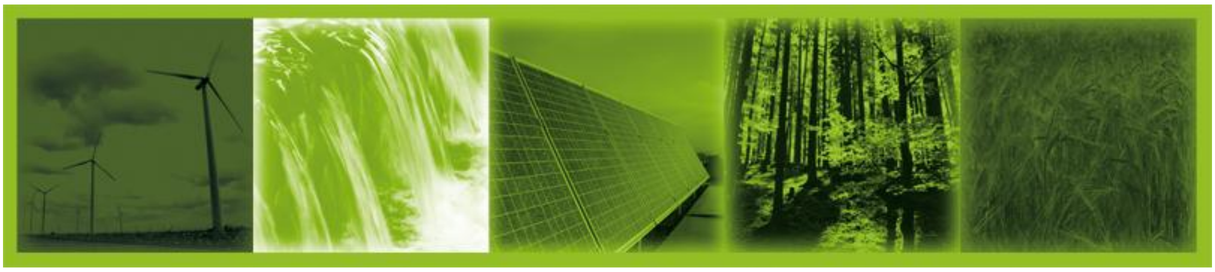
REPAP 2020

Renewable Energy Policy Action Paving the Way towards 2020



Renewable Energy Industry Roadmap for Luxembourg

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1 The case of Luxembourg

1.1 Current situation

1.1.1 Background

Luxembourg has the highest GDP per capita in purchasing power standards (PPS) of the EU27 as well as the highest energy consumption and CO_2 emissions per capita.[1]

In specific, oil accounts for about 60% of the TPES with 90% of the oil used in the transport sector. Roughly 80% of the oil used for transport is sold to foreigners mainly due to low energy taxes especially on diesel. However, Luxembourg is already increasing the excise tax on transport fuels in order to reduce the current differences with neighboring countries.[2]

Presently, Luxembourg is almost totally dependent on energy imports.[3] Although the oil supplies are well diversified by country of origin, they are still vulnerable because they are mostly based on short-term leasing contracts frequently held in neighboring countries.[4] Renewable energy sources and improvement in energy efficiency are the only domestic energy sources in Luxembourg.[5]

With regards to the electricity sector, Luxembourg relies on imports for half of its supply. For security of supply reasons Luxembourg actively supports the development of a regional electricity market in Central West Europe. In Luxembourg, electricity generation is dominated by gas accounting for 90.5% of the total generation in 2007 while coal and oil are no longer used. With regard to renewable energy for electricity generation (RES-E), the electricity supplying companies EIDA and Cegedel are main players in this sector.[6]

The renewable energy market is regulated by the Ministry of Economic Affairs and Foreign Trade and the Ministry of Environment. Both share the responsibilities for energy efficiency and renewable energy policies, while the National Energy Agency (Agence de l'Energie) is responsible for implementing the overall energy policies. The Institut Luxembourgeois de Régulation is in charge of competition, network access and usage issues in the electricity and natural gas markets.[7]

[1] Eurostat (2009) – Table: GDP per capita in PPS and EREC (2009), pag. 1

[2] IEA/OECD (2009a), pag. 8, 9

[3] Eurostat (2009) – Table: Energy dependency

[4] IEA/OECD (2009a), pag. 9

[5] Biermayr, et al. (2007)

[6] IEA/OECD (2009a), pag. 9, 61, 71

[7] IEA/OECD (2009a), pag. 16-18

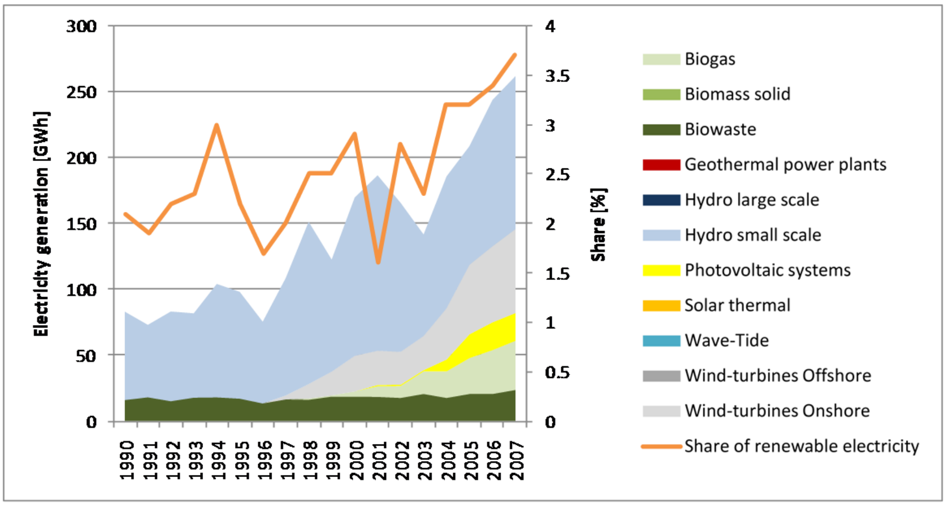
1.1.2 Current status of renewable energies

In 2007 the renewable energy share on gross final energy demand was 1.8% with a total RES deployment of 79.5 ktoe.[8] From this amount RES-Electricity, RES-Heat and RES-Transport represented 28% (22.5 ktoe), 26% (21 ktoe) and 45% (36 ktoe), respectively.[9]

Electricity:

The renewable electricity consumption of Luxembourg showed a strong growth and tripled from 83 GWh in 1990 to 256 GWh in 2007. Meanwhile, the share of renewable electricity increased from 2.1% to 3.7%. Both developments are illustrated in **Figure 1-1**. In total, the renewable electricity consumption had a compound annual growth rate (CAGR) of 6.8% between 1990 and 2007.[10]

Figure 1-1: Development of RES-Electricity generation in Luxembourg 1990 – 2007



Source: Eurostat (2009)

Until 1999, the renewable electricity generation in Luxembourg was dominated by hydro electricity accounting for about 80% of the total generation, followed by biowaste electricity with a share of about 20%. The renewable electricity market was entered in 1997 by wind, in 1998 by biogas and in 2001 by photovoltaic systems electricity production systems. Detailed renewable electricity generation data can be seen in **Table 1-1**.[11]

[8] In 2007 total gross final energy demand in Luxembourg was 4,394 ktoe according to Eurostat.

[9] Own calculations based on Eurostat (2009)

[10] Ibid.

[11] Ibid.

Table 1-1: Development of RES-Electricity generation in Luxembourg 1990 – 2007

Technology	Electricity generation			CAGR		
	1990 [GWh]	2000 [GWh]	2007 [GWh]	1990-2007 [%]	1990-2000 [%]	2000-2007 [%]
Biogas	0	4	37	:	:	37.4
Biomass solid	0	0	0	:	:	:
Biowaste	16	19	24	2.2	1.4	3.4
Geothermal power plants	0	0	0	:	:	:
Hydro large-scale	0	0	0	:	:	:
Hydro small-scale	67	120	116	3.3	6.0	-0.5
Photovoltaic systems	0	0	21	:	:	:
Solar thermal	0	0	0	:	:	:
Tide & wave	0	0	0	:	:	:
Wind-turbines offshore	0	0	0	:	:	:
Wind-turbines onshore	0	27	64	:	:	11.5
RES-E total	83	170	262	6.8	7.4	6.0

Source: Eurostat (2009)

While the installed capacity of biowaste and hydro large-scale only grew slightly from 1990 to 2007, the renewable energy technologies entering the market later such as biogas and wind-turbines onshore increased strongly as can be seen in **Table 1-2**.[12]

In 2007, the market share in terms of generation capacity of hydro electricity production was 37% followed by wind (31%) solar photovoltaic (21%) biogas (6%) and biowaste (3%) electricity production. As geothermal and solar thermal have a very low potential in Luxembourg, until today they have not been used. Furthermore, although solid biomass has a high potential, this electricity sourced is not exploited yet. In general, Luxembourg was able to establish a heterogeneous renewable electricity market, with the presence of a high variety of technologies.[13]

[12] Ibid.

[13] Ibid.

Table 1-2: Development of RES-Electricity capacities in Luxembourg 1990 – 2007[14]

Technology	Capacity			CAGR		
	1990 [MW]	2000 [MW]	2007 [MW]	1990-2007 [%]	1990-2000 [%]	2000-2007 [%]
Biogas	0	0	7	:	:	:
Biomass solid	0	0	0	:	:	:
Biowaste	3	4	4	1.9	4.1	-1.3
Geothermal power plants	0	0		:	:	:
Hydro large-scale	0	0	0	:	:	:
Hydro small-scale	34	39	42	1.2	1.4	1.0
Photovoltaic systems	0	0	24	:	:	:
Solar thermal	0	1	2	:	:	10.4
Tide & wave	0	0	0	:	:	:
Wind-turbines offshore	0	0	0	:	:	:
Wind-turbines onshore	0	14	35	:	:	14.1
RES-E total	37	58	113	6.9	4.7	10.0

Source: Eurostat (2009)

Heat:

The CAGR of renewable heat generation in Luxembourg was with 4.0% way higher since 2000 as compared to the respective value of 0.6% in the nineties. In 2007, renewable heat was solely generated by solid biomass. The non-grid usage of solid biomass was dominating with a market share of 76% as can be seen in **Table 1-3**.

