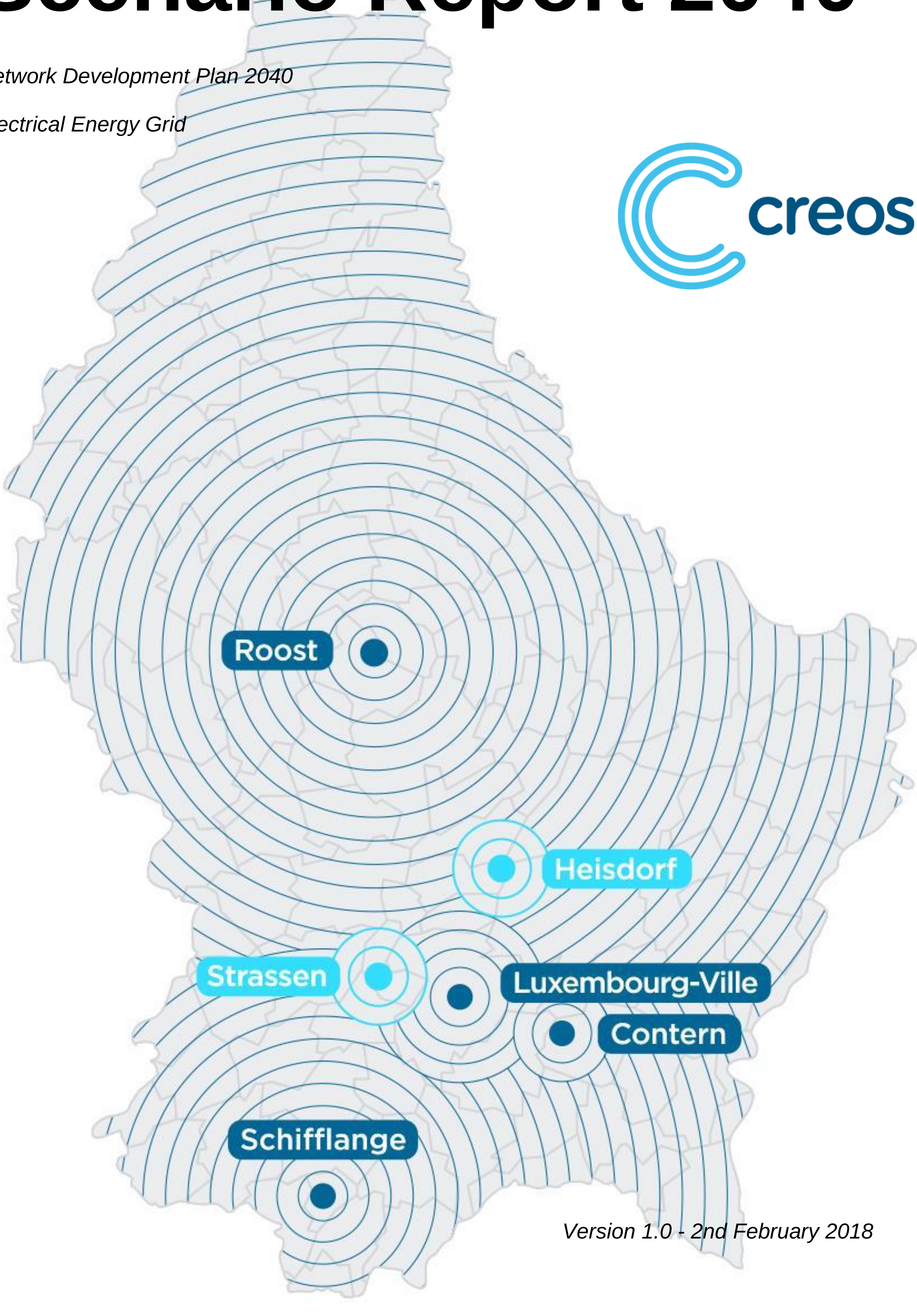
# Scenario Report 2040

*Network Development Plan 2040*

*Electrical Energy Grid*

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**Asset Management**
**Grid Planning and Calculation**
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## Foreword

The aim of all transmission and distribution system operator is to operate, maintain and develop an efficient electricity distribution system, in order to secure the customer's availability of power.

The planning of a sustainable, future-proof electrical infrastructure becomes more and more challenging due to the uncertainties of future economic, social and environmental developments.

In addition to higher electrical energy consumptions, the electrical grids of tomorrow will strongly be influenced by the desired decarbonisation process in the European Union. In order to stay in line with the EU-targets of a reduction of greenhouse gas emissions, an expansion of the use of renewable energies, and an improvement of the energy efficiency, the electrical grids must be adapted consequently. The transition to a post-carbon society will bring huge changes in the economic/industry, mobility/transport and domestic sectors, and will have a direct influence on the electrical energy needs.

The transformation of Luxembourg's economy and society has already begun. The heavy industry is on the decline, making way for a smaller, specialized, energy-efficient industry and a shift occurs towards services like logistics, e-commerce and electronic data storage and management. Heating and mobility will experience strong shifts towards electrification. Construction regulations for energy efficient buildings are in place and have to be applied, and the sales of electric vehicles or plug-in hybrid vehicles are rising.



The current trend is that the increase of the electricity consumption will happen more faster than the shift towards a much higher percentage of electricity generation from renewable energy sources, thus intensifying the need for a strong electrical transport and distribution grid.

The growing digitalization in our society will impact the energy grids of tomorrow. The evolution of the electrical energy grids, which have to fulfil consumption needs and decentralized generation demands, will strongly be influenced by the political and regulatory framework and the according incentive programs.

Considering the most recent developments together with the appearance of new projects, and in order to prepare for coming needs, we prepared new forecasts for the future electrical peak power demand of Luxembourg.

This report provides our outlook on a possible future peak power demand on the electrical high voltage grid of Creos Luxembourg as seen today.

## Political framework and considerations

In addition to the economic development, European and national environmental objectives may be significant for the projection of the electricity needs.

In accordance with the resolutions of the climate conference in Paris in 2015 and in agreement with the EU energy targets for 2030 (European Council on 23th and 24$^{th}$ of October 2014), the following goals are provided:

- commitment to continue reducing greenhouse gas emissions, setting a reduction target of 40% by 2030 relative to 1990 levels
- a renewable energy target of at least 27% of energy consumption
- an improved energy efficiency of at least 27%

The European Council noted the fundamental importance of a fully functioning and connected internal energy market, and therefore supports all measures in order to ensure the achievement of a minimum target of 10% of existing electricity interconnections, no later than 2020, with the objective of arriving at a 15% target by 2030.

According to the EU 2011 White paper ‘Roadmap to a Single European Transport Area’, the transport sector has to contribute to the EU climate engagements by reaching a target of 60% emission reduction until 2050. To reach this target, the following goals have been set:

- 50% less ‘conventionally-fuelled’ cars in urban transport by 2030
- achieve essentially CO2-free city logistics in major urban centres by 2030
- complete phase out of ‘conventionally-fuelled’ cars in cities by 2050
- shift of 30% of the road freight to rail or waterborne transport by 2030
- shift of 50% of the road freight to rail or waterborne transport by 2050



The future form of the individual inland and cross-border mobility and of the public transport will therefore influence the electrical energy needs of this sector decisively.

Recently, a strategy study, under the supervision of Jeremy Rifkin, has been elaborated by cross-disciplinary working groups with the goal to achieve the transition of the current society model of the Grand-Duchy of Luxembourg to a more sustainable, smart society, with an optimized resource and energy efficiency, and with a switch to renewable energies and e-mobility.

