ENERGY DEMAND SCENARIOS – LUXEMBOURG

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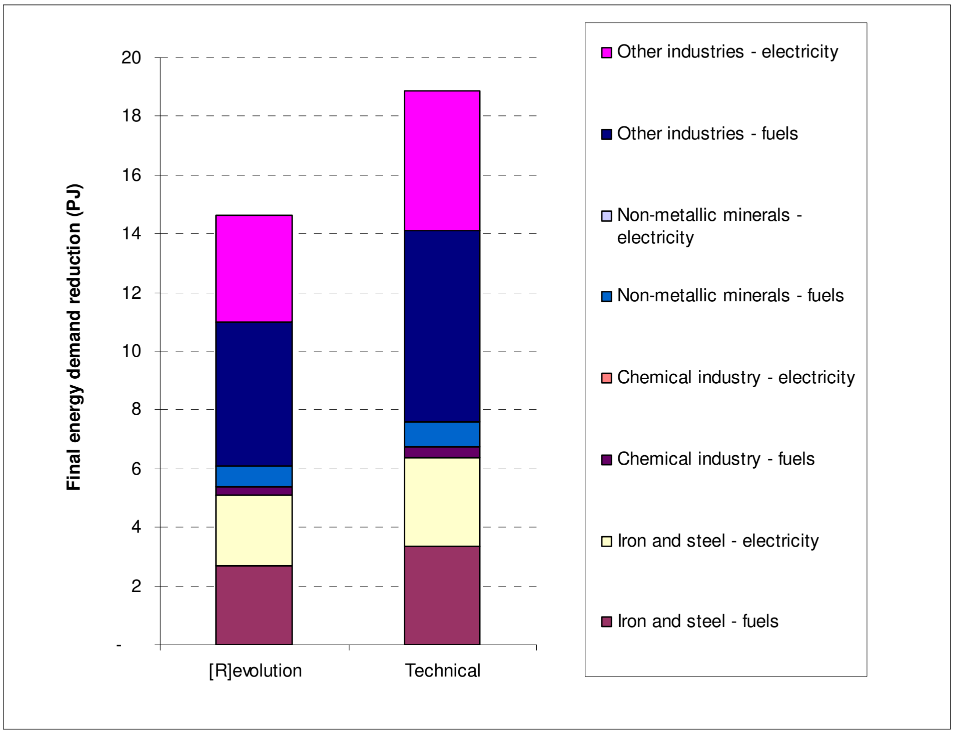
Summary

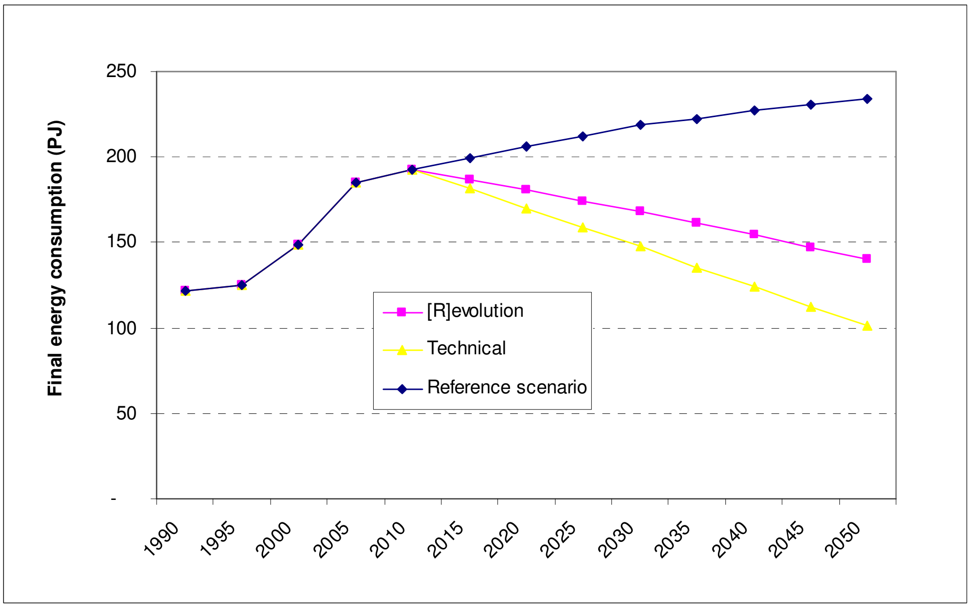
In this ‘quick scan’ study, two long-term (2050) low energy demand scenarios are developed for Luxembourg, based on the 2008 update of the Greenpeace Energy [r]evolution scenarios (Ecofys, 2008b). The ‘Technical’ scenario is based on technical energy efficiency potentials, while the ‘[r]evolution’ scenario is based on more moderate energy savings taking into account implementation barriers.

All energy savings are measured with respect to the reference scenario. The reference scenario for Luxembourg is based on the energy demand in Luxembourg in the base year 2005, and the percentage growth of final energy demand in the Energy [r]evolution reference scenario developed for OECD Europe (Ecofys, 2008b).

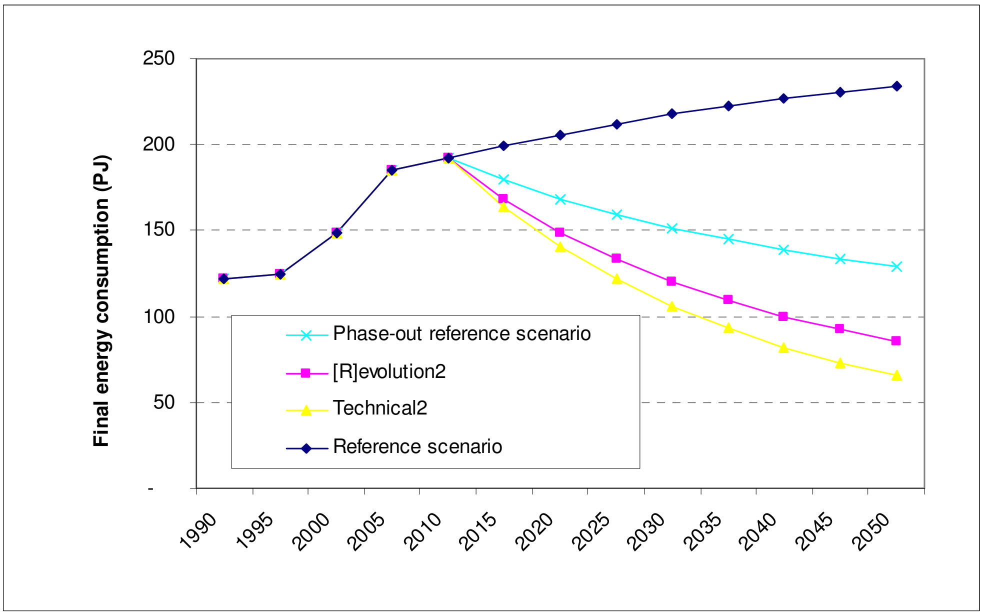
For the industry sector, energy demand reduction potentials are based on available general energy efficiency or intensity indicators in the following subsectors: iron and steel, chemical and petrochemical, non-metallic minerals and other industries. Resulting savings can be found in the figure below.



In other sectors except industry (transport, households, services, agriculture), potentials for energy demand reduction are obtained from the Greenpeace Energy [r]evolution study. It is assumed that the percentage savings potentials for OECD Europe will also hold for Luxembourg. When all measures are applied to Luxembourg, the figure below gives the final energy demand in the reference scenario, the [r]evolution scenario, and the Technical scenario.



As a large part of transport energy demand stems from the export of relatively cheap Luxembourg fuels, an alternative reference scenario was developed where a phase-out of fuel exports is assumed to take place in the future. Based on this 'phase-out reference scenario', two alternative low energy demand scenarios are constructed. The percentage savings are assumed to be the same, but since a different reference scenario is used, the absolute reduction potentials are different. Absolute reduction potentials only change for the transport sector and the total. To avoid confusion, the two alternative scenarios will be refereed to as 'Technical2' and '[r]evolution2'. Results are shown in the figure below.



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1 Introduction

The goal of this study is to develop two low energy demand scenarios for Luxembourg, based on the 2008 update of the Greenpeace Energy [r]evolution scenarios (Ecofys, 2008b). The first scenario is based on technical energy efficiency potentials and is called “Technical”. The second scenario is based on more moderate energy savings taking into account implementation barriers. This scenario is called “[r]evolution”. The [r]evolution low energy demand scenario is based on implementing a certain percentage of the technical energy efficiency improvement potentials. If no specific information is available, the default share of the technical potential that is used is 80%.