[14] These figures are based on official Eurostat data and they slightly differ from the national statistics of Luxembourg.

Table 1-3: Development of RES-Heat generation in Luxembourg 1990 – 2007[15]

Technology	Generation			CAGR		
	1990 [ktoe]	2000 [ktoe]	2007 [ktoe]	1990-2007 [%]	1990-2000 [%]	2000-2007 [%]
Biogas (grid)	0.0	0.0	0.0	:	:	:
Solid biomass (grid)	0.0	0.0	5.0	:	:	:
Biowaste (grid)	0.0	0.0	0.0	:	:	:
Geothermal heat (grid)	:	:	:	:	:	:
Solid biomass (non-grid)	15.0	16.0	16.0	0.4	0.6	0.0
Solar thermal	0.0	0.0	0.0	:	:	:
Heat pumps	:	:	:	:	:	:
RES-H total	15.0	16.0	21.0	2.0	0.6	4.0
Share of renewable heat [%]	0.8	1.4	1.8	-	-	-

Source: Eurostat (2009)

Transport:

In 2004, biofuels were firstly consumed in Luxembourg according to Eurostat. However, the share of biofuels in the transport sector still remained on a low level until 2006.[16]

As the government introduced a compulsory blending of biofuels in all transport fuels sold in Luxembourg, the share will have to change strongly. The obligation was 2% for 2007 and could only be met by imports (**Table 1-4**).[17]

Table 1-4: Development of RES-Transport fuel consumption in Luxembourg

Technology	Unit	2005	2006	2007
Biodiesel	[ktoe]	1	1	35
Bioethanol	[ktoe]	0	0	1
Biofuels, total	[ktoe]	1	1	36
Share Biofuels	[%]	0.0	0.0	1.4

Source: Eurostat (2009)

1.1.3 Current renewable energy support policies

Electricity

The electricity generated in Luxembourg is mainly supported by feed-in tariffs and investment subsidies. The current support system was introduced on 1 January 2008. This system is simpler and more transparent than the previous one and as the feed-in tariffs are guaranteed for 15 years, the support measure improves the investor security as well. Furthermore, the new system includes a degression rate of 0.25% per year for every technology except

[15] These figures are based on official Eurostat data and they slightly differ from the national statistics of Luxembourg.

[16] Eurostat (2009) – Table: Share of biofuels in fuel consumption of transport

[17] IEA/OECD (2009a), 67. Further information is given in chapter 1.1.3.

photovoltaic systems, which have a degression rate of 3%, being an incentive to companies to improve their performance over time. An overview is given by the following table.[18]

Table 1-5: Feed-in tariffs and subsidies for renewable electricity

Technology	Capacity limit [MW]	Maximum investment subsidy [%]	Feed-in tariff [€/MWh]	Degression rate [%]
Biogas	0 - 0.15	50	150	0.25
	0.151 - 0.3	50	140	0.25
	0.301 - 0.5	50	130	0.25
	0.501 - 2.5	50	120	0.25
Solid biomass	0 - 1	20	145	0.25
	1 - 5	20	110	0.25
Sludge and landfill gas	unlimited	90	65	0.25
Wood waste	0 - 1	20	130	0.25
	1 - 5	20	110	0.25
Hydropower	0 - 1	20	105	0.25
	1 - 6	20	85	0.25
Solar PV	0 - 0.03	30	420	3.00
	0.03 - 1	30	370	3.00
Wind power	Unlimited	20 - 25	83	0.25

Source: Service central de legislation de Luxembourg (2008), Art. 7 – 13 and IEA/OECD (2009a)

Private households receive a 30% investment subsidy for the installation costs of photovoltaic systems up to 30 kilowatt-peak kWp with a limit of 1,650 €, if the photovoltaic systems are installed between 1. January 2008 and 31 December 2012.[19]

Solar photovoltaic systems with 1 to 4 kWp are handled as private/non-commercial and are therefore excluded from income taxes.[20]

Heat

The government grants subsidies for investment and installation costs for solar heating, heat pumps and biomass boilers of households. The following table shows the subsidies for one-family dwellings.[21]

[18] IEA/OECD (2009a), pag. 65-68

[19] Service central de legislation de Luxembourg (2007) Art. 1, 8

[20] Direction des contributions directes (2003) par. 4.1

[21] Ministère de l'environnement (2008), pag. 7

Table 1-6: Renewable heat subsidies for one-family dwellings

Technology	Subsidy [%]	Max. Limit [€]
Solar thermal for domestic hot wat	50	3,000
Solar thermal for domestic hot water and auxiliary central	50	5,000
Ground heat pump	40	6,000
Air-to-air heat pump	40	3,000
Biomass central heating	30	4,000
Pellet stove	30	2,500
Central split logs stove	25	2,500

Source: Ministère de l'environnement (2008)

Renewable heat from CHP plants based on biogas, solid biomass and wood waste supplied to commercial customers is eligible for a feed-in tariff of 30 €/MWh. In order to be supported, 25% of the heat generated with biogas has to be supplied to commercial customers in the first three years and after that 50%. The respective minimum levels for solid biomass and wood wastes are 35% in the first three years of generation and thereafter 75%.[22]

Transport fuels

The efforts of Luxembourg to increase the share of biofuels in transport fuels initially concentrated on fiscal measures. In 2005 and 2006, biofuels were partially excluded of the excise tax. However, this measure had not been successful. Hence, the government decided to establish a new support policy, and introduced a compulsory blending of biofuels in 2007. The blending obligation was 2% in 2007 and could only be met with imported biofuels.[23]

1.2 Targets & trajectories

1.2.1 Overall renewable energy targets and trajectories

Partly because of a low available RES potential, the share of renewables in overall energy consumption in 2005 was only 0.9% in Luxembourg.[24] Therefore, the 11% target of the Directive is challenging for Luxembourg. The trajectories established by the Directive 2009/28/EC between 2005 and 2020 can be seen below.

[22] Service central de legislation de Luxembourg (2008) Art. 10, 12 and 13

[23] IEA/OECD (2009a), pag. 68

[24] According to Green-X the RES mid-term potential for Luxembourg is about 220 ktoe.

Table 1-7: Overall renewable energy targets and trajectories – Luxembourg

2005	Average 2011 - 2012	Average 2013 - 2014	Average 2015 - 2016	Average 2017 - 2018	2020
0.90%	2.92%	3.93%	5.45%	7.47%	11.00%

Source: Directive 2009/28/EC

1.2.2 Sectoral targets and trajectories

Possible future developments of the renewable energy sector in Luxembourg until 2020 have been assessed based on two scenarios using the Green-X model, the NAT and the ACT scenarios (defined in Appendix 1) and considering a moderate energy demand (based on PRIMES 20% case scenario).[25] In both scenarios the 2020 target for Luxembourg of 11% renewables in overall energy consumption is not reached. However, although the mid-term RES potential for Luxembourg is low, the target is not completely out of reach and could be achieved, for example, through imports.

The gross final energy consumption decreases by 6% from 2005 to 2020 in both scenarios. In the national target fulfillment scenario (NAT scenario), a share of 9.9% of renewables in final energy consumption is reached. In 2005, the consumption in the renewable heating and cooling as well as in the electricity sector was almost 20 ktoe. The consumption of renewables in the heating and cooling sector is eight times higher in 2020 than in 2005 while the consumption of renewable electricity during this same period gets four times higher (**Table 1-8**).

Even in the ACT scenario being the most ambitious one, the 11% target of renewables in final energy consumption is not reached. The development in this scenario and in the NAT scenario is similar.

Besides the two PRIMES scenarios mentioned above a third demand scenario was constructed, which assumes that the export of transport fuels due to transit traffic through Luxemburg will be faced out until 2020 as shown in **Table 1-10**. This additional scenario shows that the much lower transport fuel demand due to a phase out of transport fuel exports results in a much lower value of imported biofuels needed to reach the 10% target in the transport sector (39 ktoe instead of 197 ktoe). On the other hand hardly anything changes for the case of the electricity and the heat sector. Due to this reason and due to the fact that the relatively high demand of flight transport remains unchanged in this scenario to share of RES in total final consumption is hardly changed to 10% of total final demand in this scenario. For this reason all the further results will be presented based on the two main cases shown in **Table 1-8** and **Table 1-9**.