Renovations in the building sector could possibly imply more electricity needs. Fossil fuel sources used for heating could be replaced by heat pumps and / or direct water heating. Low energy houses or passive buildings could decrease or negate that effect. Positive energy buildings could generate their needs locally with solar systems and inject the surplus of electricity in the low-voltage grid at the disposal of others. Consumers could become more and more ‘producer – consumers’, prosumers. **The Rifkin study foresees a possible future share between 50 and 70 percent of domestic electricity self-generation from renewable energy sources in Luxembourg by the year 2050.**

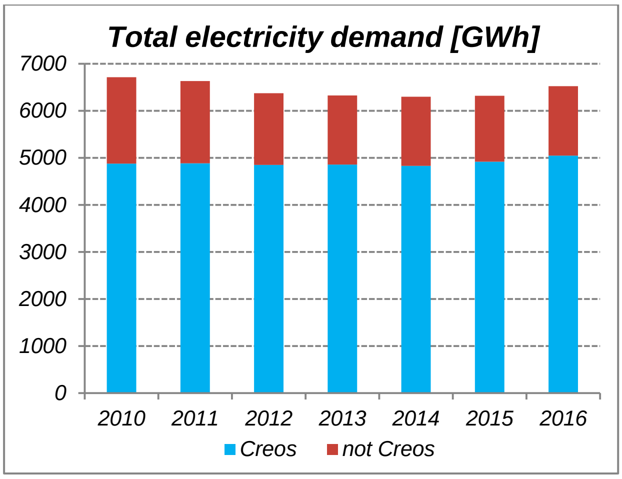
# Retrospective

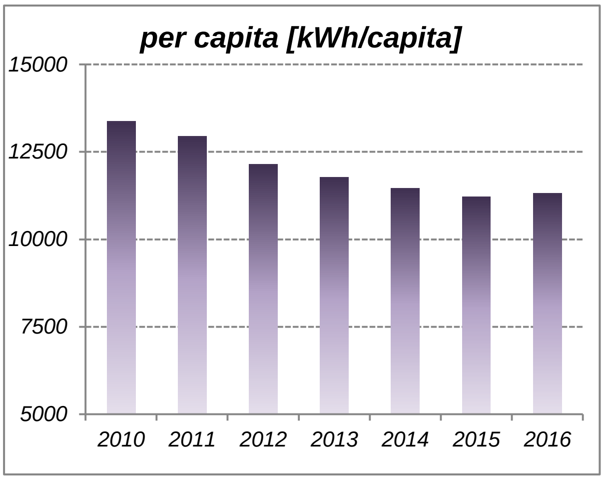
## Retrospective of the electricity demand and sectorial breakdown

The total electricity consumption and the per capita demand of the Grand-Duchy of Luxembourg have decreased from 2010 to 2015, with only a slight increase during last year. Referring to this, the most recent available data from Statec has been considered:

| *Electricity tot. Lux.* | *2010* | *2011* | *2012* | *2013* | *2014* | *2015* | *2016* |
|---|---|---|---|---|---|---|---|
| *GWh (losses incl.)* | *6714* | *6633* | *6375* | *6328* | *6302* | *6319* | *6522* |
| *Per capita (kWh/cap)* | *13373* | *12946* | *12145* | *11783* | *11464* | *11224* | *11319* |

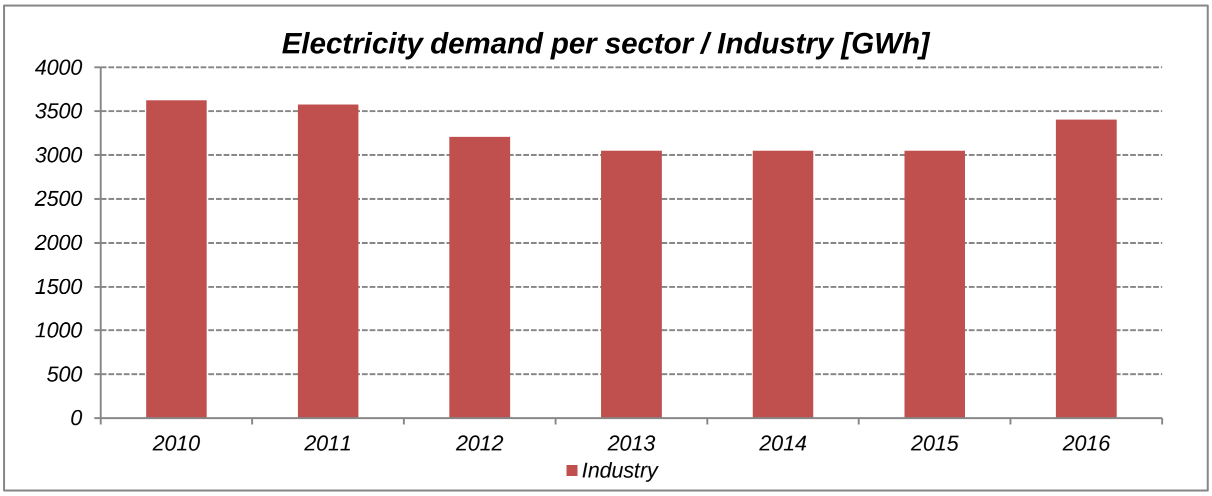
*Source: Statec & ILR*



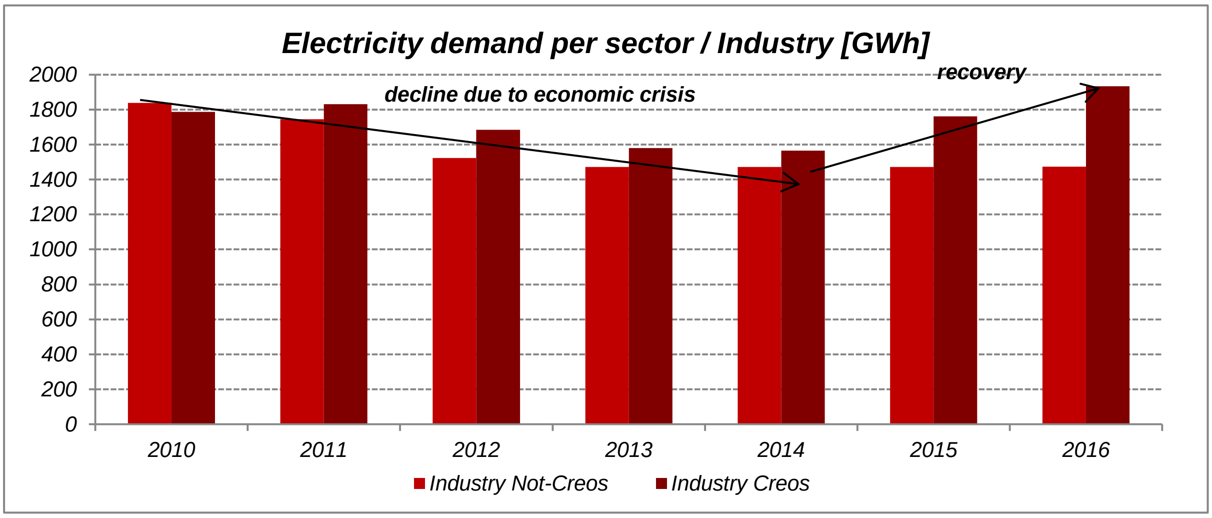

*Source: Statec & Creos Luxembourg*

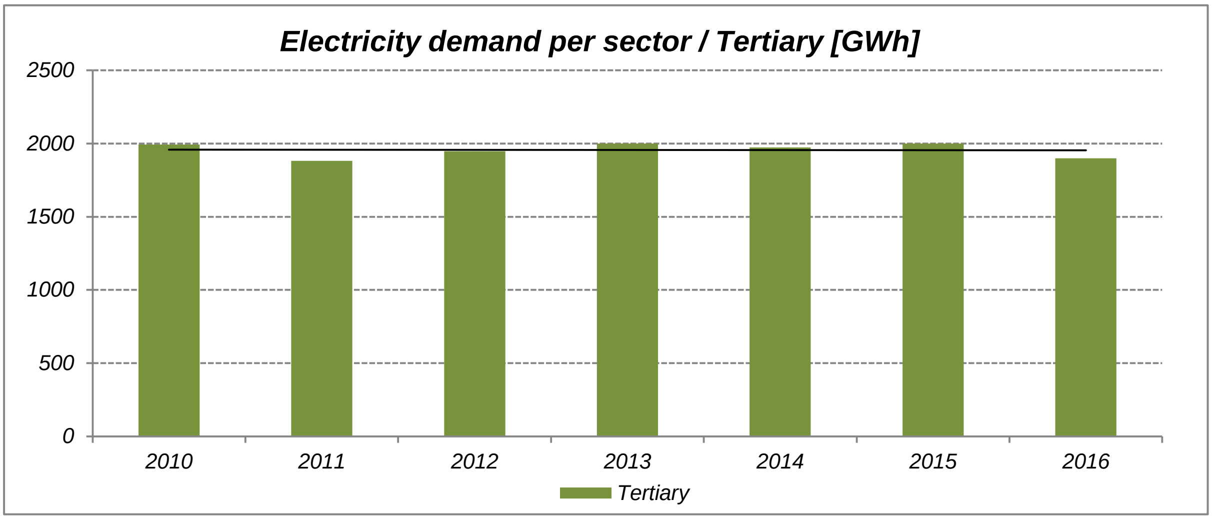
This reduced consumption in 2010 to 2015 was the result of energy saving measures throughout the industry, a decline of this sector and a weaker economic activity, though there has been a slight recovery in 2016. An overall increasing energy efficiency can be discerned in the decreasing consumption figures per capita.