In this report the following definitions are used:

Energy intensity	Final energy use per unit of gross domestic product
Energy efficiency	Final energy use per unit of physical indicator (tonne steel, kWh, m^2 building surface, etc.)
Energy demand reduction	Decrease of final energy use compared to reference scenario

Energy demand reduction figures are given in comparison to the reference scenario. In the reference scenario it is assumed that a certain amount of energy efficiency improvement is occurring automatically. This is often referred to as autonomous energy efficiency improvement. Historically, autonomous energy efficiency improvement corresponds to around 1% per year (Blok, 2004). Autonomous efficiency improvement occurs due to technological developments. Each new generation of capital goods is likely to be more energy efficient than the one before. This is mainly caused by (temporary) increases in energy prices from which economic actors try to save on energy for instance by investing in energy efficiency measures or changing their behaviour. Unless otherwise specified it is assumed that the autonomous energy efficiency improvement in the reference scenario equals 1% per year.

All savings are measured with respect to the reference scenario, which means that activities are assumed to increase as in the reference scenario. Except for the transport sector, where a small energy demand reduction and modal shift are taken into account, energy demand reduction is purely due to efficiency improvement. Energy efficiency improvement additional to the reference scenario is assumed to start in the year 2010.

This report presents the result of a ‘quick scan’ of energy efficiency potentials, which gives a good view of the overall potential. Potentials in industry are based on general efficiency indicators, and will not give a figure for individual companies. Potentials in other sectors are directly based on OECD Europe potentials from the Greenpeace Energy [r]evolution study (Ecofys, 2008b), meaning that percentage savings in a certain (sub)sector in OECD Europe also hold for Luxembourg. Further analysis could be carried out to provide more detail but was beyond the scope of this study.

2 Reference scenario

The reference scenario for Luxembourg is based on the energy demand in Luxembourg in the base year 2005, and the percentage growth of final energy demand in the energy [r]evolution reference scenario developed for OECD Europe (Ecofys, 2008b). As an example, the base year energy demand for transport in Luxembourg 114 PJ (IEA Energy Balances for 2005) is assumed to grow by the same percentage (25%) as transport demand growth in OECD Europe. Using this assumption energy demand for transport in 2050 would be 142 PJ.

The Greenpeace Energy [r]evolution reference scenario for OECD Europe is based on the World Energy Outlook 2007 (IEA, 2007b). This reference scenario only takes into account existing international energy and environmental policies. The assumptions include, for example, continuing progress in electricity and gas market reforms, the liberalisation of cross-border energy trade and recent policies designed to combat environmental pollution. Also GDP and population growth are included. The reference scenario does not include additional policies to reduce greenhouse gas emissions. As the IEA's scenario only covers a time horizon up to 2030, it has been extended by extrapolating its key macroeconomic indicators.

Figure 1 shows the development of the reference scenario in Luxembourg for the period 2005-2050 per sector.

Figure 1 Development of reference scenario in Luxembourg in period 2005-2050

The average yearly GDP growth 2005-2050 and average yearly energy intensity decrease 2005-2050 in the reference scenario for OECD Europe, and the resulting yearly growth in final energy demand, can be found in the table below. We assume that Luxembourg also follows this trend.

	GDP growth rate	Energy intensity	Growth final energy demand
OECD Europe	1.7%	-1.1%	0.6%
Luxembourg	1.7%	-1.1%	0.6%

Figure 2 shows a breakdown of final energy demand in Luxembourg in 1990 and 2005, in relative terms. The figure shows that in 2005, the transport sector was the sector with the highest energy demand, while in 1990 the fuel & heat use in industry was the largest energy consumer.

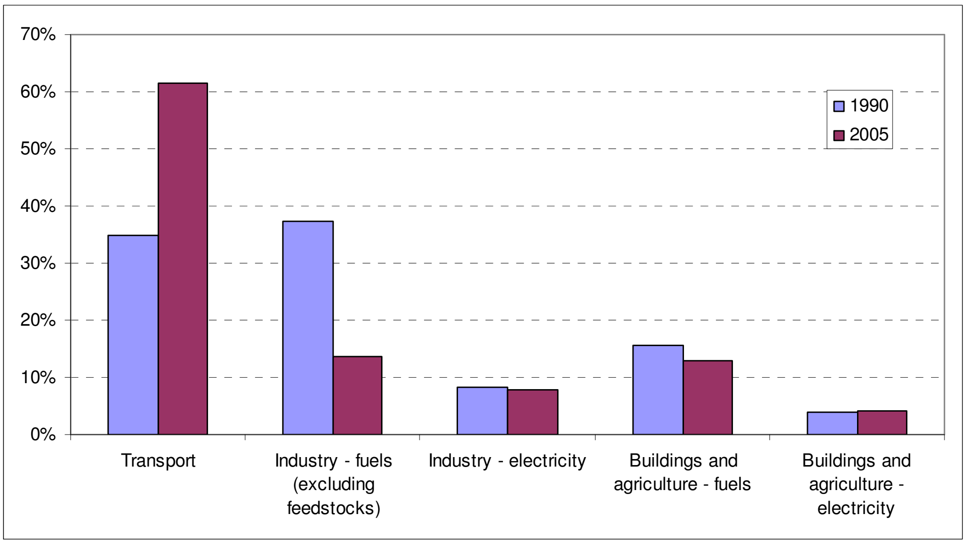

Figure 2 Breakdown of final energy demand per sector in Luxembourg in the years 1990 and 2005 (IEA, 2008)

Figure 3 shows the absolute development of final energy demand per sector from 1990 to 2005. It shows that energy demand in the transport sector increased considerably (due partly to the fact that fuels in Luxembourg are relatively inexpensive), and fuel consumption in industry showed a strong decrease. Total final energy consumption in Luxembourg was 0.4% of OECD Europe in 2005.

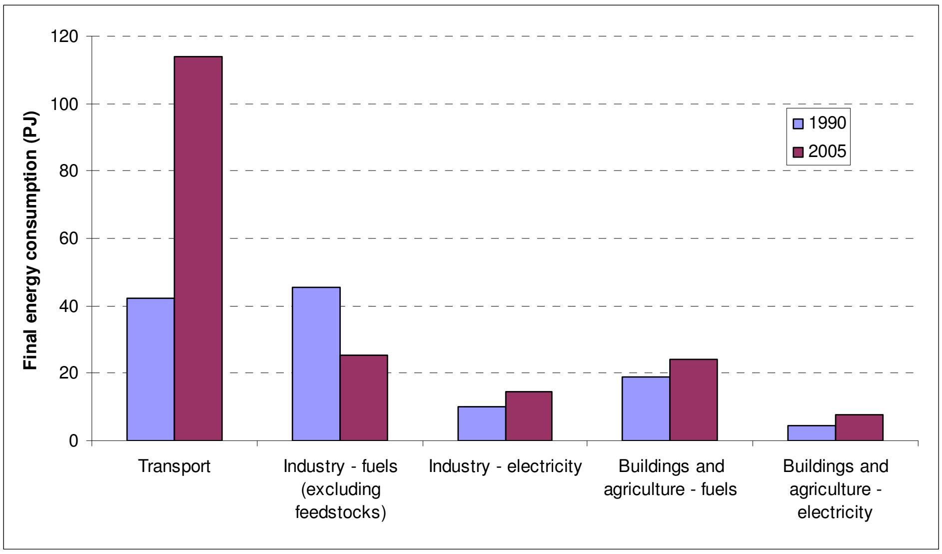

Figure 3 Absolute final energy demand per sector in Luxembourg in the years 1990 and 2005 (IEA, 2008)

3 Alternative scenarios industry

For the industry sector we determine an energy demand reduction potential based on available data for Luxembourg. The methodology for calculating the technical potentials for industry is similar to the methodology used in the 2008 update of the [r]evolution scenario. Details can be found in the report “Global low energy demand scenarios – [r]evolution 2008” (Ecofys, 2008b). Potential estimates are based on general indicators, and cannot by definition be applied at company-level.

The industry sector can be divided into different subsectors. Figure 4 shows a breakdown of final energy demand by subsector in industry in Luxembourg for the base year 2005. The choice of reduction options is based on those subsectors that have the highest energy demand.