[25] Results and figures for a low energy demand scenario (based on PRIMES high energy efficiency case scenario) are shown in Appendix 2.

Table 1-8: Sectoral targets and trajectories – NAT scenario Luxembourg and moderate demand

Luxembourg		NAT (National target fulfillment)					
Indicator	Unit	2005	Average 2011 - 2012	Average 2013 - 2014	Average 2015 - 2016	Average 2017 - 2018	2020 Targets
Expected Gross Final energy consumption	Ktoe	4,457	4,672	4,522	4,394	4,315	4,219
Total share of RES in final energy consumption	%	0.8%	4.0%	5.7%	6.9%	8.3%	9.9%
Gross Final Consumption of RES-E	Ktoe	19	33	48	63	72	76
Share of RES-E in gross final electricity consumption	%	3.3%	5.7%	8.1%	10.5%	12.1%	12.6%
Gross final energy consumption RES-H	Ktoe	18	51	77	103	131	147
Share of RES-H in final Heating and Cooling consumption	%	1.5%	4.2%	6.4%	8.7%	11.1%	12.4%
Final energy from renewable sources consumed in transport	Ktoe	1	104	132	140	157	197
Share of RES in gross final transport energy consumption	%	0.0%	4.4%	6.0%	6.7%	7.7%	10.0%

Source: Green-X Model (2009)

Table 1-9: Sectoral targets and trajectories – ACT scenario Luxembourg and moderate demand

Luxembourg		ACT (proactive support - realisable deployment)					
Indicator	Unit	2005	Average 2011 - 2012	Average 2013 - 2014	Average 2015 - 2016	Average 2017 - 2018	2020 Targets
Expected Gross Final energy consumption	Ktoe	4,457	4,672	4,522	4,394	4,315	4,219
Total share of RES in final energy consumption	%	0.8%	4.0%	5.6%	6.9%	8.3%	9.9%
Gross Final Consumption of RES-E	Ktoe	19	33	47	61	70	75
Share of RES-E in gross final electricity consumption	%	3.3%	5.7%	7.9%	10.2%	11.7%	12.3%
Gross final energy consumption RES-H	Ktoe	18	51	76	102	130	146
Share of RES-H in final Heating and Cooling consumption	%	1.5%	4.2%	6.4%	8.6%	11.0%	12.3%
Final energy from renewable sources consumed in transport	Ktoe	1	104	132	140	157	197
Share of RES in gross final transport energy consumption	%	0.0%	4.4%	6.0%	6.7%	7.7%	10.0%

Source: Green-X Model (2009)

Table 1-10: Sectoral targets and trajectories – ACT scenario Luxembourg and moderate demand including a phasing out of the transport fuel exports

Luxembourg		ACT (proactive support - realisable deployment)					
Indicator	Unit	2005	Average 2011 - 2012	Average 2013 - 2014	Average 2015 - 2016	Average 2017 - 2018	2020 Targets
Expected Gross Final energy consumption	Ktoe	4,457	2,592	2,579	2,573	2,587	2,604
Total share of RES in final energy consumption	%	0.8%	3.9%	5.6%	7.3%	8.9%	10.0%
Gross Final Consumption of RES-E	Ktoe	19	33	47	61	70	75
Share of RES-E in gross final electricity consumption	%	3.3%	5.7%	7.9%	10.2%	11.7%	12.3%
Gross final energy consumption RES-H	Ktoe	18	51	76	102	130	146
Share of RES-H in final Heating and Cooling consumption	%	1.5%	4.2%	6.4%	8.6%	11.0%	12.3%
Final energy from renewable sources consumed in transport	Ktoe	1	16	22	25	29	39
Share of RES in gross final transport energy consumption	%	0.1%	4.5%	6.0%	6.7%	7.7%	10.0%

Source: Green-X Model (2009)

1.2.3 Contribution of renewables to electricity consumption

Luxembourg has diversified renewable electricity consumption in 2005 in all the scenarios and this market remains heterogeneous until 2020.

The renewable electricity consumption is more than four times higher in 2020 than in 2005 in the scenarios. The potentials of hydro facilities with less than 10 MW and biowaste were exploited to a high share in 2005. Therefore, the consumption of hydro electricity only grows by 47% and the consumption of biowaste electricity by 13% until 2020. Solid biomass, photovoltaic and wind onshore electricity are growing strongly with a CAGR up to 20%. Respectively, photovoltaics have a market share of 30% in 2020 followed by wind (27%), hydro (16%), biogas (14%), solid biomass (11%) electricity (**Table 1-11**).

In the ACT scenario in 2020, the renewable electricity consumption is slightly lower than in the NAT scenario. The energy mix is slightly different as well, mainly as 33 GWh of hydro electricity are less consumed in 2020 (**Table 1-12)**.

Table 1-11: Contribution of renewables to electricity consumption – NAT scenario Luxembourg

Luxembourg	NAT (National target fulfillment)											
Technology	2005		Average		Average		Average		Average		2020	
	MW	GWh	MW	GWh	MW	GWh	MW	GWh	MW	GWh	MW	GWh
Biomass	9.1	48	19.3	108	25.1	144	31.9	185	39.1	224	41.5	243
Solid	0.0	0	2.3	15	5.1	33	8.0	52	10.9	71	14.6	95
Biogas	5.0	27	11.8	65	14.7	82	18.3	102	22.4	121	23.3	125
MSW	4.1	21	5.2	28	5.3	29	5.6	31	5.8	32	3.7	24
Liquid	:	:	:	:	:	:	:	:	:	:	:	:
Concentrated Solar Power	1.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0
Geothermal	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0
Hydro, total	40.0	95	41.4	117	45.0	127	47.4	133	48.8	137	49.9	140
>10MW	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0
<10MW	40.0	95	41.4	117	45.0	127	47.4	133	48.8	137	49.9	140
Of which pumping	:	:	:	:	:	:	:	:	:	:	:	:
Photovoltaic	25.0	18	84.3	63	161.8	119	267.7	197	337.5	248	362.1	266
Ocean	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0
Wind	35.0	57	55.3	100	89.3	164	117.1	212	128.3	233	131.4	239
Onshore	35.0	57	55.3	100	89.3	164	117.1	212	128.3	233	131.4	239
Offshore	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0
Gross Final Consumption of electricity from RES	110.1	218	200.3	388	321.3	554	463.9	727	553.7	842	584.9	888

Source: Green-X Model (2009)

Table 1-12: Contribution of renewables to electricity consumption– ACT scenario Luxembourg

Luxembourg	ACT (proactive support - realisable deployment)											
Technology	2005		Average		Average		Average		Average		2020	
	MW	GWh	MW	GWh	MW	GWh	MW	GWh	MW	GWh	MW	GWh
Biomass	9.1	48	20.6	117	26.5	153	32.9	191	39.9	229	44.9	260
Solid	0.0	0	3.5	23	6.2	40	8.9	58	11.5	75	14.9	97
Biogas	5.0	27	11.8	65	14.7	82	18.3	102	22.4	121	24.9	130
MSW	4.1	21	5.3	29	5.5	30	5.8	32	6.0	33	5.1	33
Liquid	:	:	:	:	:	:	:	:	:	:	:	:
Concentrated Solar Power	1.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0
Geothermal	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0
Hydro, total	40.0	95	38.0	107	38.0	107	38.0	107	38.0	107	38.0	107
>10MW	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0
<10MW	40.0	95	38.0	107	38.0	107	38.0	107	38.0	107	38.0	107
Of which pumping	:	:	:	:	:	:	:	:	:	:	:	:
Photovoltaic	25.0	18	84.3	63	161.8	119	267.7	197	337.5	248	362.6	266
Ocean	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0
Wind	35.0	57	55.3	100	89.3	164	117.1	212	128.3	233	131.4	239
Onshore	35.0	57	55.3	100	89.3	164	117.1	212	128.3	233	131.4	239
Offshore	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0
Gross Final Consumption of electricity from RES	110.1	218	198.2	386	315.6	542	455.6	707	543.6	816	576.9	872

Source: Green-X Model (2009)

1.2.4 Contribution of renewables to heating & cooling consumption

Renewable heat consumption is about eight times higher in 2020 compared to 2005 in both scenarios. Furthermore, two thirds of the renewable heat is produced by solid biomass. The development of this sector is almost the same in the two scenarios. The newer technologies, such as heat pumps and solar thermal were not consumed in 2005 at all. However, heat pumps and solar thermal can reach in 2020 28 ktoe and 14 ktoe. The detailed development is depicted in **Table 1-13**, and **Table 1-14**.