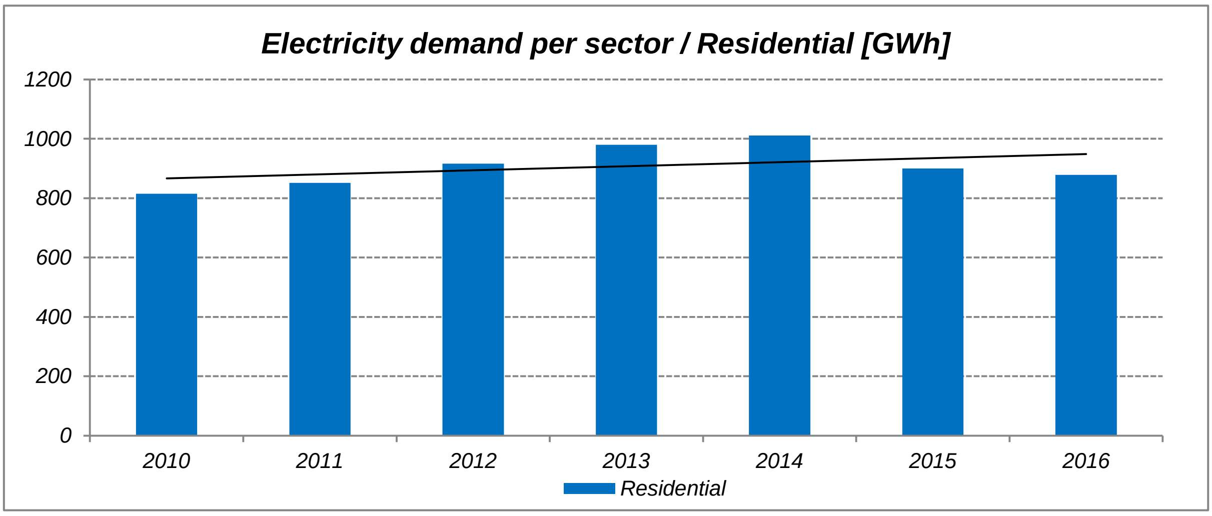



*Source: Statec & ILR*

The decrease of the electricity demand of the metal industry, which is not connected to the Creos grid, was more pronounced as that of the lighter, mixed industry connected to the Creos grid. The demand of the tertiary sector was quite stable and that of the households mostly rose during the past few years.

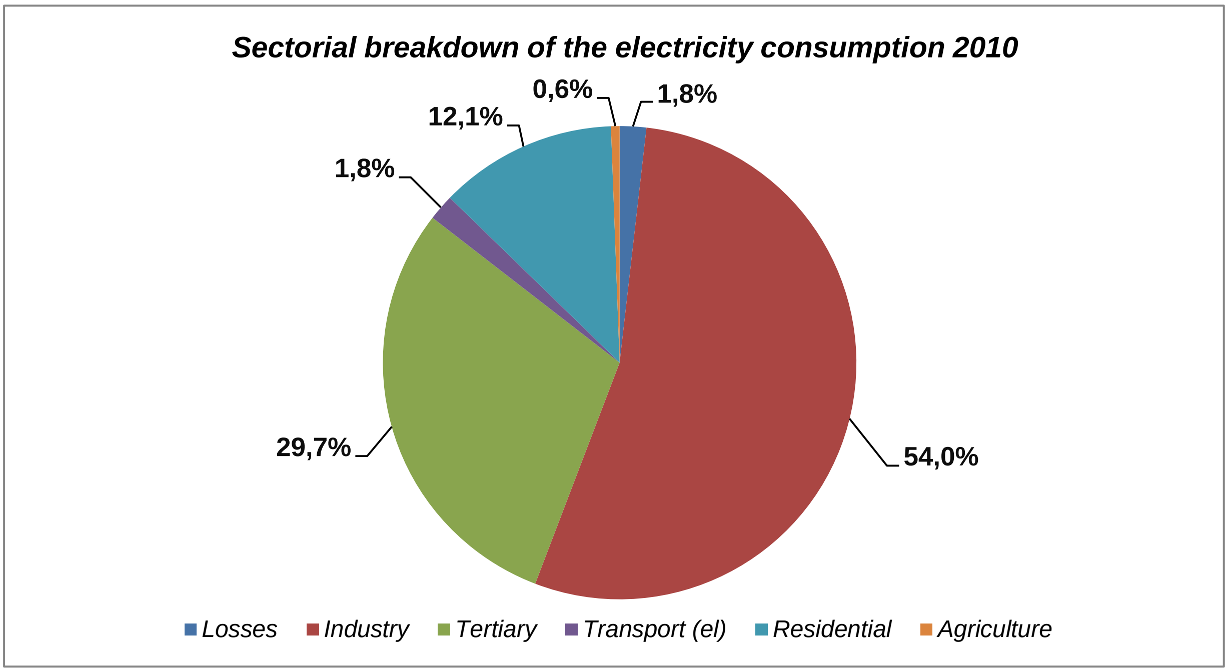


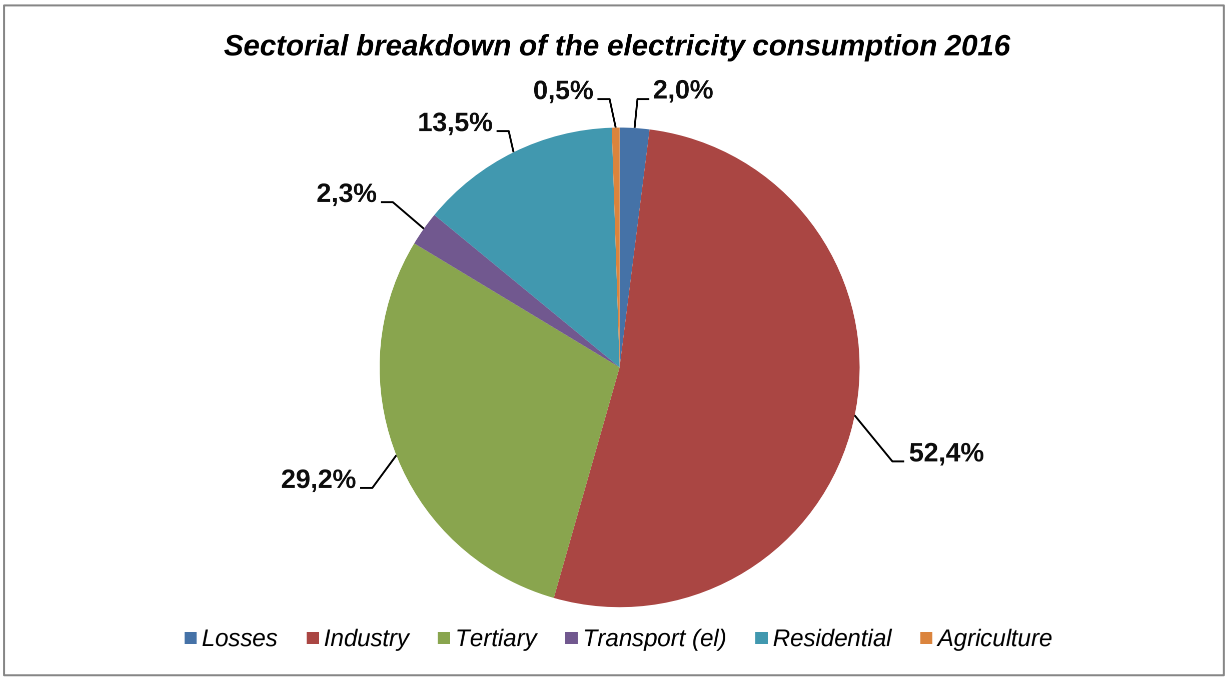




*Source: Statec &* ILR

* not included: el. transport, agriculture & losses



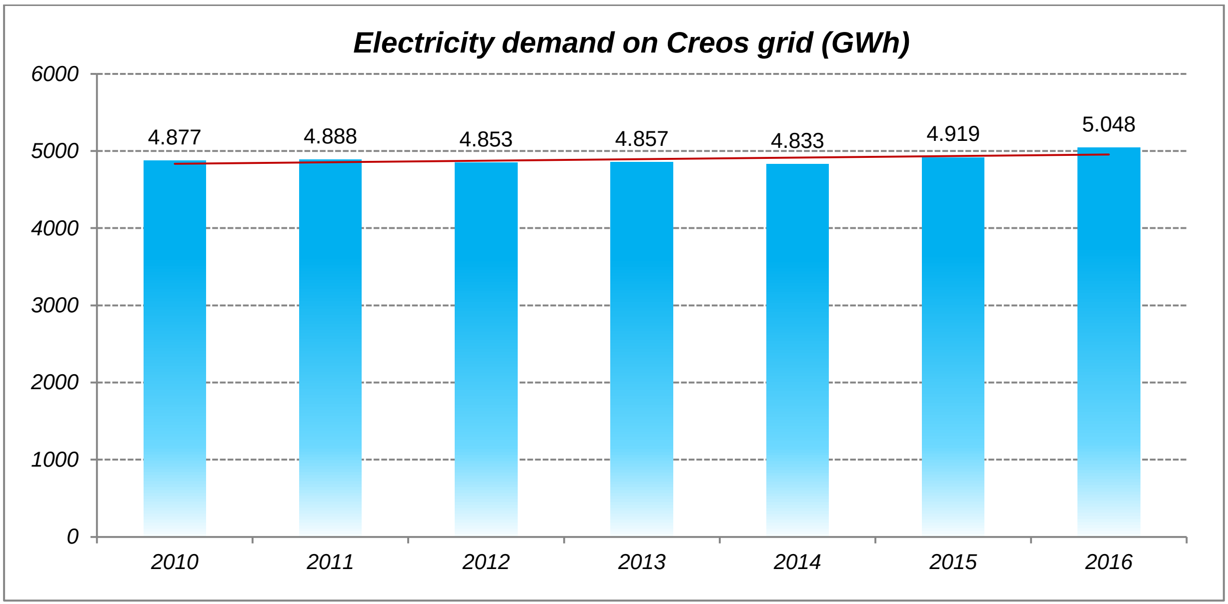




*Source: Statec &* ILR

The general trend towards a higher growth of the residential sector can easily be identified when you look at the relative numbers in the sectoral breakdown. The tertiary sector will surely grow too, but more moderately. The industry share is decreasing accordingly, but stays the biggest component of the total electricity need of Luxembourg.

