costs drop to 14 €/t by 2020 in analogy to the additional costs. The avoidance costs of the total mix in the heat sector presently figure 70 €/t CO_2. The avoidance costs for biofuels are presently relatively high at 270 €/t. As in the electricity sector, the CO_2 avoidance costs drop rapidly in the heat and fuels sectors.

14. If the economic appraisal based on unit costs of energy production is broadened to **fully internalise the external costs** (reference value: 70 €/t CO_2) of energy production, then we already arrive today at an applicable mean electricity price of approximately 10 ct/kWh$_{el}$ in the electricity sector. When placed in relation to these "full costs" of fossil electricity generation, present renewable electricity production (including existing hydropower) already saves costs today of 1.2 billions €/yr. This value rises to 14 billions €/yr by 2020, impressively confirming the macroeconomic benefits of the German Renewable Energy Sources Act (EEG).

15. A **full assessment of the macroeconomic benefits** of a strong expansion of renewable production requires a dynamic analysis of the overall development of the energy system with a sufficiently distant time horizon. It also depends crucially upon the future price impacts of an increasing scarcity of fossil resources, and upon attribution of the costs of effective climate change mitigation measures to the polluters (emissions trading). The analysis shows that the initial investment in expanding renewables still required until about 2020 is more than offset thereafter. In view of the benefits of renewables expansion that become apparent after 2020, the future deployment of financial resources proves to be an investment that is wise in terms of energy policy and reasonable in macroeconomic terms.

16. The step-by-step development of the Lead Scenario 2008 and of scenarios E1, E2 and E3 reveals that an insistent energy policy that establishes a favourable setting over lengthier periods can deliver **substantial outcomes by 2050** in terms of climate change mitigation and fossil resource conservation. Considered in the light of the set of further scenarios, the actual **Lead Scenario 2008 is a realistic trajectory**. If the goals set by the federal government for electricity efficiency and CHP expansion are achieved on schedule, Scenario E1 can also be realised by 2020. Renewables can moreover make contributions to energy supply by 2050 that go beyond those according to the lead scenario (Scenario E3 with a renewable share of 65%).

17. If a **smaller impact of the packages of measures** for efficiency improvement and CHP expansion is assumed (i.e. an increase of average energy productivity by only 2.5%/yr until 2020; CHP share 17%; Scenario D1), the resulting **higher energy demand** reduces the share of renewables in 2020 by 1.8 percentage points compared to the Lead Scenario 2008. The fossil energy requirement is then already some 1000 PJ/yr greater in 2020 than according to the Lead Scenario 2008. In that case total CO_2 emissions can

only be reduced by 28% by 2020 from the 1990 baseline. This underscores the importance of a consistent policy aiming to improve efficiency in all fields.

18. If, in addition, a **distinctly coal-based strategy** were to be pursued in the new construction of fossil power plants (Scenario D2**)**, CO_2 emissions could only be reduced by about 25% by 2020. Under favourable conditions, the deployment of carbon capture and storage **(CCS)** technologies in the electricity sector from 2020 permits a reduction of total CO_2 emissions by 2050 to 65% of the 1990 baseline. A further CO_2 reduction by means of CCS would require similarly extensive carbon capture measures as in the heat and fuel supply sectors.

19. Any **extension of the service lives of nuclear power plants** would mean that present plans to build new fossil power plant capacity would have to be completely revised in order not to jeopardise the 30% expansion target for renewables by 2020. The CHP expansion target would not be achievable. Such a development would **fundamentally call into question** the requisite **structural change of power supply** towards significantly improved electricity efficiency, substantially greater CHP contribution and strong expansion dynamics of renewable energies. The energy system would then scarcely be able to meet the climate protection target for 2050 of an 80% reduction in CO_2 emissions.

20. Overall, the present conditions for attaining within schedule the climate policy objectives set by the federal government are relatively good. It will be essential, however, to **maintain** the **dynamism** at the same level built up over the past decade in climate, environmental and energy policy, which has already led to effective measures and laws and has launched the necessary process of structural change.

21. It is essential that the expansion of renewables does not fall behind the levels recommended in the Lead Scenario 2008. In some fields, the **effects of existing incentives and instruments must be monitored critically and intensified** where appropriate. These include efficiency improvements and the expansion of renewable energies in rental housing and in non-residential buildings, and the expansion of small (distributed) CHP. The Renewable Energies Heat Act should be further developed as soon as possible and the mandatory use of renewables extended to the building stock. A considerable level of activity on the part of local authorities and municipally-owned utilities is necessary to accelerate structural change in (grid-connected) heat supply. Further, heightened incentives will also be necessary in order to boost electricity efficiency. In the transport sector, effective measures are needed to contain or shift the modal split of freight traffic, which is growing rapidly.