Table 1-13: Contribution of renewables to heating and cooling consumption – NAT scenario Luxembourg

Luxembourg	NAT (National target fulfillment)											
Technology	2005		Average		Average		Average		Average		2020	
	MWth	Ktoe	MWth	Ktoe	MWth	Ktoe	MWth	Ktoe	MWth	Ktoe	MWth	Ktoe
Biomass	0	18	330	44	488	65	634	85	777	104	760	104
Solid	0	18	293	39	449	59	594	79	736	98	726	97
Biogas	:	0	16	4	18	4	18	4	18	4	18	4
Biowaste	:	0	21	1	21	2	23	2	24	2	16	3
Geothermal	:	0	0	0	0	0	0	0	0	0	0	0
Solar Thermal	:	0	72	3	117	4	174	7	251	9	376	14
Heat pumps	:	0	32	4	53	7	86	11	133	18	214	28
Gross final energy consumption from RES in heating and cooling	0	18	434	51	659	77	894	103	1,161	131	1,350	147

Source: Green-X Model (2009)

Table 1-14: Contribution of renewables to heating and cooling consumption – ACT scenario Luxembourg

Luxembourg	ACT (proactive support - realisable deployment)											
Technology	2005		Average		Average		Average		Average		2020	
	MWth	Ktoe	MWth	Ktoe	MWth	Ktoe	MWth	Ktoe	MWth	Ktoe	MWth	Ktoe
Biomass	0	18	329	44	487	65	632	84	775	103	761	103
Solid	0	18	293	39	449	59	594	79	736	97	726	96
Biogas	:	0	16	4	18	4	18	4	18	4	21	4
Biowaste	:	0	20	1	20	1	20	1	21	2	14	3
Geothermal	:	0	0	0	0	0	0	0	0	0	0	0
Solar Thermal	:	0	72	3	117	4	174	7	251	9	376	14
Heat pumps	:	0	32	4	53	7	86	11	133	18	214	28
Gross final energy consumption from RES in heating and cooling	0	18	433	51	658	76	891	102	1,159	130	1,351	146

Source: Green-X Model (2009)

1.2.5 Contribution of renewables to transport fuel consumption

Instead of producing biofuels on its own, Luxembourg is fully importing its biofuel consumption in every considered year. The imports grow up to 197 ktoe in 2020, so that the 10% target is exactly fulfilled solely with imports. In a scenario of a phase out of transport fuel exports due to tank-tourism a significant reduction of biofuel imports from 197 ktoe to about 39 ktoe can be achieved.

The strong acceleration of electric mobility in transport could be another important measure to increase the share of renewable energies in Luxemburg's transport fuel consumption. Assuming that about 10% of all cars in Luxemburg are based on electric mobility the amount of imported biofuels could be reduced by about 40 ktoe. However, this amount of 40 ktoe is then missing for the achievement of the overall target of 11% in total final energy consumption, since electric mobility does not contribute to this target. Therefore such a strong emphasis of electric mobility would increase the need to use cooperation measures as defined in the directive.

Table 1-15: Contribution of renewables to transport consumption – all scenarios Luxembourg

Luxembourg		NAT			ACT		
Technology	Unit	2005	Average 2011 - 2012	Average 2013 - 2014	Average 2015 - 2016	Average 2017 - 2018	2020
Bioethanol	ktoe	0.0	0.0	0.0	0.0	0.0	0.0
Of which imported	ktoe	:	:	:	:	:	:
Biodiesel	ktoe	1.0	0.0	0.0	0.0	0.0	0.0
Of which imported	ktoe	:	:	:	:	:	:
Biofuels from wastes, residues, non-food cellulosic material, and ligno-cellulosic material	ktoe	:	0.0	0.0	0.0	0.0	0.0
Of which imported	ktoe	:	:	:	:	:	:
Hydrogen from RES	ktoe	:	:	:	:	:	:
Renewable electricity	ktoe	:	:	:	:	:	:
Biofuel import	ktoe	:	104.3	132.1	140.0	156.6	196.6
Final energy from renewable sources consumed in transport	ktoe	1.0	104.3	132.1	140.0	156.6	196.6

Source: Green-X Model (2009)

1.3 Measures for achieving the target

1.3.1 Policy measures

Measures on administrative procedures, regulations and codes:

- **Should authorization procedure take into account the specificities of different renewable energy technologies?**

Certainly the specifics of different RES sources should be considered for the design of authorization procedures.

- **Should the renewable energy potential be taken into account in spatial planning?**

Generally RES, and their respective potential, are insufficiently taken into account in spatial planning. In many countries and regions future development of RES projects is not taken into account at the moment of drawing up spatial planning programs. This means that spatial planning programs have to be adopted in order to allow for the implementation of a RES project in a specific area (e.g. RES-E), especially when there is a high RES potential involved in that particular area. This process can take a very long time. Often the acquirement of permits related to spatial planning is the longest trajectory of the overall period needed for development of the project. This is especially the case for projects in the field of wind and biomass. Responsible authorities should be stimulated to anticipate the development of future RES projects in their region, by allocating suitable areas.

Spatial planning, construction permits and EIA (environmental impact assessment) procedures are key problems for regulators. In the RES-E sector to obtain the necessary permits can take years in countries where the authorities take into account the opinion of many stakeholders that are hard to harmonize. Since RES-E development is not taken into consideration in the spatial planning, every project and project variants have to be evaluated on an individual basis. The number of the often long lasting appeal procedures could be effectively decreased by including RES-E development plans in local and regional spatial planning. In Germany, for example, these problems have been solved to a large extent. In the case of onshore wind projects the administrative barriers regarding spatial planning are low thanks to the Building Code (1996), which made states designate areas for onshore wind parks. Thanks to this, a wind farm can be established within 1 year. A similar approach is being followed for offshore wind parks. The federal states and the Bundesamt für Seeschifffahrt und Hydrographie (Federal Maritime and Hydrographic Agency) are responsible for designating areas and issuing permits for offshore wind installations.

- **Should timetables for processing applications be communicated in advance?**

Usually long lead times are needed to obtain necessary permits. Time needed to obtain all necessary permits for the construction of a RES plant can take many years (e.g. RES-E). Also it can be unclear what the exact length of a procedure will be. Clear guidelines for authorization procedures are highly recommended together with obligatory response periods for authorities involved in such procedures.

- **How many steps should be needed to obtain the final authorization? Should there be a one-stop shop for coordinating all the steps?**

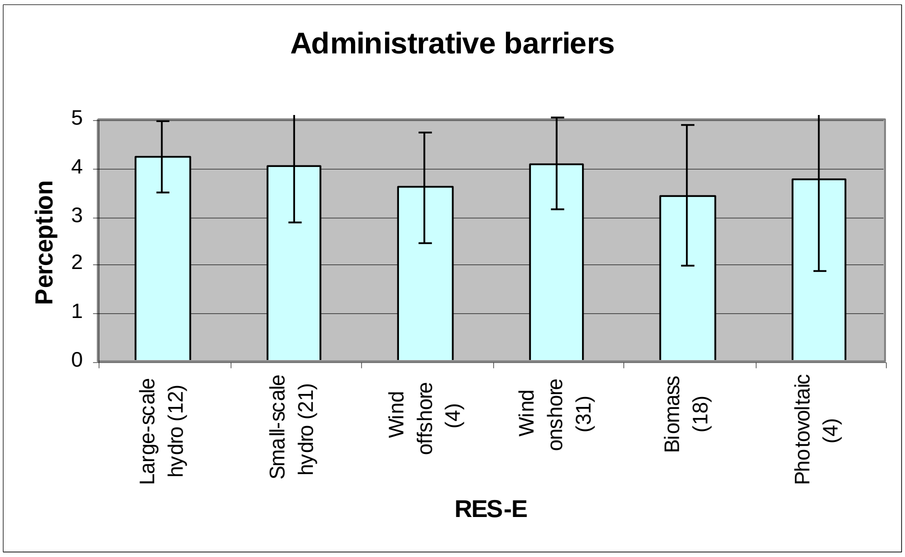
Generally, a high number of authorities are involved to obtain the final authorization. Often many authorities are involved in both permitting as well as support related procedures for renewable energy projects. Responsible authorities usually comprise several administrative bodies at national, regional and local level. An important improvement would be to reduce the number of local, regional and national administrations involved in the authorization processes for permits and financial support. Project developers are much more positive in situations where a single administrative body has been made responsible for co-ordination of several administrative procedures, such as the Bundesamt for off-shore wind in Germany.

Furthermore, there is a lack of co-ordination between different authorities. In many cases project developers need to submit similar information multiple times to different authorities. A suggestion to reduce the administrative burden for RES development would be to standardize procedures, such as standardized administrative requirements and application forms between different authorities.