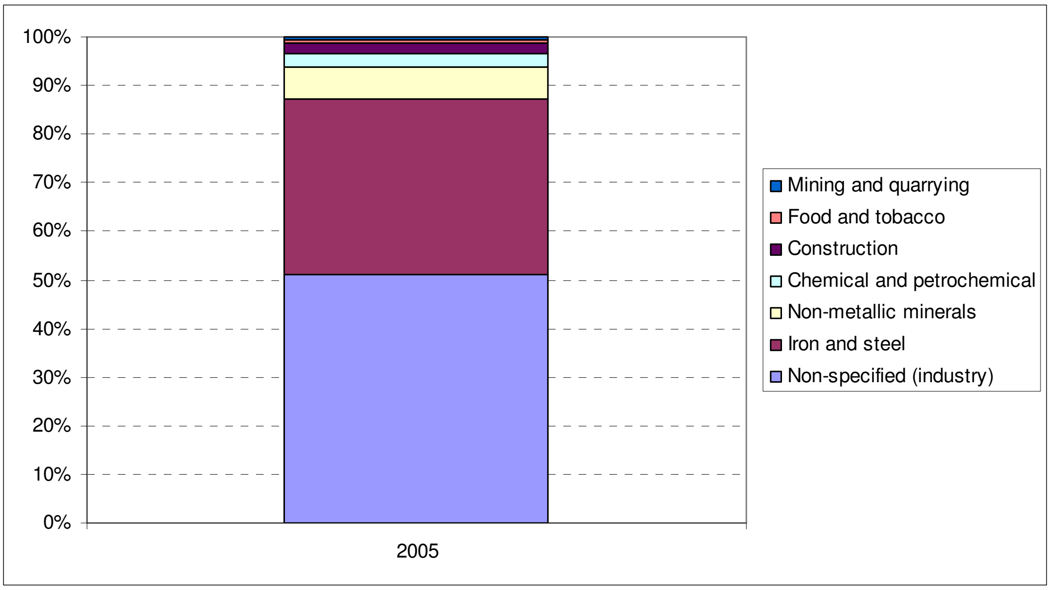

Figure 4 Breakdown of final energy consumption in 2005 by subsector for industry (IEA, 2008)

As can be seen in Figure 4, the industrial subsectors that have the highest final energy demand are ‘Other industries’, ‘Iron and steel’, ‘Non-metallic minerals’, and ‘Chemical and petrochemical’. The energy demand of the following industrial subsectors is equal to zero in Luxembourg and is therefore not shown in Figure 4: ‘Non-ferrous metals’ (aluminium), ‘Transport equipment’, ‘Machinery’, ‘Paper and pulp’, ‘Wood and wood products’, and ‘Textile and Leather’.

We assume that the share of final energy demand per subsector in the base year remains the same in the period 2005-2050.

For the four largest energy consuming sectors in industry we estimate potentials for energy efficiency improvement. Table 1 shows the selection of the measures and the indicators used for determining the energy efficiency or energy intensity potentials.

Table 1 Selection of measures and indicators

Sector	Reduction option	Indicator
Iron and steel	Best practice technologies	GJ/tonne steel
Chemical and petrochemical	Current best practices and innovative technologies	GJ/GDP
Non-metallic minerals	Implementation of best practice technologies, increased recycling and improved material efficiency	GJ/tonne cement
Other industries	Improved material efficiency, recycling, efficient motor systems, heat integration, improved process control and emerging technologies.	GJ/GDP

Below is a summary of the key assumptions per subsector for the technical potentials in the technical and [r]evolution scenarios.

3.1 Iron and steel

In general, iron and steel industry is mainly made up of:

(1) integrated steel mills that produce pig iron from raw materials (iron ore and coke), using a blast furnace and produce steel using a basic oxygen furnace (BOF) or an open hearth furnace (OHF), and

(2) secondary steel mills that produce steel from scrap steel, pig iron, or direct reduced iron (DRI) using an electric arc furnace (EAF).

The figure below shows specific energy consumption for iron and steel production by region (as defined in the Greenpeace Energy [r]evolution scenario) in 2005 (based on final energy demand from IEA (2007a) and steel production data from ISII (2007)) and in the reference scenario in 2050. The specific energy consumption in 2050 is based on an autonomous energy efficiency improvement in the reference scenario of 1% per year, based on historical developments.

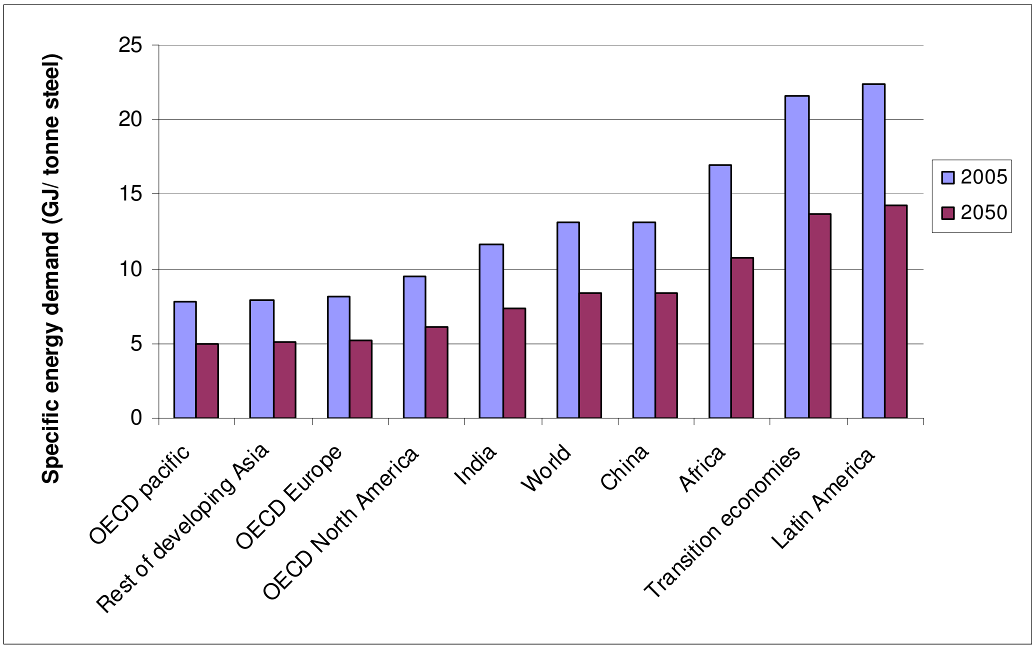

Figure 5 Specific energy consumption (GJ/tonne steel) for iron and steel production in reference scenario

The energy efficiency for iron and steel production is influenced by the technologies used and the amount of scrap input. The most energy intensive part of iron making is the production of pig iron and direct reduced iron (DRI). The higher the share of pig iron and DRI in total steel production (i.e. the lower the share of scrap input used) the higher the specific energy consumption. Luxembourg does not produce DRI and pig iron, but does produce steel.

Figure 6 shows the share of steel production by production route. One can see that Luxembourg has a 100% share of EAF in steel production, and lacks BOF or OHF. All steel is produced using electric arc furnaces. DRI, which is used as input for this process, is not produced in Luxembourg but imported from other countries.

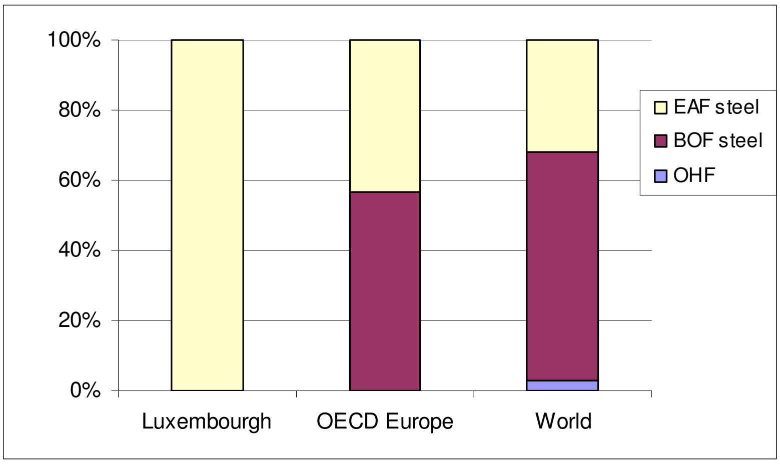

Figure 6 Share of steel production by production route (2005)

After the electric arc furnace process produces thick plates of steel (of approximately 20 cm thick), rolling is needed to reduce the plate thickness. The rolling process consists of two steps: hot rolling and cold rolling. The efficiency of the hot rolling process can be improved using thin slab casting. Table 2 shows the current best practice specific energy consumption for the different elements of steel production in Luxembourg.

Table 2 Best practice final energy consumption for iron and steel production [Kim and Worrell (2002), IISI (1998), IEA (2006) for current best practice, Fruehan et. al (2000) for theoretical and practical minimum]

Product	**Specific final energy consumption (GJ/tonne steel)**			
	Current average (world)	**Current best practice**	**Theoretical minimum (practical minimum)**	**Estimated best practice in 2030**[1]
Steel production in electric arc furnace (EAF) with scrap input	2.2	1.6	1.3 (1.6)	1.6
Hot rolling	2.2	1.7	0.03 (0.9)	0.9
Cold rolling	1.2	0.8	0.02 (0.02)	0.1

The best practice values for steel production in 2030 lead to a specific final energy consumption for iron and steel production of 2.7 GJ/tonne steel product. This is based on the following assumptions:

- 100% of steel is produced from scrap in EAF furnaces
- 117% of crude steel production is hot rolled, same as in 2005 (IISI, 2007)
- 31% of crude steel production is after hot rolling also cold rolled, same as in 2005 (IISI, 2007)

We assume that the value of 2.7 GJ/tonne steel can be achieved as average energy efficiency for iron and steel production in 2050, assuming a typical lifetime for an industrial plant of 30 years and continuous process improvements after 2030.