22. Structural change in energy supply towards better climate performance needs to be expanded more vigorously to the entire European Union, and **the European energy and climate protection strategy needs further, consistent development**. Coordinated strategic actions for the medium- and long-term expansion of renewables beyond national boundaries is paramount in this regard. A strategy for a European interconnected grid should be elaborated as a priority and its implementation prepared in order to **make optimum use of major renewable production potential** and effectively integrate large quantities of renewable-generated electricity in power supply systems. The foundation underpinning all efforts, however, must be set by providing effective incentives for **substantially more efficient energy management** in all fields of conversion and use. With such a strategy Europe can drastically reduce its dependence upon fossil energy imports and can thus greatly improve the security of its energy supply. This would also prevent potential conflicts arising over increasingly scarce energy resources.

Tables

Table 1: Electricity generation from renewable sources according to the Lead Scenario 2008

In TWh/yr	2000	2007	2010	2015	2020	2025	2030	2040	2050
Hydropower	**24.9**	**20.7**	**22.5**	**23.9**	**24.3**	**24.5**	**24.6**	**24.8**	**24.8**
Wind	**7.6**	**39.5**	**46.0**	**60.7**	**87.2**	**114.7**	**142.2**	**186.7**	**209.3**
- Onshore	7.6	39.5	44.8	49.6	53.5	55.8	58.1	63.7	66.9
- Offshore	-	-	1.2	11.1	33.7	58.9	84.1	123.0	142.4
Photovoltaics	**0.1**	**3.5**	**6.2**	**11.0**	**15.5**	**18.7**	**21.9**	**25.3**	**27.7**
Biomass	**4.1**	**23.7**	**30.2**	**39.8**	**46.2**	**48.8**	**51.4**	**53.8**	**53.8**
- Biogas, etc.	1.7	12.0	15.6	21.9	25.6	26.0	26.3	26.3	26.3
- Solid biomass	0.6	7.4	10.3	13.6	16.3	18.5	20.8	23.2	23.2
- Biogenic waste	1.8	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3
Geothermal	**-**	**0**	**0.1**	**0.6**	**1.8**	**3.9**	**6.0**	**14.7**	**35.7**
EU interconnected grid	**-**	**-**	**-**	**-**	**3.0**	**19.4**	**35.8**	**82.0**	**121.0**
- Solar thermal power plants	-	-	-	-	1.0	8.5	18.2	52.0	91.0
- Other sources	-	-	-	-	2.0	10.9	17.6	30.0	30.0
Total electricity from renewable sources	**36.7**	**87.5**	**105.1**	**136.1**	**178.2**	**230.0**	**282.1**	**387.2**	**472.4**

Table 2: Production of heat and fuels from renewable sources according to the Lead Scenario 2008

In TWh/yr	2000	2007	2010	2015	2020	2025	2030	2040	2050
Biomass	**54.3**	**84.2**	**97.9**	**112.8**	**123.6**	**128.6**	**133.5**	**138.7**	**138.7**
- Biogas, etc.	1.0	8.0	9.5	14.8	19.0	19.4	19.8	19.8	19.8
- Solid biomass	50.0	71.3	83.4	93.0	99.6	104.2	108.7	113.9	113.9
- Biogenic waste	3.3	4.9	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Solar collectors	**1.3**	**3.7**	**5.8**	**12.1**	**20.0**	**30.7**	**41.3**	**64.4**	**94.5**
- Individ. installations	1.3	3.6	5.5	10.5	16.1	22.4	28.7	37.4	46.5
- Local district heat	0	0.1	0.3	1.6	3.9	8.3	12.6	27.0	48.0
Geothermal	**1.4**	**2.3**	**3.1**	**8.0**	**17.3**	**30.2**	**43.1**	**66.8**	**99.8**
- Individ. installations	1.3	2.0	2.6	5.4	9.1	13.0	17.0	19.5	21.9
- Local district heat	0.1	0.3	0.5	2.6	8.2	17.2	26.1	47.3	77.9
Total renewable heat	**57.0**	**90.2**	**106.8**	**123.9**	**160.9**	**189.5**	**217.9**	**269.9**	**333.0**
Biofuels	2.6	46.6	61.1	69.4	77.0	80.6	83.3	83.3	83.3
Renewable hydrogen	-	-	-	-	-	-	7.0	24.1	50.9
Total renewable fuels *)	**2.6**	**46.6**	**61.1**	**69.4**	**77.0**	**80.6**	**90.3**	**107.4**	**134.2**

*) renewable electricity for transport is contained in Table 1

Table 3: Key data of the Lead Scenario 2008, highlighting the contributions of renewables (RES)