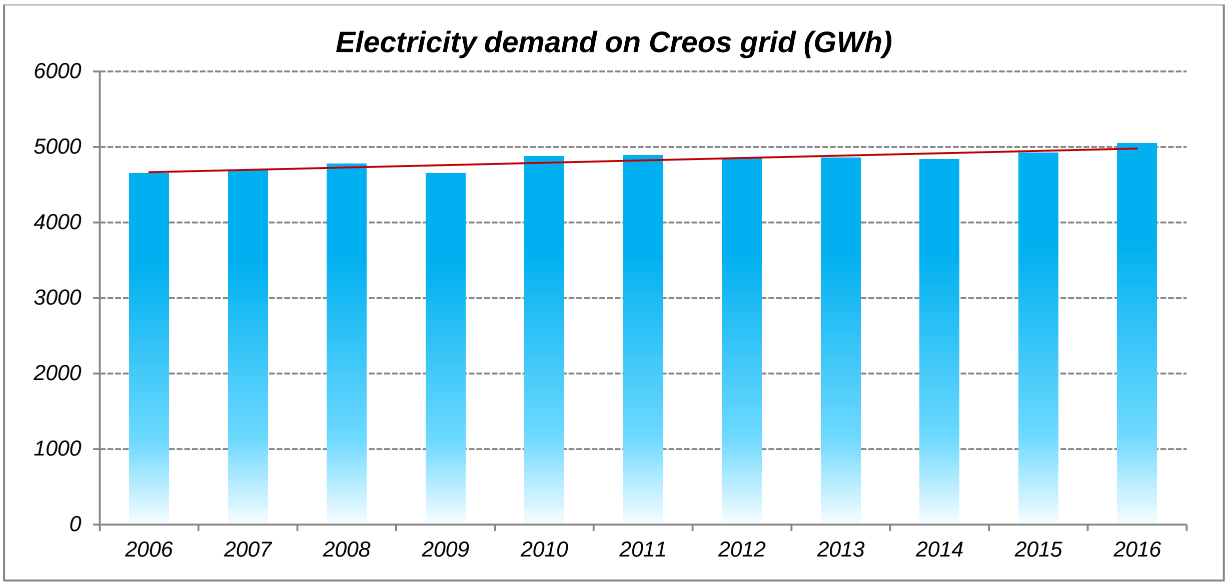
In total, during the last few years, thlight decrease of the demand of the industry sector connected to the Creos grid has been compensated by the growth of the demand by the residential and the tertiary sector.

Looking at the years 2010-2015, you could conclude that the total demand of electricity is stagnating or only slightly increasing.




*Source: Creos Luxembourg*

However, by enlarging the period of review, the steady growth of the total electricity demand becomes more apparent.

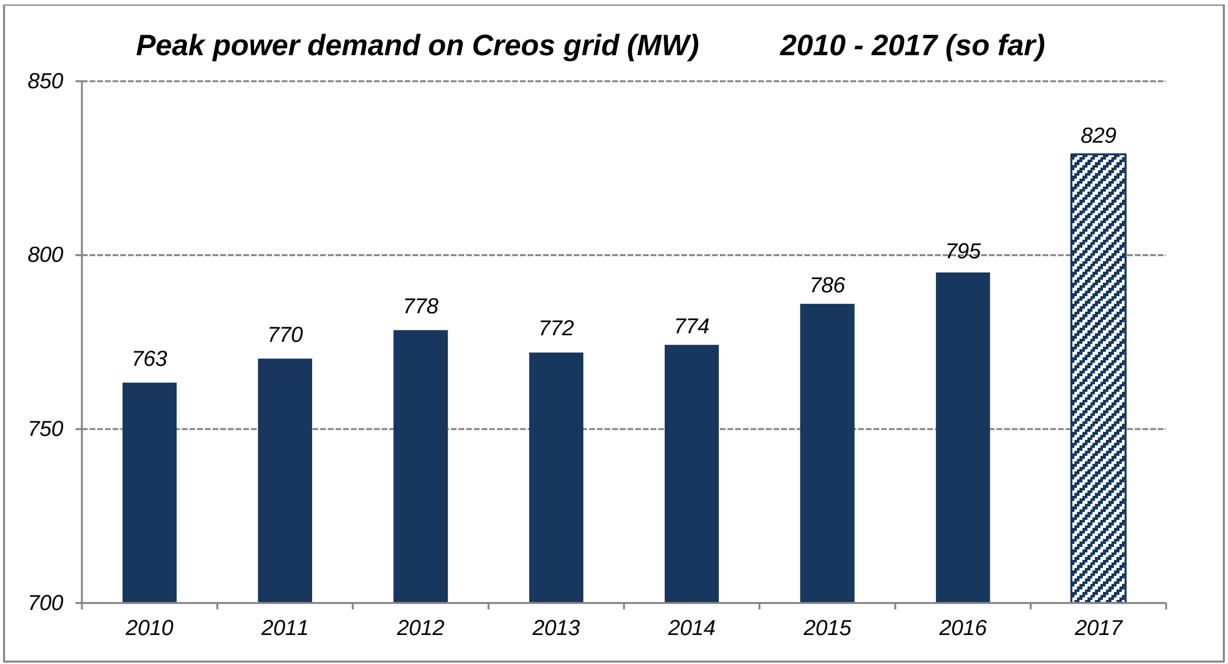



*Source: Creos Luxembourg*

This shows that, long-term projections can have temporary opposite trends, which could be misleading. Only a long-term review of a projection can really confirm the assumptions made.

## Retrospective of the peak power demand

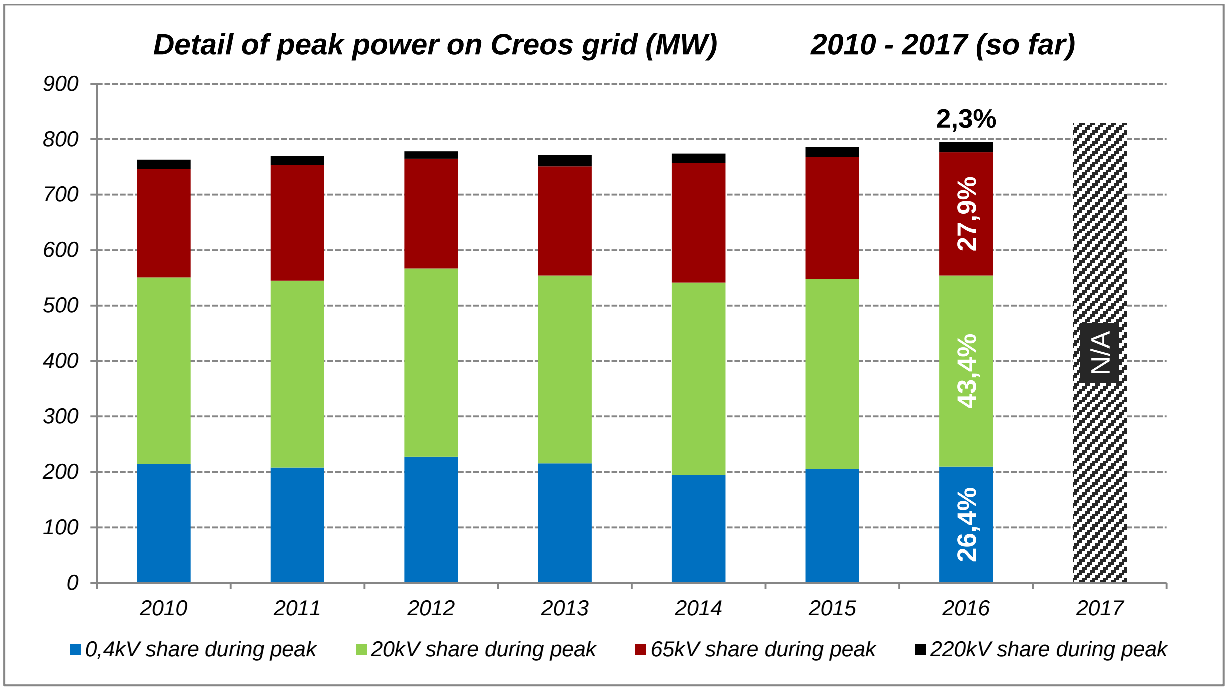
The most important value for the grid development is the peak power demand. It has risen constantly during the last four years and has made a disquieting leap in 2017, which was mostly caused by a temporary switch of a part of the Sotel load on the Creos grid:






*Source: Creos Luxembourg*

The detailed decomposition of the peak power can be interesting for further grid analysis, as shown here:

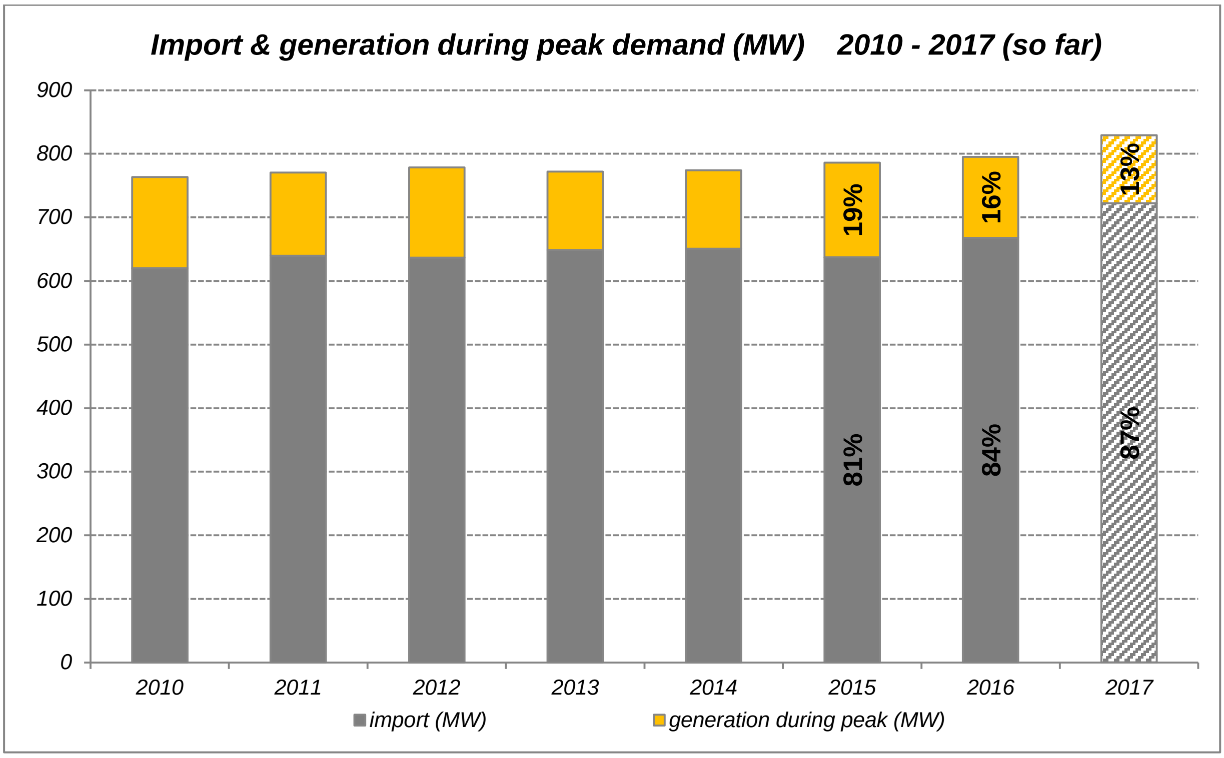



*Source: Creos Luxembourg*

At the moment of greatest power demand, 2.3 percent of the power was needed for 220kV customers, 27.9 percent for 65kV customers, 43.4 percent for 20kV customers and 26.4 percent for the remaining low-voltage distribution.

Approximately, the 65kV grid stands for the supply of the industries, the 20kV grid for bigger office buildings, commerce and service companies and the low-voltage distribution for the supply of the households and smaller businesses.

During the highest power demand in 2016, 84 percent of it had to be imported and 16 percent were generated on national territory. During the peak demand in the beginning of 2017, only 13 percent were generated inland and 87 percent had to be imported.




As can be seen, the generation during the peak power demand is diminishing.

Further details will be covered in the chapter ‘Electrical energy generation and renewables energies’.

## Approach for the future electricity demand and the related peak power projections

In the context of the Rifkin Study, the additional needs for total energy and for electricity have been estimated for Luxembourg for the year 2050 by the Fraunhofer Institute (Energy demand scenarios 2050 for Luxembourg).

In a simplified model, it can be assumed that the energy demand will increase proportionally to the growth rate of the population, but will also decrease proportionally to efficiency improvements.

It can be reasonably assumed that fossil fuels will mostly be replaced to cover the future final energy demand. A shift towards the use of more electricity will surely take place. For instance, the future electrical transportation means will be more energy efficient as 'conventionally-fuelled' vehicles, but the greater needs for electricity must be provided. For new houses, energy efficient heat pumps, which are more energy efficient than conventional heating solutions using fossil fuels, will certainly be used for heating needs.

The Fraunhofer Institute has made two different scenarios for the time period 2015 – 2050:

1) STATEC-Scenario with a final energy decrease of -44% per inhabitant
2) Ambitious energy efficiency scenario with -63% of final energy demand per inhabitant



With a projected population growth of 86% until 2050 (about 1,026 million inhabitants), the following figures have been estimated:

| | Unit | 2015 | 2050 | Growth |
|---|---|---|---|---|
| Population | inh. | 551.885 | 1.026.876 | 86% |

*Absolute values - Scenario STATEC*

| | | | | |
|---|---|---|---|---|
| **Final energy demand** | **GWh** | **25.419** | **25.545** | **0%** |
| - Electricity demand | GWh | 5.895 | 6.924 | 17% |
| - Heating demand | GWh | 13.322 | 13.015 | -2% |
| - Mobility demand | GWh | 6.202 | 5.606 | -10% |

*Values per inhabitant - Scenario STATEC*

| | | | | |
|---|---|---|---|---|
| **Final energy demand** | **kWh/inh** | **44.448** | **24.876** | **-44%** |
| - Electricity demand | kWh/inh | 10.308 | 6.743 | -35% |
| - Heating demand | kWh/inh | 23.295 | 12.674 | -46% |
| - Mobility demand | kWh/inh | 10.845 | 5.459 | -50% |

*Values per inhabitant - Scenario ambitious energy efficiency*

| | | | | |
|---|---|---|---|---|
| **Final energy demand** | **kWh/inh** | **44.448** | **16.534** | **-63%** |
| - Electricity demand | kWh/inh | 10.308 | 5.669 | -45% |
| - Heating demand | kWh/inh | 23.295 | 8.153 | -65% |
| - Mobility demand | kWh/inh | 10.845 | 2.711 | -75% |

*Absolute values - Scenario ambitious energy efficiency*

| | | | | |
|---|---|---|---|---|
| **Final energy demand** | **GWh** | **25.419** | **16.978** | **-33%** |
| - Electricity demand | GWh | 5.895 | 5.822 | -1% |
| - Heating demand | GWh | 13.322 | 8.372 | -37% |
| - Mobility demand | GWh | 6.202 | 2.784 | -55% |

Mobility: Road without transit, fuel tourism, plus rail

Especially the following absolute and relative values have been calculated:

## Absolute values

**Final energy demand 2015**

| in GWh | Electricity* | Heating | Transport | Total | Share |
|---|---|---|---|---|---|
| Residential | 753 | 5.723 | | 6.476 | 25% |
| Services and Agriculture | 2.091 | 2.953 | | 5.044 | 20% |
| Industry | 3.051 | 4.646 | | 7.697 | 30% |
| Transport** | | | 6.202 | 6.202 | 24% |
| **Final energy demand** | **5.895** | **13.322** | **6.202** | **25.419** | **100%** |
| Share | 23% | 52% | 24% | 100% | |

**Final energy demand 2050 according STATEC**

| in GWh | Electricity* | Heating | Transport | Total | Share |
|---|---|---|---|---|---|
| Residential | 1.202 | 6.671 | | 7.873 | 31% |
| Services and Agriculture | 2.929 | 1.906 | | 4.835 | 19% |
| Industry | 2.793 | 4.438 | | 7.231 | 28% |
| Transport** | | | 5.606 | 5.606 | 22% |
| **Final energy demand** | **6.924** | **13.015** | **5.606** | **25.545** | **100%** |
| Share | 27% | 51% | 22% | 100% | |