In **Figure 1-2** we present the perception of administrative barriers per renewable energy source, as identified by the stakeholder consultation[26].

Figure 1-2: Perception of administrative barriers

[26] OPTRES (2007).



Source: OPTRES (2007)

Perception from 0 (no perceived barrier) to 5 (high perceived barrier). Number of received answers per source is provided in brackets, while standard deviation is marked by bars. Only those RES-E types with at least 4 answers have been depicted.

Figure 1-2 shows that the respondents of the stakeholder consultation perceived the administrative problems to be highest for hydropower projects and on-shore wind. However, also for the other renewable energy sources the administrative barriers are perceived an important obstacle in the development of renewable energy projects.

Measures concerning buildings:

- **What measures should be introduced into the building codes to ensure the share of renewable energy used in the building sector will increase?**

Policy instruments should be introduced that provide incentives for integrating a RES-H/C device into the heating/cooling system. But since RES-H/C applications operate only effectively if they are fitted to the overall system design, the chosen policy instrument should create incentives for a good overall system performance. Hence, it should also support the reduction of a building's energy consumption (e.g. by improving its insulation) and motivate for an efficient use of the RES-H/C equipment.

As far a possible the policy instrument should motivate the utilization of high efficiency equipment, e.g. through linking the financial incentives to quality standards of a determined minimum rate of efficiency.

- **How should an obligation for minimum levels of renewable energy in new and newly refurbished buildings be drafted to best ensure renewable energy integration in buildings? At what levels should it be set?**

The obligation should take the different target groups and their different needs into account and might be different for each of these groups. The target groups are private homeowners living in their own home, homeowners renting to others as well as private, municipal and social housing organizations. As such companies often own and manage a large number of buildings they can become a key driver (but also key barrier) for switching buildings to RES-H/C.

Whereas housing companies often have sufficient technical skills to handle even innovative RES-H/C technologies they generally base their economic calculation on shorter pay back times e.g. private building owners in the domestic sector. In addition, the level of willingness to pay might generally be lower than with small scale investors. These circumstances should be considered in the setting of minimum levels for RES and in the corresponding support schemes.

From the perspective of the building owner (investor) apart from the level of support one of the main indicators is the share of the investment costs he can and/or legally is allowed to allocate to the tenants (by increasing the rent). From the perspective of tenants the crucial question concerns the relationship between the financial burden that might derive from an allocation of the investment costs on the rent and potentially reduced costs for heating/cooling due to the reduced use of conventional fuel.

The chosen obligation should ensure that investment is still effectively motivated. Costs for building owners and tenants shall not be too high to discourage investments (e.g. by postponing the reconstruction of heating systems as long as possible).

- **What is the projected increase of renewable energy use in the building sector until 2020?**

Measures on information:

- **How should specific information be targeted at different groups, as end consumers, builders, property managers, property agents, installers, architects, farmers, suppliers of equipment using renewable energy sources, public administration?**

The question is basically about information sharing to all stakeholders. General information for example about subsidies for renewable technologies needs to be broadcasted to all stakeholders. As the internet offers 24 hours access to information and can be updated easily, a base for general information would be a web page. A best practice examples is given in Luxembourg, where Subsidies for heat in households are communicated with the information paper “Förderprogramm zur Energieeinsparung und Nutzung erneuerbarer Energien im Wohnbereich” of the Ministère de l'Environnement of Luxembourg in an easy manner. Thereby, the paper targets not only public administration, but also especially end consumers, property managers and agents, installers and architects and is kept in an understandable and clear style.

End users can be informed by customer information brochures about the possibility to make use of support for renewables. The information brochures can be shared among installers, property managers and suppliers of equipment to hand them over to the end consumers.

Furthermore, there could be a subsidy for consultancy on renewable energy and energy efficiency related tops for end consumers. This would give the advantage, that consumers would choose the most appropriate efficiency and renewable energy option according to an energy expert.

Renewable energy and energy efficiency exhibitions are a great possibility to get to know information physically and are therefore for energy experts as well as for technology end consumers adequate. With expositions, it is possible to share specific information as well. For instance, the SOLTEC exhibition in Germany is mainly focusing in solar technologies and through this focus, information can be shared in more detail.[27]

Workshops and speeches provide the possibility to share specific information only of major interest for a small target group. Workshops and speeches can be integrated to exhibitions as well.

Experts and public administration members need the most up to date information having a higher degree of details than the ones for example for end users. Regularly reports published by the responsible administrative bodies keep the legal framework up-to-date. A best practice example is the German "Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit", which published a brochure of the environment policy from 2005 to 2009 in July 2009 being detailed and giving an overview of the topic as well.[28] With published articles in RES journals, the dynamics of the market can be analyzed in detail.

Specific information for a smaller target group can be shared via internet as well. It would be possible to establish a work group in a small field of work being responsible for specific field publishing news on their own internet platform.

- **How should guidance for planners and architects be provided to help them consider the optimal combination of renewable energy sources, high efficiency technologies and district heating and cooling when planning, designing, building and renovating industrial or residential areas?**

Planners and architects should be provided with an internet platform that holds information on possible options of including renewable energy, high efficiency technologies and districts heating and cooling into new or existing buildings. It should not only contain up-to-date information on technology, how it can be installed and how profitable such investments are on the long run. It should also include detailed information on successfully completed exemplary projects, legislation and events related to the topic. Local information on the applicability of solar technology and the availability of district heating and cooling is desirable. Furthermore it should be possible to order printed copies of the contained information as well as publications explaining the various concerns in greater detail. Contact information to all

[27] Information about the exhibition is given on the web page: http://www.soltec.de/s

[28] Document available on http://www.bmu.de/ministerium/aufgaben/aufgaben/doc/44214.php

relevant professional associations and their local members would complete the web page's content.

The information should be gathered in consultation with experts in energy, technology, construction and installation and be updated continuously to secure a high level of relevance and actuality. The web page should be supervised with the help of the chambers of architects as well as planners associations respectively consumers advice centers to secure that the target groups are addressed properly. These organizations could also contact their members and customers to raise the web page's awareness level within the target groups.

Measures on electricity infrastructure development:

- **Should there be priority connection rights or reserved connection capacities provided for new installations producing electricity from renewable energy sources?**

In general and according to stakeholder consultation, the legally guaranteed access to the grid for RES-E sources and priority transmission and distribution is not considered as a key barrier in countries where this guarantee is currently not applied.

Introduction of positive discrimination of RES-E as regards the guarantee of grid access or transmission and distribution of RES-E, however, may become an additional motivating factor for reasons of investment security, low transaction costs and the acknowledgement of RES-E system benefits.

Priority/guaranteed access to the grid:

- **Should priority or guaranteed access be ensured? Explain.**

Priority grid access is an essential condition for the rapid expansion of renewable energies. In Member States in which it is applied it has enabled new entrants to the market in particular to supply and sell the power they have generated under clear-cut conditions and at foreseeable costs. Priority grid connection prevents the existing oligopolies from squeezing out renewable energy producers, especially in markets where networks and generation capacity are largely in the hands of similarly-sized companies.

- **How should it be ensured that transmission system operators, when dispatching electricity generating installations give priority to those using renewable energy sources?**

Clear statutory regulations and consistent enforcement are required.

- **How should the transmission and distribution of electricity from renewable energy sources be guaranteed by the transmission and distribution system operators?**

Measures to increase the availability of wood for energy use:

To increase the domestic wood supply for energy use in Luxemburg a number of measures have been proposed recently at the workshop “wood and energy” held on the 12th of April 2010 in Luxemburg. Relevant measures include the increase of wood supply from privately owned forests due to increasing awareness by forest owners by means of information campaigns and by increasing demand for domestically harvested wood. Furthermore the extension of heating grids constitutes an important element in this respect.

1.3.2 Financial support

Table 1-16 gives an indication on the necessary financial support by illustrating the weighted average (2011 to 2020) levelised (to a period of 15 years) total remuneration per MWh of RES generation for new installations in the investigated cases (NAT and ACT). This shows the gross support requirements as besides the financial premium offered by a RES support scheme also default revenues from the selling of the produced energy on the related energy market are included.[29] Gross figures were selected here as net expenditures largely depend on the future development of energy and carbon prices at European as well as at global scale.[30]

A comparison of the technology- or sector-specific figures by scenario shows significant differences between both cases. This illustrates the need to increase support levels if an ambitious and accelerated RES deployment is targeted. However, the figures of the ACT case represent the upper limit of such support requirements, where a fine tuning of the EU-wide equally conditioned technology-specific support levels to the circumstances in Luxembourg offers a significant potential for cost reduction.[31]

Consequently, if Luxembourg follows the NAT policy track the support requirements would decrease significantly. An important precondition for that is however that the implemented RES policy needs to be classified as stable and the investor’s risk is reduced to a low level (e.g. by offering a guaranteed duration of support (incl. support levels)).