Table 3 shows the technical potential for energy efficiency improvement in 2050 for Luxembourg, OECD Europe and the average for the world. The energy efficiency improvement in the [r]evolution scenario is based on implementing 80% of the technical potential; this corresponds to an energy intensity of 3.0 GJ final energy per tonne steel product.

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[1] Based on 2% per year energy-efficiency improvement of best practice technologies. An exception is made for EAF, where current best practice is equal to practical minimum. Another exception is made for cold rolling, where best practice is estimated to be lower due to low practical minimum in comparison to current best practice.

Table 3 Potential savings in iron and steel sector

	Specific energy consumption reference scenario		Best practice	[r]evolution	Technical	[r]evolution	Technical
	2005	2050	2050	2050	2050	2050	2050
	GJ/tonne steel product			Energy demand reduction in comparison to reference scenario		Energy-efficiency improvement (%/yr)	
OECD Europe	8.2	5.2	3.5	26%	33%	1.8%	2.1%
Luxembourg	6.5	4.2	2.7	28%	35%	1.8%	2.2%
World	13.2	8.4	3.5	47%	58%	2.6%	3.3%

Source: specific energy consumption is based on IEA Energy Balances 2008 (final energy consumption iron and steel sector) and IISI statistical yearbook 2007 (total steel production).

3.2 Chemical and petrochemical industry

IEA (2006) estimates that the energy efficiency of key chemicals production can be improved by at least 20% by implementing current state-of the art technologies. By implementing innovative technologies the potential is significantly higher. Due to lack of specific data for this industry, the potential for energy-efficiency improvement is directly based on an estimate of decrease in energy intensity (GJ/unit of GDP).

An important energy consuming step in the chemical industry is cryogenic, pressurized product separation. An alternative to this is separation by membranes. A membrane can be described as a selective barrier between two phases. This barrier is not equally permeable for different components. A driving force, e.g. a (partial) pressure difference, is applied over the membrane. The result is a separation of the feed stream into two streams: the stream that flows through the membrane (permeate) and the remaining stream (retentate). Unfortunately, membrane selectivity and permeability are often inversely related. Membranes can be used for both liquid and gas separation.

The use of membranes for product separation reduces compression energy requirements by 50% and separation energy requirements by 80% (Phylipsen et al, 1999). In total this corresponds to 35% of the overall energy consumption of an ethylene plant.

Although membranes are used for a number of products, like the recovery of hydrogen in refineries, it is not yet used for bulk chemicals. We assume that by implementing current state of the art technologies and innovative technologies like the use of membranes, the energy efficiency in the chemical industry can be improved by 45% in 2050. We assume that the energy efficiency improvement in the chemical sector equals 1% per year in the reference scenario. This means that the additional potential in comparison to the reference scenario is estimated to be 0.5% per year. The potential does not take into account increased material efficiency and increased recycling. We assume that both can reduce energy efficiency by an additional 0.5% per year.

3.3 Non-metallic minerals

Non-metallic minerals include cement, lime, glass, soda, ceramics, bricks and other materials. Cement accounts for two-thirds of total energy use in the production of non-metallic minerals worldwide (IEA, 2006). In Luxembourg, there is one cement factory (Ciments Intermoselle) and there are two glass factories (both Guardian Luxguard). In 2005, CO_2 emissions from the cement factory were 77% of non-metallic mineral emissions included in the National Allocation Plan (NAP) (Greenpeace, 2008). Assuming a direct link between CO_2 emissions and energy demand, we will focus only on energy demand reduction in cement production in this section, and assume that the energy efficiency improvement potentials will hold for the whole non-metallic minerals subsector.

Two important processes in producing cement are clinker production and the blending of clinker with additives to produce cement. Clinker is produced by burning a mixture of mainly limestone ($CaCO_3$), silicon oxides, aluminium oxides and iron oxides in a kiln. Production can take place in the wet process, the dry process and some intermediate forms (referring to the conditions of raw materials processing). The dry process is more energy efficient than the wet process. After the melt has cooled down, clinker is blended with gypsum and, depending on the desired product, fly ash, blast furnace slag, or other additives. Product qualities depend on the relative amount of clinker in the cement (ranging from 95% in Portland cement to 30% for blast furnace cement). Clinker production is the most energy intensive step in cement production (about 90% of the energy consumed in the cement making process (Worrell *et al.*, 2008)). The current state of the art kilns consume 3.0 GJ/tonne clinker. It is estimated that the fuel efficiency of kilns can be further reduced to 2.8 GJ/tonne clinker by 2015 (Sinton *et al.,* 2002). The thermodynamic minimum is 1.8 GJ/tonne clinker, but strongly depends on the moisture content. The current typical energy use for cement production is between 3.5 and 5 GJ/tonne clinker (Phylipsen *et al.*, 2003). The current energy use per tonne cement ranges from 1.2 to 5 GJ/tonne cement and depends largely on the share of clinker in cement production (ENCI, 2002). Substantial energy savings can be obtained by reducing the amount of clinker required. One option to reduce clinker use is by substituting clinker by industrial by-products such as coal fly ash, blast furnace slag or pozzolanic materials (e.g. volcanic material). The relative importance of additive use can be expressed by the clinker to cement ratio. The clinker to cement ratio for current cement production ranges from 25-99% (ENCI, 2002). The energy use for cement production can be reduced by implementing best practice technologies and by reducing the clinker content in cement.

Sinton *et al.* (2002) estimate the energy savings potential in cement to be 50% by applying state-of the art processes and use of waste fuels[2]. We assume that the specific energy consumption of cement production can be reduced to 1.7 GJ/tonne cement, based on the use of state of the art kilns consuming 2.8 GJ/tonne clinker, a clinker to cement ratio of 70% and the use of waste fuels for 15% of energy use.

We apply the energy efficiency improvement potential for cement production to the total non-metallic minerals sector.

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[2] Strictly speaking this is not an energy saving measure, but it reduces the use of fossil fuels.

Table 4 shows the potential for energy efficiency improvement in the non-metallic minerals sector, based on the specific energy consumption of cement production. The energy efficiency improvement in the [r]evolution scenario is based on implementing 80% of the technical potential. Due to lack of specific data for Luxembourg we have assumed the average of Belgium and France.

Table 4 Potential savings in non-metallic minerals sector (based on specific energy consumption cement production)

	Specific energy consumption		**Best practice**	**[r]evolution**	**Technical**	**[r]evolution**	**Technical**
	2004	**2050**	**2050**	**2050**	**2050**	**2050**	**2050**
	GJ/tonne cement			**Energy demand reduction in comparison to reference scenario**		**Energy-efficiency improvement (%/yr)**	
Luxembourg	3.7	2.4	1.7	23%	28%	1.6%	1.9%
Belgium	3.9	2.5	1.7	25%	31%	1.7%	2.1%
France	3.5	2.2	1.7	19%	24%	1.5%	1.8%
EU15	2.9	2.0	1.7	12%	15%	1.3%	1.3%

Source: Specific energy consumption for cement production in Belgium, France, EU15 is based on Ecofys (2008a) and data from Enerdata (IEA, 2008). Due to lack of specific data for Luxembourg we have assumed the average of Belgium and France.

3.4 Other industries

For the energy efficiency potential of the remaining industries (51% of industrial energy demand) we base the potential for energy efficiency improvement on an estimate of decrease in energy intensity (GJ/unit of GDP).

By implementing policies aimed at reducing energy demand, an energy efficiency improvement rate of 2% per year is often considered as achievable. Blok (2004) shows that an energy efficiency improvement rate of 5% per year for new equipment, installations and buildings is feasible and has occurred in a number of energy appliances over longer periods. Taking into account the average lifetime of equipment in industries, this corresponds to an overall energy efficiency improvement rate of around 3.5% per year in the period 2010-2050. This rate of energy efficiency improvement requires continuous efforts in the field of innovation.

Since no specific data is available in this study regarding the energy efficiency improvement potential for industry in Luxembourg by 2050 we base the potential on the [r]evolution scenario for OECD Europe (Ecofys, 2008b). In the Technical scenario the potential for energy efficiency improvement in industries corresponds to 2.2% per year for fuel use and 2.3% per year for electricity use in OECD Europe. In the [r]evolution scenario these numbers are 1.9% per year for fuel use and 2.0% per year for electricity use. We assume the same improvement potentials hold for Luxembourg.

The energy efficiency of the other industries can be improved by using state of the art processes, improved material efficiency in product design and material and product recycling. Examples of cross-cutting measures for energy efficiency improvement are:

- High efficiency motor systems
- Process optimisation and integration
- Improved monitoring and process control

These three are discussed in more detail as examples below.

Electric motor systems

Electric motors systems in the industry make up a large share of the electricity use in industry. Approximately 65% of the electricity use by industry is used to drive electric motor systems. Ways of reducing electricity consumption in electric motor systems are:

1. Variable Speed Drives (VSDs). VSDs can lead to savings of electricity consumption of 15% to 35% of the electricity consumption of electric motor systems (EC, 1999). VSDs can be applied in approximately 40% to 60% of the cases.