**Growth rate 2015 to 2050**

| in GWh | Electricity* | Heating | Transport | Total | |
|---|---|---|---|---|---|
| Residential | 60% | 17% | | 22% | |
| Services and Agriculture | 40% | -35% | | -4% | |
| Industry | -8% | -4% | | -6% | |
| Transport** | | | -10% | -10% | |
| **Final energy demand** | 17% | -2% | -10% | 0% | |

* without heating
** Road without transit, fuel tourism, plus rail, electricity for rail included in transport

*Source: Energy Demand Scenarios 2050 for Luxembourg, Fraunhofer ISE*

### Values per inhabitant

**Final energy demand 2015 per inhabitant** (571.885 inh)

| in kWh | Electricity* | Heating | Transport | Total | Share |
|---|---|---|---|---|---|
| Residential | 1.317 | 10.007 | | 11.324 | 25% |
| Services and Agriculture | 3.656 | 5.164 | | 8.820 | 20% |
| Industry | 5.335 | 8.124 | | 13.459 | 30% |
| Transport** | | | 10.845 | 10.845 | 24% |
| **Final energy demand** | **10.308** | **23.295** | **10.845** | **44.448** | **100%** |
| Share | 23% | 52% | 24% | 100% | |
| *Germany* | *6.240* | *15.800* | *8.900* | *30.940* | *70%* |

**Final energy demand 2050 according STATEC per inh.** (1.026.876 inh.)

| in kWh | Electricity* | Heating | Transport | Total | Share |
|---|---|---|---|---|---|
| Residential | 1.171 | 6.496 | | 7.667 | 31% |
| Services and Agriculture | 2.852 | 1.856 | | 4.708 | 19% |
| Industry | 2.720 | 4.322 | | 7.042 | 28% |
| Transport** | | | 5.459 | 5.459 | 22% |
| **Final energy demand** | **6.743** | **12.674** | **5.459** | **24.876** | **100%** |
| Share | 27% | 51% | 22% | 100% | |



**Growth rate 2015 to 2050 per inhabitant** (inh. Growth rate: 79.6%)

| in GWh | Electricity* | Heating | Transport | Total | |
|---|---|---|---|---|---|
| Residential | -11% | -35% | | -32% | |
| Services and Agriculture | -22% | -64% | | -47% | |
| Industry | -49% | -47% | | -48% | |
| Transport** | | | -50% | -50% | |
| **Final energy demand** | -35% | -46% | -50% | -44% | |
| | | | | | |

*Source: Energy Demand Scenarios 2050 for Luxembourg, Fraunhofer ISE*

There is a slight difference between the values of the electric energy demand as found in the Fraunhofer study and the historical values given by the Statec. We trust that the numbers given by Statec are more accurate as the absolute values of the Fraunhofer study. Nonetheless, this has no influence on the key statements and the relative values of this study.

Comparing the trends of the specific sectors, the suppositions of the Fraunhofer ISE, concerning the relative growth of the electrical energy demand of the sectors, can be confirmed by the historical values.

## Forecast of the future electricity need and peak power demand (p.1)

## Ordinary load

In accordance with the estimation of the Fraunhofer ISE 'Energy demand scenarios 2050 for Luxembourg', the electric energy need is supposed to rise up to 17% till the year 2050 (till the year 2040, about 12%). That can be viewed as the **ordinary load.**

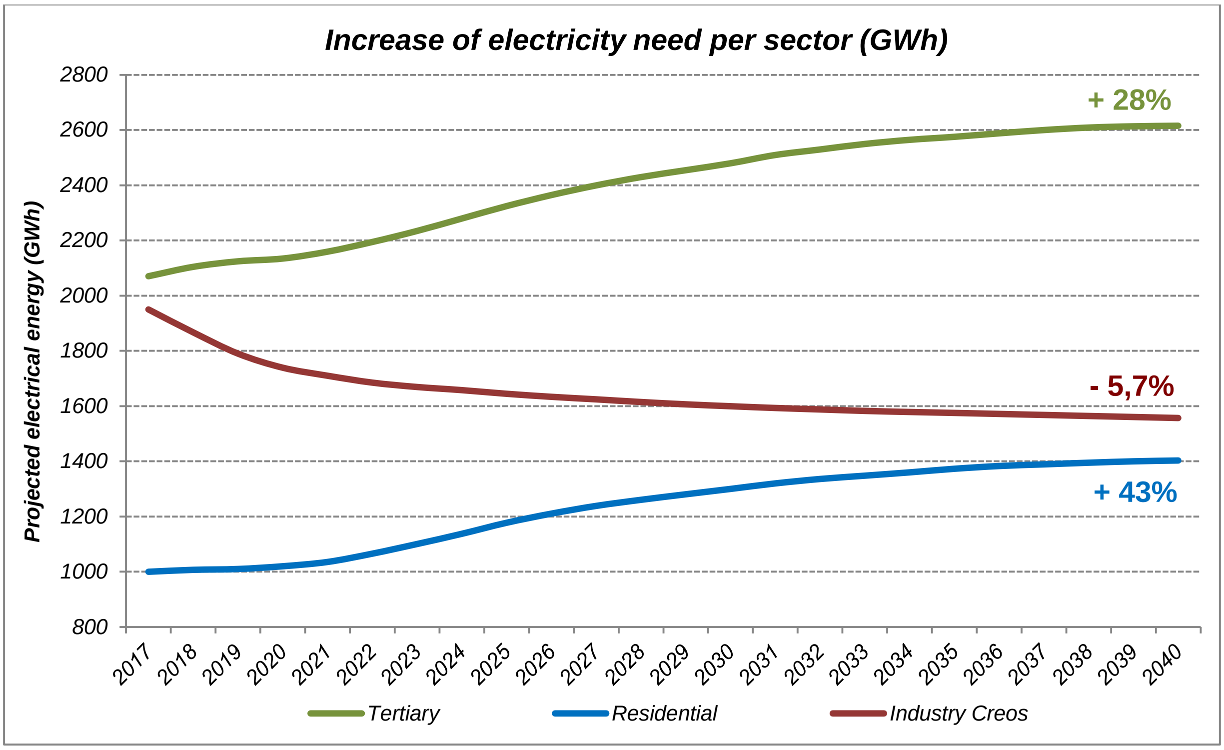
For the year 2040, the following future energy variations can be calculated for the different sectors:

| Increase of electrical energy need | 2015 - 2050 | 2015 - 2040 |
|---|---|---|
| Residential | 60% | 43% |
| Tertiary | 40% | 28% |
| Industry | -8% | -5,7% |
| **Total** | **17%** | **12%** |

*Source: Energy Demand Scenarios 2050 for Luxembourg, Fraunhofer ISE*

We suppose that the growth of the industry, tertiary and residential sectors will not happen linearly. A certain saturation might occur at the end of the projection period.






*Source: Creos Luxembourg*

The total inland electricity demand is expected to rise up to 12 percent until 2040. Furthermore, transportation means using electricity and all extraordinary loads must also be added. In detail, the electricity demand of the residential sector is predicted to rise by 43%, of the tertiary sector by 28% and the electricity demand of the industry is expected to fall by 5,7%.

## Residential sector

The increased demand in the residential sector will come from the direct growth of the population. New buildings will be more energy efficient, so that a lot less thermal energy per inhabitant will be necessary, and the additional electric energy demand will be cushioned. The increased energy efficiency of future electric devices should also help to reduce the electricity needs per inhabitant.

## Tertiary sector

The growth in the service sector will come from the additional workplaces. Here, new administrative buildings will also be more energy efficient, so that a lot less thermal energy per inhabitant will be necessary, and the additional electric energy demand will be reduced.

## Industry sector

As already mentioned, a transformation of the current European industry form will surely occur. Existing heavy industries tend to be replaced by smaller, more specialized industries with a high know-how and lesser energy hunger. This could lead to a reduction of the electrical energy consumption of this sector. New investments in this field guarantee, throughout a targeted cost efficiency and environmental protection reasons, a more sparing and sustainable use of energy resources.