	2005	2007	2010	2020	2030	2040	2050
Primary energy, PJ/yr	14469	13842	13855	12044	10252	8972	8066
Primary energy RES, PJ/yr	665	932	1317	1953	2599	3218	3843
Share of RES, %	**4.7**	**6.7**	**9.5**	**16.2**	**25.4**	**35.9**	**47.6**
Final energy, PJ/yr	9240	9423	8996	8133	7238	6469	5845
Final energy RES PJ/yr	602	807	966	1480	2019	2552	3045
Share of RES , %	**6.6**	**8.6**	**10.7**	**18.2**	**27.9**	**39.4**	**52.1**
Electricity final energy, PJ/yr	1852	1829	1871	1791	1687	1622	1568
Electricity RES, PJ/yr	229	314	361	624	909	1194	1364
Share of RES, %	**12.3**	**17.2**	**19.3**	**34.8**	**53.9**	**73.6**	**87.0**
Heat final energy, PJ/yr	4859	4995	4605	4033	3499	2919	2480
Heat RES , PJ/yr	292	325	385	579	785	971	1198
Share of RES, %	**6.0**	**6.6**	**8.4**	**14.4**	**22.4**	**33.3**	**48.3**
Fuels final energy, PJ/yr	2529	2599	2521	2308	2051	1928	1796
Fuels RES, PJ/yr	81	167	220	277	325	387	483
Share from RES, %	**3.2**	**6.4**	**8.7**	**12.0**	**15.8**	**20.1**	**26.9**
Gross electricity consumption, TWh/yr	612	617	617	586	562	565	583
Generation RES, TWh/yr	63.6	87.5	104	178	282	387	472
Share from RES, %	**10.4**	**14.2**	**16.9**	**30.4**	**50.1**	**68.5**	**80.9**
Primary energy, PJ/yr	14469	13842	13855	12044	10252	8972	8066
Renewable energies	**665**	**932**	**1317**	**1953**	**2599**	**3218**	**3843**
Mineral oil	5154	4678	4855	4219	3458	2853	2387
Coal	3576	3563	2871	2244	1321	707	301
Lignite	3295	3136	3315	3269	2873	2193	1535
Fossil fuels, total	**12025**	**11377**	**11141**	**9732**	**7652**	**5768**	**4223**
Energy productivity GDP/PEC (1990 = 100)	**130**	**142**	**149**	**202**	**269**	**336**	**394**
Reduction in CO_2 emissions since 1990; %	**15.5**	**17.2**	**23.7**	**35.7**	**52.7**	**67.1**	**78.5**
CO_2 emissions avoided by renewables, million t/a	**86**	**115**	**129**	**192**	**271**	**356**	**416**

Table 4: Key data of the Lead Scenario 2008 and of the scenario variants for the year 2020

	2007	Lead 2008	Scen E1	Scen E2	Scen E3	Scen D1	Scen D2
Primary energy, PJ/yr	13842	12044	11548	11414	11405	13016	13058
Primary energy RES , PJ/yr	932	1953	1953	2147	2149	1886	1886
Share of RES , %	**6.7**	**16.2**	**16.9**	**18.8**	**18.8**	**14.5**	**14.4**
Final energy, PJ/yr	9423	8133	7822	7819	7818	8937	8937
Final energy RES , PJ/yr	807	1480	1482	1654	1654	1436	1436
Share of RES, %	**8.6**	**18.2**	**18.9**	**21.1**	**21.1**	**16.1**	**16.1**
Electricity final energy, PJ/yr	1829	1791	1734	1735	1737	1856	1856
Electricity RES, PJ/yr	314	624	626	743	744	605	605
Share of RES, %	**17.2**	**34.8**	**36.1**	**42.8**	**42.8**	**32.6**	**32.6**
Heat final energy, PJ/yr	4995	4033	3875	3876	3877	4533	4533
Heat RES, PJ/yr	325	579	579	611	611	554	554
Share of RES, %	**6.6**	**14.4**	**14.9**	**15.8**	**15.8**	**12.2**	**12.2**
Fuels final energy, PJ/yr	2599	2308	2213	2208	2203	2548	2548
Fuels RES, PJ/yr	167	277	277	300	300	277	277
Share of RES, %	**6.4**	**12.0**	**12.5**	**13.6**	**13.6**	**10.9**	**10.9**
Share of road transport, %	7.3	14.6	15.3	16.6	16.6	13.0	13.0
Gross electricity consumption, TWh/yr	617	586	571	571	571	604	604
Generation RES, TWh/yr	87.5	178	178	211	211	172	172
Share of RES, %	**14.2**	**30.4**	**31.2**	**37.0**	**37.0**	**28.5**	**28.5**
Share of CHP, %	~ 12	20.4	24.0	24.0	24.0	16.8	16.8
Primary energy, PJ/yr	13842	12044	11548	11414	11405	13016	13058
Renewable energies	**932**	**1953**	**1953**	**2147**	**2149**	**1886**	**1886**
Mineral oil	4678	4219	3787	3725	3721	5034	5034
Coal	3563	2244	2140	2122	2031	2434	2926
Lignite	3136	3269	3309	3061	3144	3302	2853
Fossil energies, total	11377	9732	9235	8908	8896	10770	10812
Reduction in CO_2 emissions since 1990; %	17.2	35.7	39.7	41.7	41.7	27.6	25.2