2. High Efficiency Motors (HEMs). HEMs reduce energy losses through improved design, better materials, tighter tolerances, and improved manufacturing techniques. The specific energy savings depend on the efficiency of the current motor. For large motors the savings are likely to be small (1-2%) and for smaller motors larger (up to 75%) (Keulenaer *et al.*, 2004). On average HEMs lead to an electricity savings of 3% to 5% (UU, 2001).

3. Implementing efficient pumps, compressors and fans.

a. A case study has shown that 25% of the electricity consumption of a compressor can be saved by measures as process control, heat recovery and improvement of air treatment. Compressors account for about 15% of the electricity consumption of industrial motor systems. (Keulenaer *et al.*, 2004)

b. A case study has shown that 30% of the electricity consumption of a pump system can be saved by adapting the design. The payback time is twelve weeks. Pumps account for about 35% of electricity consumption of industrial motor systems. The technical electricity savings potential for conventional pumping systems is 55%. This includes low friction pipes, with an efficiency of 90% in comparison to 69% for conventional pipes. (Keulenaer *et al.*, 2004)

c. The payback time of efficient fans is estimated to be 0.4 years (Keulenaer *et al.*, 2004). Fans account for about 15% of electricity consumption of industrial motor systems. (Keulenaer *et al.*, 2004)

Together these measures lead to a technical electricity savings potential of 40%. According to a study for EU-15, the economic savings potential is 29% of the electricity consumption for industrial motor systems (Keulenaer *et al.*, 2004). The economic savings potential includes measures with payback times up to three years.

Process Optimization and Integration (pinch analysis)

Process integration or pinch technology refers to the exploitation of potential synergies that are inherent in any system that consists of multiple components working together. In plants that have multiple heating and cooling demands, the use of process integration techniques may significantly improve efficiencies.

The methodology involves the linking of hot and cold streams in a process in a thermodynamic optimal way (i.e. not over the so-called ‘pinch’). Process integration is the art of ensuring that the components are well suited and matched in terms of size, function and capability.

The energy savings potential using pinch analysis far exceeds that from well-known conventional techniques such as heat recovery from boiler flue gas, insulation and steam trap management. There is usually a large potential for improvement in overall site efficiency through inter-unit integration via utilities, typically 10 to 20% at a two-year payback. (Kumana, 2000) A number of refineries have applied total site pinch analysis. Typical savings identified in these site-wide analyses are around 20-30%, although the economic potential was found to be limited to 10-15% (Linnhoff March, 2000).

Improved monitoring and process control

The use of energy monitoring and process control systems can play an important role in energy management and in reducing energy use. Typically, energy and cost savings are around 5% or more for many industrial applications of process control systems (Worrell and Galitsky, 2005). Although, energy management systems are already widely disseminated in various industrial sectors, the performance of the systems can often still be improved. In many cases, only one process or a limited number of energy streams were monitored and managed. Various suppliers provide site-utility control systems (HCP, 2001). Payback times range generally from 6 to 18 months (Worrell and Galitsky, 2005).

A variety of process control systems are available for virtually any industrial process. Below is an overview of process control systems.

System	Characteristics	Typical energy savings (%)
Monitoring and Targeting	Dedicated systems for various industries, well established in various countries and sectors	Typical savings 4-17%, average 8%
Computer Integrated Manufacturing (CIM)	Improvement of overall economics of process, e.g. stocks, productivity and energy	> 2%

Sources: Martin et al. (2000) and Worrell and Galitsky (2005)

3.5 Summary potentials and assumptions

Table 5 gives the key assumptions for the technical potentials in Luxembourg and the energy savings in 2050 in comparison to the reference scenario. As an example, 35% savings in Technical scenario in iron and steel, translates directly to a 35% reduction in energy demand in 2050 in the iron and steel sector.

Table 5 Summary of key assumptions for technical potential in Luxembourg

	Specific energy demand per tonne			**Key assumption final energy use**		**Energy demand reduction in comparison to reference**	
	Reference scenario		Technical potential	Technical scenario	[r]evolution scenario	Technical	[r]evolution
	2005	**2050**	**2050**	**2050**	**2050**	**2050**	**2050**
Iron and steel	6.5	4.2	2.7	in GJ/tonne steel product	80% of technical potential	35%	28%
Chemical industry	n.a.	n.a.	n.a.	1.5% per year potential for energy-efficiency improvement and 0.5% per year for increased material efficiency and recycling.		33%	26%
Non-metallic minerals	3.7	2.4	1.7	in GJ/tonne cement		28%	23%
Other industries	n.a.	n.a.	n.a.	2.3% for fuel use and 2.4% for electricity per year energy-efficiency improvement		42%	32%
Average industries	n.a.	n.a.	n.a.	n.a.		38%	30%

The total potential in the alternative scenarios in industry is based on the share of the energy demand per subsector in total energy demand in industries. This is shown in Table 6. For example: the share of 43% for power consumption in the iron and steel sector in Luxembourg, means that total power consumption by the iron and steel sector accounts for 43% of total power consumption in industries in Luxembourg in 2005. We assume that these shares remain constant until 2050.

Table 6 Share of subsector in total energy demand in industry in Luxembourg in 2005

2005	**Share in power, heat or total consumption in industry**		
	Power	Fuel	Total
Iron and steel	43%	32%	36%
Chemical industry	0%	4%	3%
Non-metallic minerals	0%	10%	7%
Other industries	57%	53%	54%
Total industries	**100%**	**100%**	**100%**

Source: IEA Energy Balances (2008)

The share of industry power consumption in total industry energy consumption is 36% in 2005 in Luxembourg and the share of fuels and heat in total energy consumption is 64%. We assume that this remains constant up to 2050.

Table 7 shows the savings per subsector as share in total power or fuel consumption in industry in Luxembourg. For example: 15% for iron and steel means that by improving energy efficiency in the iron and steel sector, 15% of total power consumption in industries in Luxembourg in 2050 can be reduced. The row ‘energy demand reduction in comparison to reference’ specifies the yearly decrease of final energy use compared to the reference scenario (for instance: 39% decrease in the technical scenario between 2010 and 2050 means 1.2% decrease per year). Assuming that the reference scenario includes 1% autonomous energy efficiency improvement per year, the total energy efficiency improvement is given in the row ‘total industries (energy efficiency improvement %/year 2010-2050)’.

Table 7 Savings per subsector per scenario

	Technical			[r]evolution		
	Power	**Fuels**	**Total**	**Power**	**Fuels**	**Total**
Iron and steel	15%	11%	13%	12%	9%	10%
Chemical industry	0%	1%	1%	0%	1%	1%
Non-metallic minerals	0%	3%	2%	0%	2%	1%
Other industries	24%	22%	23%	18%	17%	17%
Total industries	**39%**	**38%**	**38%**	**30%**	**29%**	**30%**
Energy demand reduction in comparison to reference	**1.2%**	**1.2%**	**1.2%**	**0.9%**	**0.9%**	**0.9%**
Total industries (energy-efficiency improvement %/year 2010-2050)	2.2%	2.2%	2.2%	1.9%	1.9%	1.9%

3.6 Scenario results Industry

The figure below gives the energy demand reduction per measure in the [r]evolution and the Technical scenario in 2050 in Luxembourg for the industry sector.

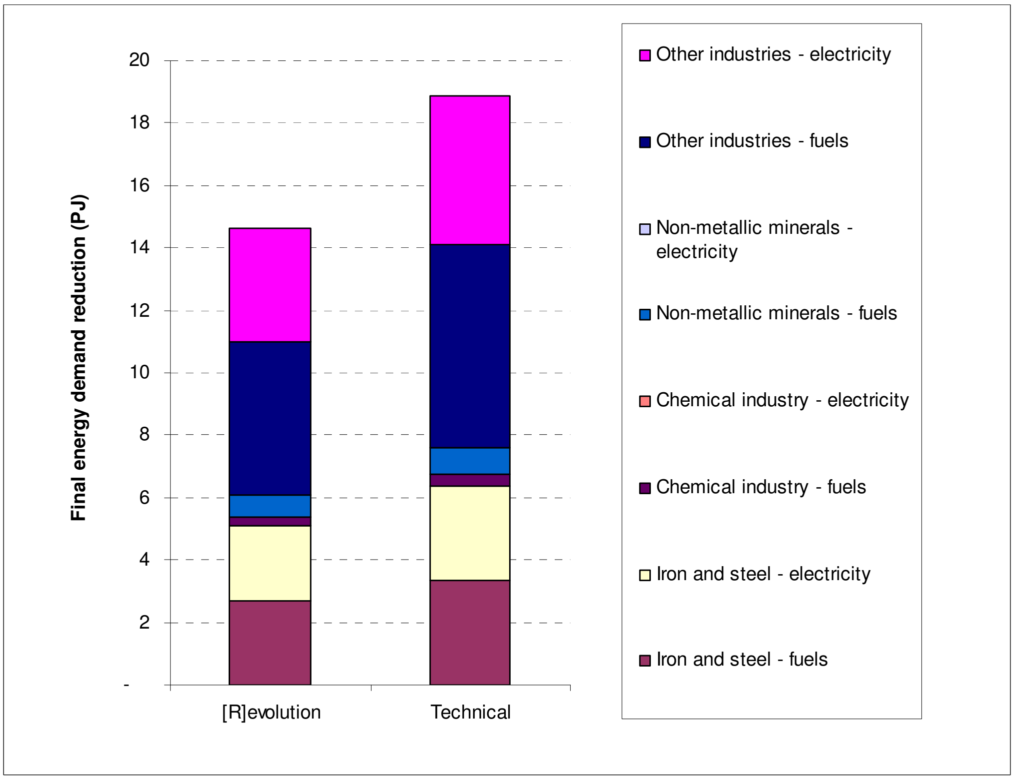

Figure 7 Luxembourg industry reduction potential in [r]evolution and Technical scenario