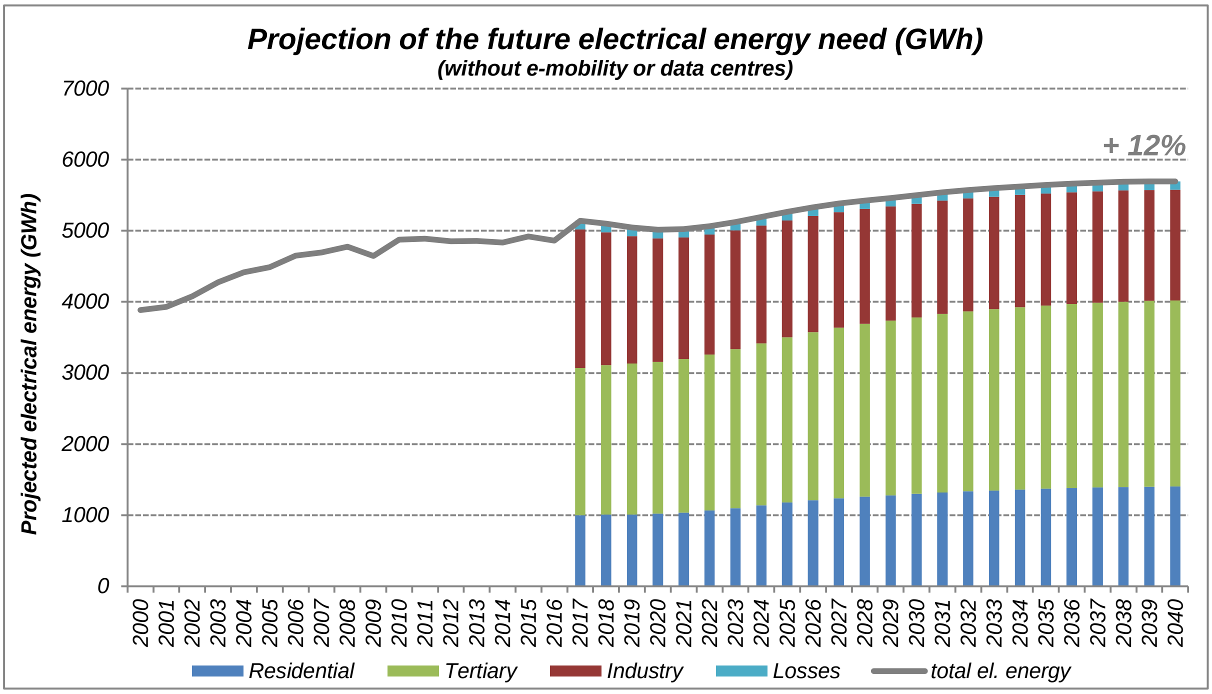
The expert group of the Fraunhofer Institute made the assumption that the future energy need of the industry sector will decrease by several percent. In order to stay competitive, future industries will surely be more energy efficient than in the past.

Nonetheless, during the past year, a lot of grid connection requests for several new industry facilities have reached us, as can be seen in the table below. **This may bring quite opposite growth results.**

| ***List of projects and demands with high electrical energy needs*** | | | | | | |
|---|---|---|---|---|---|---|
| ***Industry*** | | | | | | |
| *Voltage level* | *Locality* | *Adress* | *Name of partner or project* | *power requested* | *n° project* | *Comments* |
| *65kV* | *Niederkorn* | *Z.I. Hahneboesch* | / | *7,5MVA phase 1*<br>*32MVA final phase* | / | / |
| *65kV* | *Sanem* | *Z.I. Gadderscheier* | / | *+10MVA* | / | / |
| *65kV* | *Bettembourg* | *Z.I. Wolser* | / | *12MVA* | / | / |
| *65kV* | *Potaschbierg* | *Z.I. Op der Ahlkërrech* | / | *+4MVA* | / | / |
| *65kV ou 20kV* | *Sanem* | *Z.I. Gadderscheier* | / | *5MVA phase 1*<br>*8MVA phase 2* | / | / |
| *20kV* | *Riedgen* | *Z.I. Riedgen / Eurohub* | / | *8MVA* | / | / |
| *20kV* | *Riedgen* | *Z.I. Riedgen* | / | *4,5MVA phase 1*<br>*9MVA phase 2*<br>*13,5MVA phase 3* | / | / |
| *20kV* | *Mertert* | *Rte de Wasserbillig* | / | *6MVA* | / | / |
| *20kV* | *Diekirch* | *Z.I. Fridhaff* | / | *4MVA phase 1*<br>*6MVA phase 2*<br>*8MVA phase 3* | / | / |
| ***Subtotal*** | | | | ***61MVA short term***<br>***97MVA long term*** | | |

*Source: Creos Luxembourg*

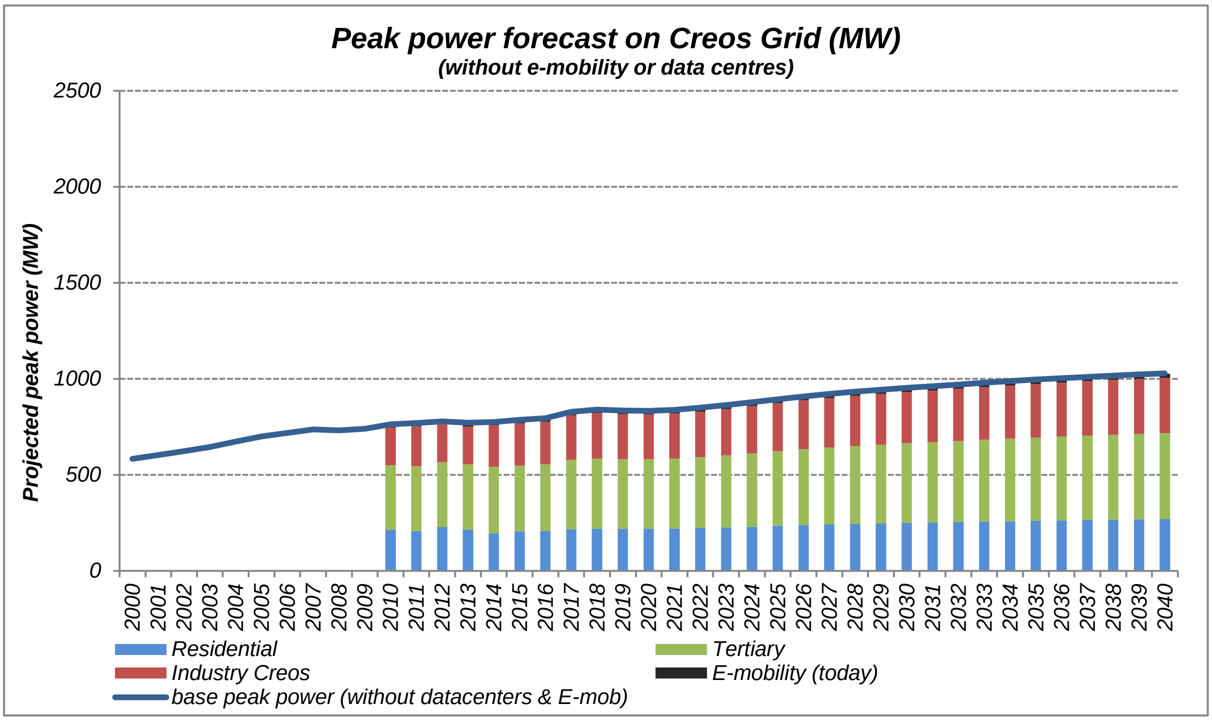
The projection of the future electrical energy need of the ordinary load can be seen hereafter: (*Source: Creos Luxembourg)*




*Source: Creos Luxembourg*

**The related future peak power on the Creos grid can then be calculated with the projected future electricity need and with given average usage hours.**






*Source: Creos Luxembourg*

**However, extraordinary loads such as E-mobility, data centres and all other projects with extraordinary energy needs** must not be forgotten and **have to be added to the projection.** Those extraordinary loads are described in detail in the following chapters.

## Extraordinary loads

## Transportation operated by electricity / E-mobility

The future need of electrical energy of the transportation sector is the most difficult to predict. As ambitious political goals in emission limitations have been set, a decarbonisation of the transport sector will lead to other propulsion technologies as used today. In combination with electricity from renewable energies, electric vehicles could replace fossil fuelled cars in the long term. The on-going evolution of electric vehicles will undoubtedly lead to a lower energy need per inhabitant as in the past and present. Nonetheless, the electricity needed in future for transportation of any kind, assuming there is a shift to E-mobility, will have to be provided by the electrical grids. This has been utterly left open ended in the projection scenarios of the Fraunhofer Institute.

**A complete shift of the energy needs of the transport sector from fossil fuels to electricity would exceed the present grid capacities on all voltage levels and would lead to overloads.** Optimized, smart charging of electric vehicles is a must and could lessen the risks of congestions on the grids, but cannot prevent the necessity of further electrical grid reinforcements. This situation could be aggravated by an ‘E-fuel tourism’, which would be provoked by attractive inland electricity costs. Cross-border commuters could also want to charge their electric cars during the working hours on their workplace in Luxembourg.



The coalescence of transport, electrical grid and communication infrastructure to a new system is going to be a huge challenge, but could also offer the chance of a better utilization of the infrastructures and more selective investments. Sustainable mobility is one of the major challenges of the present and the future. Hybrid vehicles and electric cars could play a central role in the achievement of a clean, future-viable individual transport, because carbon dioxide emissions could be lowered and the dependency from fossil fuels could be reduced due to the more energy efficient drive technologies of these vehicles. Paired with enough electricity generation from renewable energy sources, an ecological energy cycle could be formed, with which the fulfilment of the ambitious European climate targets could be attempted.