29 For the case of small-scale RES heating systems this shall mean the price of heat supply based on a typical conventional reference technology.

30 Obviously, also gross figures are not independent from the future development of energy prices. As the price development for energy related equipment in the years before the financial crisis (2008) has shown, prices (and largely also cost) for most types of power plants coincided to a large extent with rising energy and raw material prices.

The overall impact of energy prices on support cost is however seen larger on net compared to gross figures.

31 Compare e.g. total remuneration for RES in the heat sector: Although support is significantly higher in the ACT case differences in terms of resulting RES deployment are comparatively small.

Table 1-16: Weighted average (2011 to 2020) total remuneration for yearly new RES installation in Luxembourg – NAT and ACT scenario

RES policy indicator (i.e. required total remuneration)	Weighted average (2011 to 2020) total remuneration for yearly new RES installations [€/MWh$_{RES}$]	
	NAT (National target fulfillment)	ACT (proactive support - realisable deployment)
Biogas	145.4	150.7
(Solid) Biomass	143.7	149.7
Biowaste	95.2	102.5
Geothermal electricity	0.0	0.0
Hydro large-scale	0.0	0.0
Hydro small-scale	159.7	0.0
Photovoltaics	372.2	397.1
Solar thermal electricity	0.0	0.0
Tide & Wave	0.0	0.0
Wind onshore	104.4	108.7
Wind offshore	0.0	0.0
RES-E (average)	212.1	224.6
RES heat (district heat)	0.0	0.0
RES heat (decentral)	107.0	130.3
Biofuel (average)	105.7	105.7

Source: Green-X Model (2009)

1.3.3 Increasing biomass availability

In 2020 the primary energy use of biomass is 294 ktoe in the NAT and 300 ktoe in the ACT scenario. The main biomass source is in both scenarios forestry products with roughly 66 ktoe. Almost half of the biomass is imported in 2020, of which agricultural products are the most important source. Further information is given in the following tables.

Table 1-17: Availability of biomass in Luxembourg – NAT scenario

Luxembourg		NAT (National target fulfillment)			
Feedstock category	Unit	Total 2015	Imports 2015	Total 2020	Imports 2020
Agricultural products	[ktoe]	0	67	0	113
Agricultural residues	[ktoe]	31	:	44	:
Forestry products	[ktoe]	48	:	66	:
Forestry residues	[ktoe]	12	25	22	33
Biowaste	[ktoe]	19	:	16	:
Total biomass availibility	[ktoe]	202		294	

Source: Green-X Model (2009)

Table 1-18: Availability of biomass in Luxembourg – ACT scenario

Luxembourg		ACT (proactive support - realisable deployment)			
Feedstock category	Unit	Total 2015	Imports 2015	Total 2020	Imports 2020
Agricultural products	[ktoe]	0	67	0	113
Agricultural residues	[ktoe]	31	:	46	:
Forestry products	[ktoe]	48	:	66	:
Forestry residues	[ktoe]	12	26	22	33
Biowaste	[ktoe]	19	:	20	:
Total biomass availibility	[ktoe]	204		300	

Source: Green-X Model (2009)

1.3.4 Flexibility/Joint projects/European perspective

Excess and deficit production of renewable energy compared to the indicative trajectory

This section compares the usage of renewables in a scenario considering European trade (EU scenario) with the indicative trajectory set by the Directive.

Luxembourg can't reach the trajectories in all regarded years in the EU scenario. The deficit is hereby constantly increasing. In 2020 the EU scenario has the highest shortfall with 1,055 ktoe to be compensated by the use of flexibility mechanisms. Further information is given in the following table.

Table 1-19: Excess and deficit production of renewables compared to the indicative trajectory in Luxembourg – EU scenario

Luxembourg		EU (European perspercitve) vs. Indicative trajectory				
Sector	Unit	Average 2011 - 2012	Average 2013 - 2014	Average 2015 - 2016	Average 2017 - 2018	2020
Excess	[ktoe]	:	:	:	:	:
Deficit	[ktoe]	172	255	421	650	1,055

Source: Fraunhofer ISI; EEG; Rütter + Partner; LEI; SEURECO (2009)

1.4 Estimated costs & benefits of RES policy support measures

Expected renewable energy use

The renewable energy consumption is quite similar in the scenarios. In the NAT and ACT scenario a renewable deployment of 420 ktoe and 417 ktoe is reached in 2020.

The contribution of the transport sector to the 2020 overall renewable energy consumption is very high, although all biofuels are imported in 2020 due to a lack of potential.

Expected GHG reduction

The cumulative avoided CO_2 emissions are 8.4 $MtCO_2$ in the NAT and ACT scenario The high usage of biofuels in Luxembourg results in a high avoidance of CO_2 from the transport sector. 4.5 $MtCO_2$ are cumulatively saved in the scenarios between 2006 and 2020 in the transport segment being more than half of the total savings.

Expected job creation

The effects on the job market are based on the study EmployRES published by Fraunhofer ISI, EEG, Rütter + Partner, LEI and SEURECO. In this study, the total gross employees due to the renewable energy field are analyzed in three scenarios. The first scenario is a business as usual scenario (BAU scenario) assuming the current renewable energy policy will be retained. The second scenario assumes a stronger RES policy and is comparable to the EU scenario of Green-X. The third scenario is a hypothetical scenario assuming that no further support for renewables is given after 2006.

The efforts to achieve the target to produce 11% of Luxembourg's energy from renewable sources will add additional 800 total gross jobs due to the renewable energy sector as compared to a case with no RES policies applied after 2006 as can be seen in the following figure:

Table 1-20: Additional employees in the renewable energy sector of Luxembourg

Indicator	Unit	2010	2015	2020
BAU scenario	**1000 employees**	0.1	0.1	0.1
Advanced policy scenario	**1000 employees**	0.3	0.6	0.9

Source: Fraunhofer ISI; EEG; Rütter + Partner; LEI; SEURECO (2009)

Avoided fossil fuel imports

Avoided fossil fuel imports in energy terms:

The cumulative avoided fossil fuel imports in energy terms are 3,210 ktoe in the NAT and 3,183 ktoe in the ACT scenario cumulatively seen from 2006 to 2020.

The development is similar in the scenarios, particularly for the values of RES-H and RES-T. The savings are steadily growing especially after 2010. In both scenarios, the cumulative fuel savings from 2006 to 2020 in the transport sector are 1,572 ktoe and the savings in the heat sector 819 ktoe. Avoided fuels saved in the electricity sector are between 792 and 819 ktoe.[32] In the NAT scenario despite lower support expenditures than in the ACT scenario, 27 ktoe more fuel imports are avoided in the electricity sector.

Avoided fossil fuel imports in monetary terms:

[32] In these calculations it is again assumed that the average national fuel mix for electricity generation in Luxembourg is replaced.

In monetary terms, 1,528 M€ are avoided cumulatively in the NAT and 1,517 M€ in the ACT scenario. Most cumulative fossil fuel imports are avoided in the transport sector.

Avoided external costs

For this section, the total avoided GHG emissions of the different scenarios got multiplied with the expected future CO_2 prices.

In Luxembourg, the avoided external costs are 244 M€ in the NAT and 242 M€ in the ACT scenario in 2020. The transport sector shows the highest contribution of roughly half of the total avoidance in 2020.

Expected capital expenditures

The cumulative capital expenditures from 2005 to 2020 are higher in the ACT scenario with 1,707 M€ compared to the NAT scenario (1,447 M€).

While the investments in the electricity and transport sectors are similar in both scenarios, the investments in the heat sector are more than 50% higher in the ACT scenario.

Expected costs of achieving the 2020 target

Policy costs:

The cumulated expenditures for support mechanisms from 2006 to 2020 are the lowest in the NAT scenario (1,447 M€). The ones of the ACT scenario (1,707 M€) are clearly above.

In both scenarios, the most money is spent on the electricity sector. The second highest policy costs are caused by the heat sector and the smallest costs by the transport sector.

Additional generation costs:

The cumulative additional generation costs between 2006 and 2020 are 609 M€ in the NAT and 595 M€ in the ACT scenario.

Thereby, no additional generation costs are caused by the heat sector, despite the renewable heat consumption rises from 18 ktoe in 2005 to almost 150 ktoe in 2020. More than 80% of the additional costs are due to the electricity and less than 20% due to the transport sector in the NAT and ACT scenario.