4 Alternative scenarios other sectors

4.1 Alternative scenarios other sectors

In other sectors except industry (services, households, agriculture, transport), potentials for energy demand reduction are obtained from the Greenpeace Energy [r]evolution study. We will assume that the percentage potentials for OECD Europe will also hold for Luxembourg. A detailed account of assumptions and possibilities to decrease energy demand in these sectors can be found in the report “Global low energy demand scenarios – [r]evolution 2008” by Ecofys (2008b).

Examples to reduce energy demand in these other sectors can be found in Table 1.

Table 1 Measures to reduce energy demand in sectors other than industry (Ecofys, 2008b)

Measure	Reduction option
Reduction of transport demand	Reduction of volume of passenger transport in comparison to reference scenario
	Reduction of volume of freight transport in comparison to reference scenario
Modal shift	Modal shift from trucks to rail
	Modal shift from cars to public transport
Energy efficiency improvement	Efficient passenger cars (hybrid fuel cars)
	Efficient buses
	Efficiency improvement airplanes
	Efficient freight vehicles
	Efficiency improvement ships
Buildings	Reduce heating demand by insulation and building design
	Efficient electric appliances (set top boxes, cold appliances, computers, servers), lighting, air conditioning, and reduction of standby power
Agriculture and non-specified others	Energy efficiency improvement

4.2 Total scenarios results

Figure 8 shows reduction potentials in the Technical and [r]evolution scenarios in terms of final energy demand. Reduction potentials are shown per measure (including the more detailed industry potentials we determined in this study). The figure shows that there is a large potential for energy demand reduction in the transport sector. As shown in Figure 2 and Figure 3, energy demand for the transport sector is high in Luxembourg; this is mainly due to the large share of fuels being exported to other countries (fuels in Luxembourg are relatively inexpensive). Here we assume that energy reduction measures for the transport sector (for instance efficiency improvement of vehicles) also applies to the foreign vehicles that purchase fuels in Luxembourg.

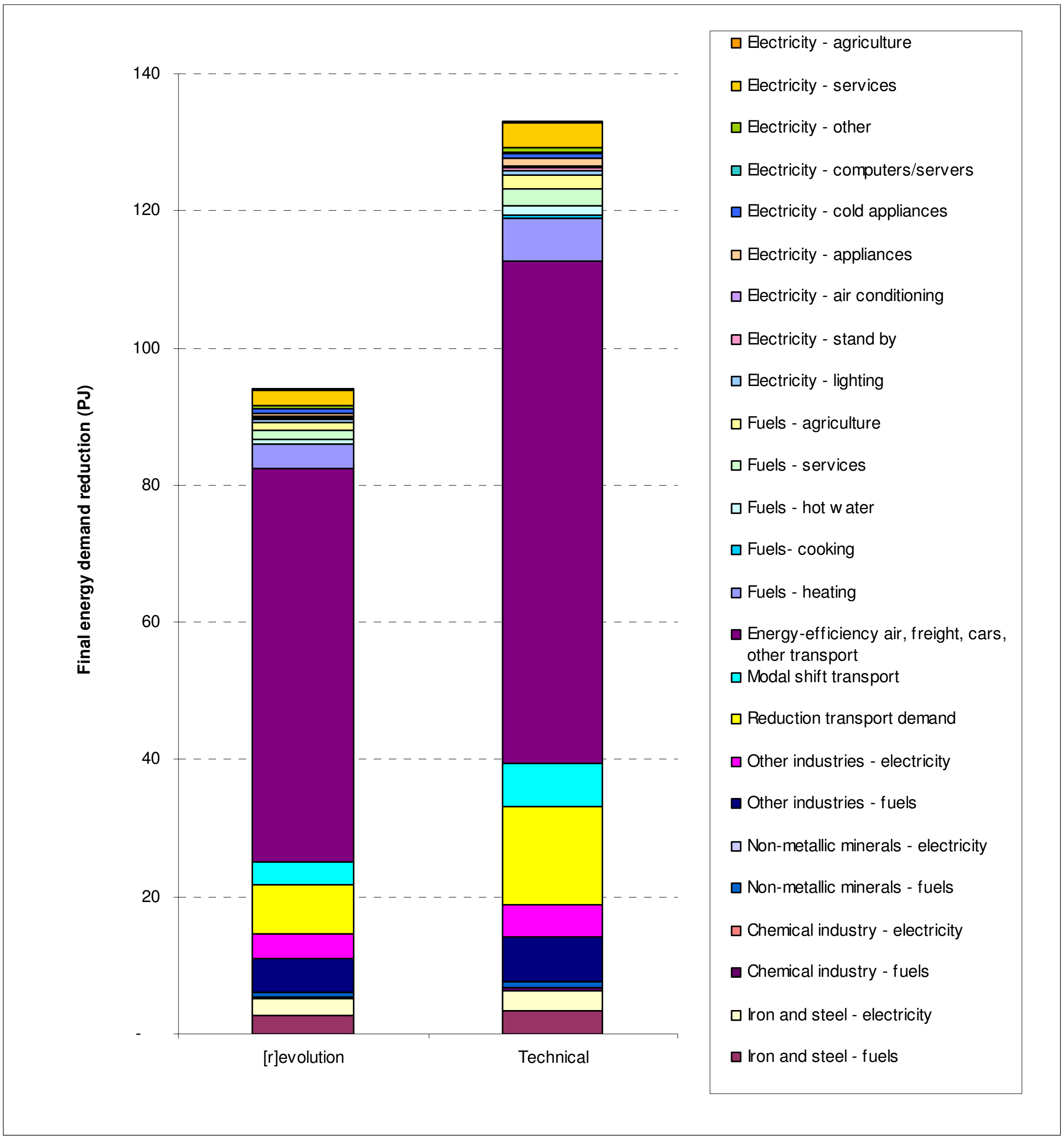

Figure 8 Luxembourg reduction potential in [r]evolution and Technical scenario

Table 2 shows the relative savings compared to the Luxembourg reference scenario. Savings are compared to the 2050 reference energy demand in the respective sector (transport, industry-fuels, industry-electricity, other-fuels, other-electricity). The fact that a large share of transport fuels is exported, distorts the modal shares. It would be wrong to assume that modal shares in Luxembourg are the same as in OECD Europe. For this reason, energy efficiency improvement of all transport modes is taken as one measure.

Table 2 Energy savings potentials compared to the Luxembourg reference scenario in the Technical and [r]evolution scenarios, based on Ecofys (2008b)

	Technical	[r]evolution
Reduction transport demand	10%	5%
Modal shift transport	4%	2%
Energy-efficiency air, freight, cars, other transport	52%	40%
Fuels - heating	22%	12%
Fuels- cooking	1%	1%
Fuels - hot water	4%	2%
Fuels - services	8%	4%
Fuels - agriculture	7%	4%
Electricity - lighting	4%	3%
Electricity - stand by	3%	2%
Electricity - air conditioning	2%	1%
Electricity - appliances	9%	4%
Electricity - cold appliances	5%	3%
Electricity - computers/servers	1%	0%
Electricity - other	6%	4%
Electricity - services	26%	16%
Electricity - agriculture	2%	1%
Iron and steel - fuels	11%	9%
Iron and steel - electricity	15%	12%
Chemical industry - fuels	1%	1%
Chemical industry - electricity	0%	0%
Non-metallic minerals - fuels	3%	2%
Non-metallic minerals - electricity	0%	0%
Other industries - fuels	22%	17%
Other industries - electricity	24%	18%

Numbers in this table are based on OECD potentials and are applied directly to Luxembourg.

When all measures are applied to Luxembourg, Figure 9 gives the final energy demand in the reference scenario, the [r]evolution scenario and the Technical scenario (including the industry potentials determined in more detail in this report).

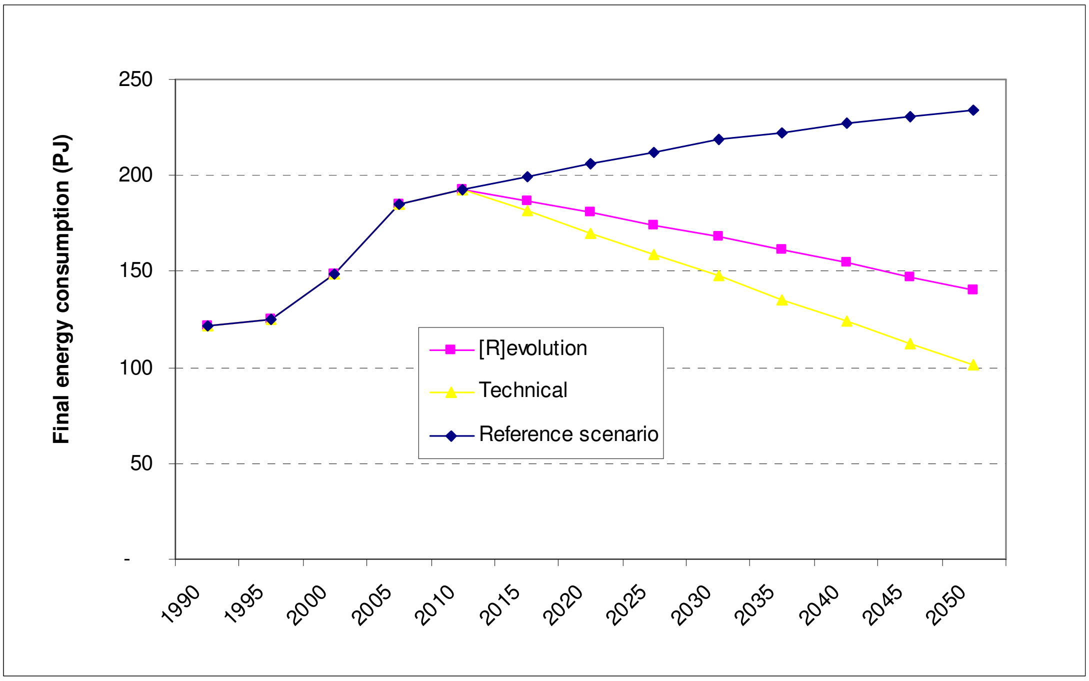

Figure 9 Luxembourg final energy consumption in reference, [r]evolution and Technical scenario

4.3 Underlying data scenarios

Luxembourg

Based on interpolation of scenario OECD Europe, except industry, based on potential estimates for Luxembourg

[R]evolution

Final energy consumption (PJ)	**1990**	**2005**	**2010**	**2015**	**2020**	**2030**	**2040**	**2050**
Transport	42	114	118	113	107	96	85	74
Industry - fuels	46	25	26	26	25	24	22	21
Industry - electricity	10	14	15	15	15	15	15	14
Other - fuels	19	24	25	24	24	24	23	23
Other - electricity	5	7	8	8	9	9	9	9
Total final energy consumption (PJ)	122	185	192	187	181	168	154	140
Savings	0%	0%	0%	6%	12%	23%	32%	40%

Technical

Final energy consumption (PJ)	**1990**	**2005**	**2010**	**2015**	**2020**	**2030**	**2040**	**2050**
Transport	42	114	118	109	101	83	66	48
Industry - fuels	46	25	26	26	24	22	20	18
Industry - electricity	10	14	15	15	15	14	13	12
Other - fuels	19	24	25	23	22	21	19	17
Other - electricity	5	7	8	8	8	7	7	6
Total final energy consumption (PJ)	122	185	192	181	170	148	124	101
Savings	0%	0%	0%	9%	17%	32%	45%	57%

Reference scenario

Final energy consumption (PJ)	**1990**	**2005**	**2010**	**2015**	**2020**	**2030**	**2040**	**2050**
Transport	42	114	118	122	126	133	138	142
Industry - fuels	46	25	26	27	28	28	29	29
Industry - electricity	10	14	15	16	17	18	19	20
Other - fuels	19	24	25	25	26	27	28	29
Other - electricity	5	7	8	9	10	11	12	14
Reference scenario	122	185	192	199	206	218	227	234
[R]evolution	122	185	192	187	181	168	154	140
Technical	122	185	192	181	170	148	124	101

5 Phase-out of transport fuel export scenarios

5.1 Phase-out reference scenario

Due to the fact that the high demand for transport fuels in Luxembourg is mainly caused by fuel exports (as mentioned in chapter 4, fuels are relatively inexpensive compared to surrounding countries), we here present an extra scenario, assuming a total phase-out of fuel exports.

In 2005, different transportation modes consumed in total 98,521 TJ of fuels. The breakdown of energy use in that year was as follows (UNFCCC, 2008):

a. Civil Aviation	0.01%
b. Road Transportation	99.61%
c. Railways	0.30%
d. Navigation	0.08%

According to data from the Luxembourg Ministry of Environment (personal communication, Martina Holbach, Greenpeace Luxembourg), CO_2 emissions from transport fuel export in 2005 were 73.8% of total transport CO_2 emissions.

Assuming that

- In the reference scenario, 73.8% of transport energy use in 2050 will be exported (same as 2005);
- energy use and CO_2 emissions have a linear relationship (so we assume that 73.8% of CO_2 emissions corresponds to 73.8% of energy use);
- emission factors do not change through time (2005 – 2050);

we construct an alternative reference scenario (“phase-out reference scenario”). In this scenario, fuel exports are phased out in 2050, with linear implementation starting in 2010.

In Figure 10 both the reference scenario and the ‘phase-out’ reference scenario are shown. The figure shows that phasing out of transport fuel export can decrease energy use in Luxembourg significantly.

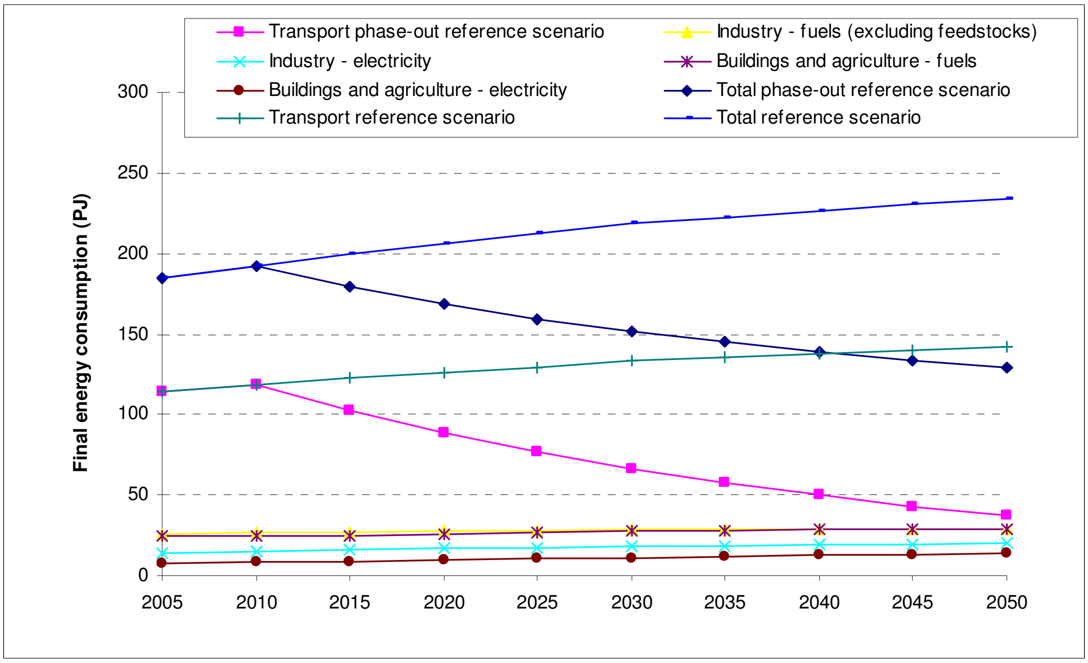

Figure 10 Graph showing both the reference scenario and the 'phase-out' reference scenario. These scenarios only differ for the transport sector, and thus also the total.

5.2 Alternative scenarios based on phase-out reference scenario

Based on this 'phase-out reference scenario', we construct alternative scenarios as in chapter 4. The methodology is exactly the same, but since we now use a different reference scenario, namely the phase-out reference scenario, the absolute reduction potentials will be different (the reduction potentials in percentages will not be changed, so they will be as in Table 2). Absolute reduction potentials are only changing for the transport sector and the total.

Changing the reference scenario means that the relative potentials in Table 2 will apply to domestic fuel use only.

To avoid confusion, the two alternative scenarios will be referred to as 'Technical2' and '[r]evolution2'. Results are presented in Figure 11 and Figure 12.