1.5 Outline of RES industry

This chapter reflects the view of the RES industry of Luxembourg and is based on the main outputs from the RES industry collaboration workshop organized on the 26th of October 2009 by the “Chambre des Métiers” of Luxembourg. More than 40 people participated in this event all representing companies and institutions active in the renewable energy sector.

One key finding within the workshop was the need in the creation of RES industry associations. Hence and for this purpose the “Chambre des Métiers” offered its help in the creation of such associations.

Within the biogas sector the targets defined in the LuxRes study of March 2007 could be achieved because of 3 plants for municipal biowaste in “Itzig Kehlen” and “Monnerich”. The plants will be capable to use almost all the organic waste available in Luxembourg, hence no other biogas plants are expected to be constructed in the medium-term. In order to reach the 2020 target for biogas, biogas plants in the agricultural sector need to be developed. Currently, a support structure based on three tariffs (also considered of a low level by the industry as well as unclear and complicated) is a key instrument for the development of this sector. Furthermore industry pointed out, that continuous changes in the law result in a low planning security for investors and the long approval procedure (ie. 1 to 4 years) hampers the development of this sector. In addition, it was stated that financial support during biogas project development would help to reduce the involved high financial risk at the early stage of the projects.

According to the participants of the workshop, solar thermal energy should become obligatory for new buildings. The current support instruments were considered insufficient for solar thermal energy development within Luxembourg.

For photovoltaic systems a financial support for unlimited size and for field sites was demanded. Furthermore, the consumption of the own production together with a feed-in tariff for the production surplus should be made possible (i.e. comparable to Belgium). Concerning the administration of RES support, predictable support levels as well as more simple administrative procedures were mentioned to be important issues by the workshop participants. An eco credit with an interest rate of 0% (i.e. French case) would be an appropriate additional support instrument for solar photovoltaics.

Regarding wind power, since 2004 only 4 new wind power plants were connected to the grid. As a result, the targets of the LuxRes potential study were not reached so far. Concerning the support of wind power, the feed-in tariff should be increased and index-bounded. The support duration should be raised up to 20 years. Furthermore, the current wind atlas is out of date. Only some measurements are available in a height of 30 meters while modern wind plants demand data up to 100 meters. Therefore, a new wind atlas needs to be established. The approval procedure should be simplified. Especially the noise regulation is a problem. Most countries demand noise data for 6 m/s, while the data is demanded in Luxembourg for 8 m/s. This data is not available and needs to be gathered through costly measurements. Therefore, a plan “sectoriel éoliennes” is needed, which specifies detailed framework conditions for e.g. shadow-projection, air ports, radar, birds or bats. Long electric power lines are expensive and should therefore receive a government grant. The costs of the feed-in tariff are shared through the “Fonds de compensation”, but the distribution is unfair and at the expense of small consumers. Hence it should be amended. Lastly, communities cannot participate in wind power projects through stocks, and this is a relevant barrier to let communities become energy producers and thus to involve citizens in this sector.

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Appendix 1 - Overview on investigated cases

Within this project we have calculated three different scenarios of the future renewable energy development up to 2020. These scenarios are meant to form a basis for establishing the 27 national energy roadmaps. The following gives an overview of the three aims of the scenarios. Generally, in all scenarios it is preconditioned to pursue the overall 20% RES by 2020 on EU scale. All results of the scenario calculations are depicted in terms of RES deployment as well as the associated costs and benefits.

NAT – National target fulfillment:

Within the NAT scenario each Member States tries to fulfil its national RES target by its own. The use of cooperation mechanisms as agreed in the RES Directive is reduced to necessary minimum: For the exceptional case that a member state would not possess sufficient RES potentials, cooperation mechanisms would serve as a complementary option. Additionally, if a member state possesses barely sufficient RES potentials, but their exploitation would cause significantly higher consumer expenditures compared to the EU average, cooperation would serve as complementary tool to assure target achievement. As a consequence of above, the required RES support will differ comparatively large among the countries.

EU – European perspective:

In contrast to the NAT case, within the EU scenario the use of cooperation mechanisms does not represent the exceptional case: If a member state would not possess sufficient potentials that can be economically[33] exploited, cooperation mechanisms as defined in the RES directive would serve as a complementary option. Consequently, the prior aim of the EU scenario is to fulfil the 20% RES target on EU level, rather than fulfilling each national RES target purely domestically. Generally, it reflects a 'least cost' strategy in terms of consumer expenditures (due to RES support). In contrast to simple short-term least cost policy approaches, the applied technology-specification of RES support does however still allow an EU-wide well balanced RES portfolio.

ACT – proactive support – realizable deployment:

Finally, the ACT scenario depicts an optimistic future with respect to RES exploitation. The assumption is taken that all EU member states apply proactive RES support whereby EU-wide equal incentives are preconditioned for individual RES technologies (e.g. by applying a harmonised but technology-specific premium feed-in system to support RES-E). With EU-wide effective and efficient RES support this scenario ends up with a higher RES exploitation as foreseen in the RES directive.

[33] In the EU case economic restrictions are applied to limit differences in applied financial RES support among countries to an adequately low level. Consequently, if support in a country with low RES potentials and / or an ambitious RES target exceeds the upper boundary, the remaining gap to its RES target would be covered in line with the flexibility regime as defined in the RES Directive via (virtual) imports from other countries.

Appendix 2 - Results and figures for a low energy demand

Based on PRIMES high energy efficiency case scenario

Sectoral targets and trajectories – NAT scenario Luxembourg

Luxembourg		NAT (National target fulfillment)					
Indicator	Unit	2005	Average 2011 - 2012	Average 2013 - 2014	Average 2015 - 2016	Average 2017 - 2018	2020 Targets
Expected Gross Final energy consumption	Ktoe	4,457	4,775	4,637	4,508	4,399	4,268
Total share of RES in final energy consumption	%	0.8%	4.1%	5.8%	7.1%	8.5%	10.2%
Gross Final Consumption of RES-E	Ktoe	19	33	48	63	72	76
Share of RES-E in gross final electricity consumption	%	3.3%	5.6%	7.9%	10.4%	11.9%	12.3%
Gross final energy consumption RES-H	Ktoe	18	51	77	103	131	145
Share of RES-H in final Heating and Cooling consumption	%	1.5%	4.2%	6.5%	8.9%	11.5%	12.9%
Final energy from renewable sources consumed in transport	Ktoe	1	109	144	156	172	213
Share of RES in gross final transport energy consumption	%	0.0%	4.4%	6.0%	6.7%	7.7%	10.0%

Source: Green-X Model (2009)

Sectoral targets and trajectories – ACT scenario Luxembourg

Luxembourg		ACT (proactive support - realisable deployment)					
Indicator	Unit	2005	Average 2011 - 2012	Average 2013 - 2014	Average 2015 - 2016	Average 2017 - 2018	2020 Targets
Expected Gross Final energy consumption	Ktoe	4,457	4,775	4,637	4,508	4,399	4,268
Total share of RES in final energy consumption	%	0.8%	4.0%	5.8%	7.1%	8.5%	10.2%
Gross Final Consumption of RES-E	Ktoe	19	33	47	61	70	75
Share of RES-E in gross final electricity consumption	%	3.3%	5.5%	7.8%	10.1%	11.5%	12.1%
Gross final energy consumption RES-H	Ktoe	18	51	76	102	130	146
Share of RES-H in final Heating and Cooling consumption	%	1.5%	4.2%	6.5%	8.9%	11.4%	12.9%
Final energy from renewable sources consumed in transport	Ktoe	1	109	144	156	172	213
Share of RES in gross final transport energy consumption	%	0.0%	4.4%	6.0%	6.7%	7.7%	10.0%

Source: Green-X Model (2009)

Contribution of renewables to electricity consumption – NAT scenario Luxembourg

Luxembourg	NAT (National target fulfillment)											
Technology	2005		Average 2011 - 2012		Average 2013 - 2014		Average 2015 - 2016		Average 2017 - 2018		2020 Targets	
	MW	GWh	MW	GWh	MW	GWh	MW	GWh	MW	GWh	MW	GWh
Biomass	9.1	48	19.3	108	25.1	144	31.9	185	39.1	224	41.5	243
Solid	0.0	0	2.3	15	5.1	33	8.0	52	10.9	71	14.6	95
Biogas	5.0	27	11.8	65	14.7	82	18.3	102	22.4	121	23.3	125
MSW	4.1	21	5.2	28	5.3	29	5.6	31	5.8	32	3.7	24
Liquid	:	:	:	:	:	:	:	:	:	:	:	:
Concentrated Solar	1.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0
Geothermal	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0
Hydro, total	40.0	95	41.4	117	45.0	127	47.4	133	48.8	137	49.9	140
>10MW	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0
<10MW	40.0	95	41.4	117	45.0	127	47.4	133	48.8	137	49.9	140
Of which pumping	:	:	:	:	:	:	:	:	:	:	:	:
Photovoltaic	25.0	18	84.3	63	161.8	119	267.7	197	337.5	248	362.1	266
Ocean	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0
Wind	35.0	57	55.3	100	89.3	164	117.1	212	128.3	233	131.4	239
Onshore	35.0	57	55.3	100	89.3	164	117.1	212	128.3	233	131.4	239
Offshore	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0
Gross Final Consumption of electricity from RES	110.1	218	200.3	388	321.3	554	463.9	727	553.7	842	584.9	888