Since in this case energy use of modal shares is not distorted by the high share of exported fuels, we can assume modal shares for Luxembourg are the same as in OECD Europe in the Greenpeace Energy [r]evolution study. This increases the level of detail in the transport measures; they are summarized in Table 1.

Table 1 Transport measures for the Technical2 and [r]evolution2 scenarios, based on Ecofys (2008b)

	Technical2	**[r]evolution2**
Reduction transport demand	10%	5%
Modal shift transport	4%	2%
Energy-efficiency other transport	3%	2%
Energy-efficiency air	8%	5%
Energy-efficiency freight	11%	8%
Energy-efficiency cars	30%	25%

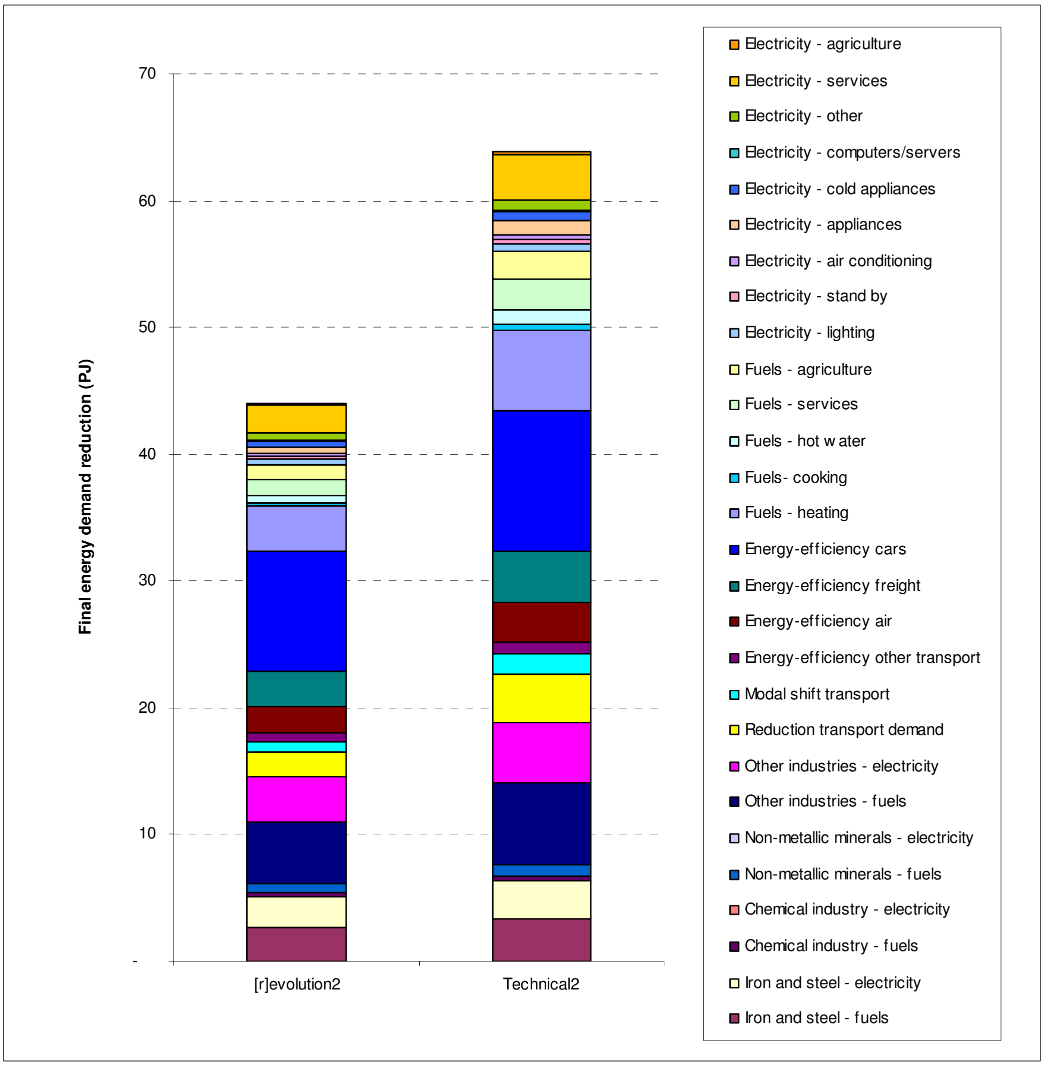

Figure 11 Luxembourg reduction potential in [r]evolution2 and Technical2 scenario, based on the phase-out reference scenario

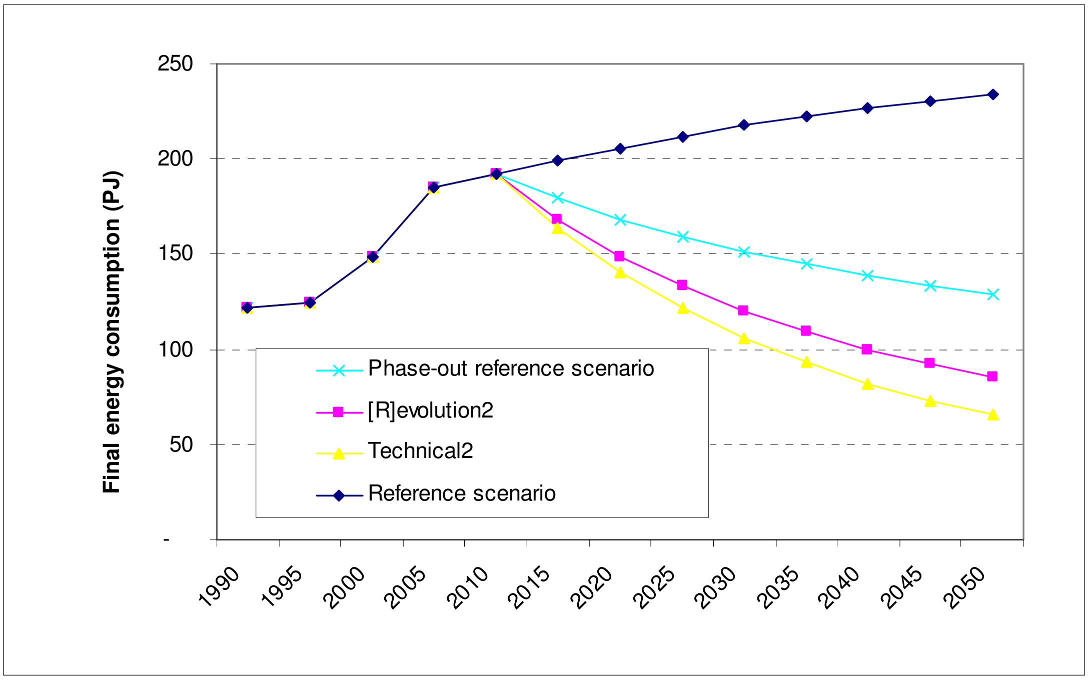

Figure 12 Luxembourg final energy consumption in reference, phase-out reference, [r]evolution2 and Technical2 scenario

5.3 Underlying data scenarios

Luxembourg

Based on interpolation of scenario OECD Europe, except industry, based on potential estimates for Luxembourg

[R]evolution2

Final energy consumption (PJ)	**1990**	**2005**	**2010**	**2015**	**2020**	**2030**	**2040**	**2050**
Transport	42	114	118	94	75	48	31	19
Industry - fuels	46	25	26	26	25	24	22	21
Industry - electricity	10	14	15	15	15	15	15	14
Other - fuels	19	24	25	24	24	24	23	23
Other - electricity	5	7	8	8	9	9	9	9
Total final energy consumption (PJ)	122	185	192	168	149	120	100	85
Savings	0%	0%	0%	16%	28%	45%	56%	64%

Technical2

Final energy consumption (PJ)	**1990**	**2005**	**2010**	**2015**	**2020**	**2030**	**2040**	**2050**
Transport	42	114	118	91	71	41	24	13
Industry - fuels	46	25	26	26	24	22	20	18
Industry - electricity	10	14	15	15	15	14	13	12
Other - fuels	19	24	25	23	22	21	19	17
Other - electricity	5	7	8	8	8	7	7	6
Total final energy consumption (PJ)	122	185	192	163	140	106	82	66
Savings	0%	0%	0%	18%	32%	52%	64%	72%

Final energy consumption (PJ)	**1990**	**2005**	**2010**	**2015**	**2020**	**2030**	**2040**	**2050**
Transport	42	114	118	122	126	133	138	142
Industry - fuels	46	25	26	27	28	28	29	29
Industry - electricity	10	14	15	16	17	18	19	20
Other - fuels	19	24	25	25	26	27	28	29
Other - electricity	5	7	8	9	10	11	12	14
Reference scenario	122	185	192	199	206	218	227	234
Phase-out reference scenario	122	185	192	179	168	151	139	129
[R]evolution2	122	185	192	168	149	120	100	85
Technical2	122	185	192	163	140	106	82	66

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