Source: Green-X Model (2009)

Contribution of renewables to electricity consumption – ACT scenario Luxembourg

Luxembourg	ACT (proactive support - realisable deployment)											
Technology	2005		Average 2011 - 2012		Average 2013 - 2014		Average 2015 - 2016		Average 2017 - 2018		2020	
	MW	GWh	MW	GWh	MW	GWh	MW	GWh	MW	GWh	MW	GWh
Biomass	9.1	48	20.6	117	26.5	153	32.9	191	39.9	229	44.9	260
Solid	0.0	0	3.5	23	6.2	40	8.9	58	11.5	75	14.9	97
Biogas	5.0	27	11.8	65	14.7	82	18.3	102	22.4	121	24.9	130
MSW	4.1	21	5.3	29	5.5	30	5.8	32	6.0	33	5.1	33
Liquid	:	:	:	:	:	:	:	:	:	:	:	:
Concentrated Solar	1.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0
Geothermal	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0
Hydro, total	40.0	95	38.0	107	38.0	107	38.0	107	38.0	107	38.0	107
>10MW	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0
<10MW	40.0	95	38.0	107	38.0	107	38.0	107	38.0	107	38.0	107
Of which pumping	:	:	:	:	:	:	:	:	:	:	:	:
Photovoltaic	25.0	18	84.3	63	161.8	119	267.7	197	337.5	248	362.6	266
Ocean	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0
Wind	35.0	57	55.3	100	89.3	164	117.1	212	128.3	233	131.4	239
Onshore	35.0	57	55.3	100	89.3	164	117.1	212	128.3	233	131.4	239
Offshore	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0
Gross Final Consumption of electricity from RES	110.1	218	198.2	386	315.6	542	455.6	707	543.6	816	576.9	872

Source: Green-X Model (2009)

Contribution of renewables to heating and cooling consumption – NAT scenario Luxembourg

Luxembourg	NAT (National target fulfillment)											
Technology	2005		Average 2011 - 2012		Average 2013 - 2014		Average 2015 - 2016		Average 2017 - 2018		2020	
	MWth	Ktoe	MWth	Ktoe	MWth	Ktoe	MWth	Ktoe	MWth	Ktoe	MWth	Ktoe
Biomass	0	18	330	44	488	65	634	85	777	104	760	104
Solid	0	18	293	39	449	59	594	79	736	98	726	97
Biogas	:	0	16	4	18	4	18	4	18	4	18	4
Biowaste	:	0	21	1	21	2	23	2	24	2	16	3
Geothermal	:	0	0	0	0	0	0	0	0	0	0	0
Solar Thermal	:	0	72	3	117	4	174	7	250	9	333	13
Heat pumps	:	0	32	4	53	7	86	11	133	18	214	28
Gross final energy consumption from RES in heating and cooling	0	18	434	51	659	77	894	103	1,161	131	1,306	145

Source: Green-X Model (2009)

Contribution of renewables to heating and cooling consumption – ACT scenario Luxembourg

Luxembourg	ACT (proactive support - realisable deployment)											
Technology	2005		Average 2011 - 2012		Average 2013 - 2014		Average 2015 - 2016		Average 2017 - 2018		2020	
	MWth	Ktoe	MWth	Ktoe	MWth	Ktoe	MWth	Ktoe	MWth	Ktoe	MWth	Ktoe
Biomass	0	18	329	44	486	65	631	84	773	103	758	103
Solid	0	18	293	39	449	59	593	79	734	97	724	96
Biogas	:	0	16	4	18	4	18	4	18	4	21	4
Biowaste	:	0	20	1	20	1	20	1	21	2	14	3
Geothermal	:	0	0	0	0	0	0	0	0	0	0	0
Solar Thermal	:	0	72	3	117	4	174	7	251	9	376	14
Heat pumps	:	0	32	4	53	7	86	11	133	18	214	28
Gross final energy consumption from RES in heating and cooling	0	18	433	51	657	76	890	102	1,157	130	1,348	146

Source: Green-X Model (2009)

Contribution of renewables to transport consumption – all scenarios Luxembourg

Luxembourg		NAT			ACT		
Technology	Unit	2005	Average 2011 - 2012	Average 2013 - 2014	Average 2015 - 2016	Average 2017 - 2018	2020
Bioethanol	ktoe	0.0	0.0	0.0	0.0	0.0	0.0
Of which imported	ktoe	:	:	:	:	:	:
Biodiesel	ktoe	1.0	0.0	0.0	0.0	0.0	0.0
Of which imported	ktoe	:	:	:	:	:	:
Biofuels from wastes, residues, non-food cellulosic material, and ligno-cellulosic material	ktoe	:	0.0	0.0	0.0	0.0	0.0
Of which imported	ktoe	:	:	:	:	:	:
Hydrogen from RES	ktoe	:	:	:	:	:	:
Renewable electricity	ktoe	:	:	:	:	:	:
Biofuel import	ktoe	:	109.1	143.9	155.8	172.2	213.0
Final energy from renewable sources consumed in transport	ktoe	1.0	109.1	143.9	155.8	172.2	213.0

Source: Green-X Model (2009)

Appendix 3 - Short characterization of the Green-X model

As in previous projects such as FORRES 2020, OPTRES or PROGRESS the ***Green-X*** model was applied to again perform a detailed quantitative assessment of the future deployment of renewable energies on country-, sectoral- as well as technology level. The core strength of this tool lies on the detailed RES resource and technology representation accompanied by a thorough energy policy description, which allows assessing various policy options with respect to resulting costs and benefits. A short characterisation of the model is given below, whilst for a detailed description we refer to www.green-x.at.

*Short characterisation of the **Green-X** model*

*The model **Green-X** has been developed by the Energy Economics Group (EEG) at Vienna University of Technology in the research project "Green-X – Deriving optimal promotion strategies for increasing the share of RES-E in a dynamic European electricity market", a joint European research project funded within the 5th framework program of the European Commission, DG Research (Contract No. ENG2-CT-2002-00607). Initially focussed on the electricity sector, this tool and its database on RES potentials and costs have been extended within follow-up activities to incorporate renewable energy technologies within all energy sectors.*

***Green-X** covers geographically the EU-27, and can easily be extended to other countries such as Turkey, Croatia or Norway. It allows to investigate the future deployment of RES as well as accompanying cost – comprising capital expenditures, additional generation cost (of RES compared to conventional options), consumer expenditures due to applied supporting policies, etc. – and benefits – i.e. contribution to supply security (avoidance of fossil fuels) and corresponding carbon emission avoidance. Thereby, results are derived at country- and technology-level on a yearly basis. The time-horizon allows for in-depth assessments up to 2020, accompanied by concise out-looks for the period beyond 2020 (up to 2030).*

Within the model, the most important RES-Electricity (i.e. biogas, biomass, biowaste, wind on- & offshore, hydropower large- & small-scale, solar thermal electricity, photovoltaics, tidal stream & wave power, geothermal electricity), RES-Heat technologies (i.e. biomass – subdivided into log wood, wood chips, pellets, grid-connected heat -, geothermal (grid-connected) heat, heat pumps and solar thermal heat) and RES-Transport options (e.g. first generation biofuels (biodiesel and bioethanol), second generation biofuels (lignocellulotic bioethanol, BtL) as well as the impact of biofuel imports) are described for each investigated country by means of dynamic cost-resource curves. This allows besides the formal description of potentials and costs a detailed representation of dynamic aspects such as technological learning and technology diffusion.

Besides the detailed RES technology representation the core strength of the model is the in-depth energy policy representation. Green-X is fully suitable to investigate the impact of applying (combinations of) different energy policy instruments (e.g. quota obligations based on tradable green certificates / guarantees of origin, (premium) feed-in tariffs, tax incentives, investment incentives, impact of emission trading on reference energy prices) at country- or at European level in a dynamic framework. Sensitivity investigations on key input parameters such as non-economic barriers (influencing the technology diffusion), conventional energy prices, energy demand developments or technological progress (technological learning) typically complement a policy assessment.