### *Electrical transport on rail*

It is important to note that the largest part of public passenger and goods transport on rail in Luxembourg is already electrically driven. The electrical assets of the national railway company, which increased by 25% in the last two years, are partly connected to the Creos grid and partly to the Sotel grid, but a full connection to the Creos grid is planned in near future.

In addition, a new funicular railway and a railcar network are to be built in the capital city. (*Source: Creos Luxembourg)*

| ***Electrically driven transport on rail*** | | | | | | |
|---|---|---|---|---|---|---|
| *Voltage level* | *Locality* | *Adress* | *Name of partner or project* | *power requested* | *n° project* | *Comments* |
| *220kV* | *Flebour* | */* | ***CFL*** | *30MVA* | | *about 2019* |
| *65kV* | *Luxembourg* | *Kirchberg* | ***CFL*** | *3MVA* | | *funicular railway* |
| *20kV (phase 1)*<br>*65kV (phase 2)* | *Luxembourg* | *Kirchberg* | ***Luxtram*** | *4MVA phase 1*<br>*6MVA phase 2*<br>*8,5MVA phase 3*<br>*10MVA phase 4* | *37092* | *railcar in the capital city* |
| ***Subtotal*** | | | | ***37MVA short term***<br>***43MVA long term*** | | |

## *Electrical transport on road*

## *Electric buses*

Currently, there are about 2000 buses shuttling on the roads of the country, together making approximately 60 million km per year. Recent practical experiences have shown that the average energy consumption of electric buses is about 2.2 kWh per km.

In total, that would make an electrical energy consumption of:

$$\textit{Total electrical energy consumption e-Buses} = 60.000.000\ km \times 2.2 \frac{kWh}{km} = 132\ GWh$$

Assuming, that energy has to be recharged overnight, i.e.from 22h to 6h, which would represent an average charging power of:

$$\textit{Average power during night-charging e-Buses} = \frac{132\ GWh}{(8h \times 365 days)} = 45\ MW$$

In daily operation, E-buses may need to quickly recharge their batteries on their respective routes with the aid of opportunity charging stations. The operating power of opportunity charging stations ranges from 250kW to 550kW.

If only ten percent of all the buses would recharge their batteries during the day with these stations, the cumulative power would be:

$$\textit{Power needed for opportunity charging e-Buses} = 10\% \times 2000\ buses \times 300kW = 60\ MW$$



Those power needs have been considered in the projection curves for the additional load of e-mobility.

The use of electric buses for public transport is rising quickly, and a lot of projects for E-bus charging stations are already planned:

***E-Bus charging stations / projects***

| *Locality* | *Street / Place* | *Partner / Customer* | *Installed power (kVA)* |
|---|---|---|---|
| Luxembourg | Place de la Gare | / | 1600 |
| Luxembourg | rue de Cents | / | 1000 |
| Bertrange | rue de l'industrie | / | 400 |
| Differdange | rue M. Rodange | / | 1000 |
| Differdange | avenue de la Liberté | / | 1000 |
| Alzingen | rue Thionville/rue Roeser | / | 400 |
| Bascharage | Rue Laangwiss | / | 2000 |
| Canach | Rue d'Oetrange | / | 400 |
| Luxembourg | Merl près poste Belair | / | 2100 |
| Luxembourg | Hollerich / dépot bus VDL | / | 3000 |
| Bettembourg | Z.I. Scheleck | / | 2000 |
| Luxembourg | Bonnevoie / dépot bus CFL | / | 1250 |
| Echternach | dépot bus CFL | / | 1000 |
| | | | |
| Total | | | 17150 |
| *in 6 - 8 years* | | | |
| *Luxembourg* | *Cloche d'Or près nouv. Stade* | */* | *15000* |

Source: Creos Luxembourg

## Electrical transport on road

### Electric cars

The number of electric cars in Luxembourg is still quite modest. So far (until august of the year 2017), there are about 821 electric vehicles (60% private use, 40% commercial / mixed use) and about 254 plug-in hybrid vehicles (estimated 10% of all hybrid) registered in Luxembourg. **In total, that makes roughly 1100 vehicles which can be connected and recharged on the electrical grid.** The evolution of the registration during the past few years can be reviewed in the following spreadsheet table:

| Year | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 s.f. |
|---|---|---|---|---|---|---|---|---|
| *Cycles with auxiliary drive* | 25569 | 26339 | 27109 | 27998 | 8527 | 9385 | 9690 | 9768 |
| *electric* | 48 | 73 | 113 | 144 | 160 | 186 | 173 | 203 |
| *hybrid* | / | / | / | / | / | / | / | / |
| ***Motorcycles*** | **15551** | **15753** | **16225** | **16528** | **17226** | **17890** | **18569** | **19485** |
| *electric* | 2 | 6 | 8 | 9 | 11 | 16 | 23 | 29 |
| *hybrid* | / | / | / | / | / | / | / | / |
| ***Passenger cars*** | **191197** | **184633** | **207642** | **207902** | **205132** | **203926** | **202766** | **201732** |
| *electric* | 0 | 1 | 21 | 60 | 187 | 400 | 447 | 533 |
| *hybrid* | 357 | 486 | 713 | 879 | 980 | 1162 | 1178 | 1156 |
| ***Commercial vehicles / mixed usage*** | **139280** | **151812** | **137309** | **147456** | **157747** | **168612** | **178094** | **189004** |
| *electric* | 2 | 2 | 15 | 49 | 76 | 124 | 133 | 152 |
| *hybrid* | 235 | 313 | 318 | 588 | 677 | 845 | 1088 | 1324 |
| ***Utility vehicles*** | **1026** | **794** | **624** | **492** | **368** | **289** | **243** | **199** |
| *electric* | / | / | / | / | / | / | / | / |
| *hybrid* | / | / | / | / | / | / | / | / |
| ***Buses and motor coaches*** | **1623** | **1636** | **1703** | **1728** | **1759** | **1778** | **1857** | **1904** |
| *electric* | 0 | 0 | 2 | 2 | 4 | 2 | 2 | 2 |
| *hybrid* | 51 | 50 | 66 | / | / | / | 46 | 57 |
| ***Light goods road vehicles*** | **23837** | **24800** | **26089** | **27046** | **27635** | **28521** | **29668** | **31138** |
| *electric* | 7 | 5 | 6 | 30 | 70 | 85 | 84 | 102 |
| *hybrid* | / | / | / | / | / | / | / | / |
| ***Trucks / Lorries*** | **5354** | **5358** | **5368** | **5339** | **5298** | **5311** | **5404** | **5594** |
| *electric* | / | / | / | / | / | / | / | / |
| *hybrid* | / | / | / | / | / | / | / | / |
| ***Agricultural tractors and machines*** | **5550** | **5469** | **5356** | **4934** | **4726** | **4602** | **4502** | **4516** |
| *electric* | / | / | / | / | / | / | / | / |
| *hybrid* | / | / | / | / | / | / | / | / |
| ***Special vehicles*** | **2456** | **2560** | **2671** | **2764** | **2827** | **2936** | **3044** | **3132** |
| *electric* | 1 | 0 | 0 | 0 | 1 | 1 | 2 | 3 |
| *hybrid* | / | / | / | / | / | / | / | / |
| **Total (without bicycles or scooters)** | ***385874*** | ***392815*** | ***402987*** | ***414189*** | ***422718*** | ***433865*** | ***444147*** | ***456704*** |
| Total (electric without buses) | 12 | 14 | 50 | 148 | 345 | 626 | 689 | 819 |
| Total (hybrid without buses) | 592 | 799 | 1031 | 1467 | 1657 | 2007 | 2266 | 2480 |
| Total (electric - buses) | 0 | 0 | 2 | 2 | 4 | 2 | 2 | 2 |
| Total (hybrid - buses) | 51 | 50 | 66 | / | / | / | 46 | 57 |
| Total electric | 12 | 14 | 52 | 150 | 349 | 628 | 691 | 821 |
| Total hybrid | 643 | 849 | 1097 | 1467 | 1657 | 2007 | 2312 | 2537 |
| 5% of plug-in hybrid | 32 | 42 | 55 | 73 | 83 | 100 | 116 | 127 |
| 10% of plug-in hybrid | 64 | 85 | 110 | 147 | 166 | 201 | 231 | 254 |
| ***Total electric & plug-in hybrid (10%)*** | ***76*** | ***99*** | ***162*** | ***297*** | ***515*** | ***829*** | ***922*** | ***1075*** |
| electric buses here included | 0 | 0 | 2 | 2 | 4 | 2 | 2 | 2 |
| hybrid buses here included | 51 | 50 | 66 | / | / | / | 46 | 57 |

*Source: SNCT / Statec*

In order to promote the E-mobility and to offer public recharging possibilities, eight hundred public charging stations for electric vehicles (1600 charging points), under the label 'Chargy', are currently being installed on public parking lots throughout the country.

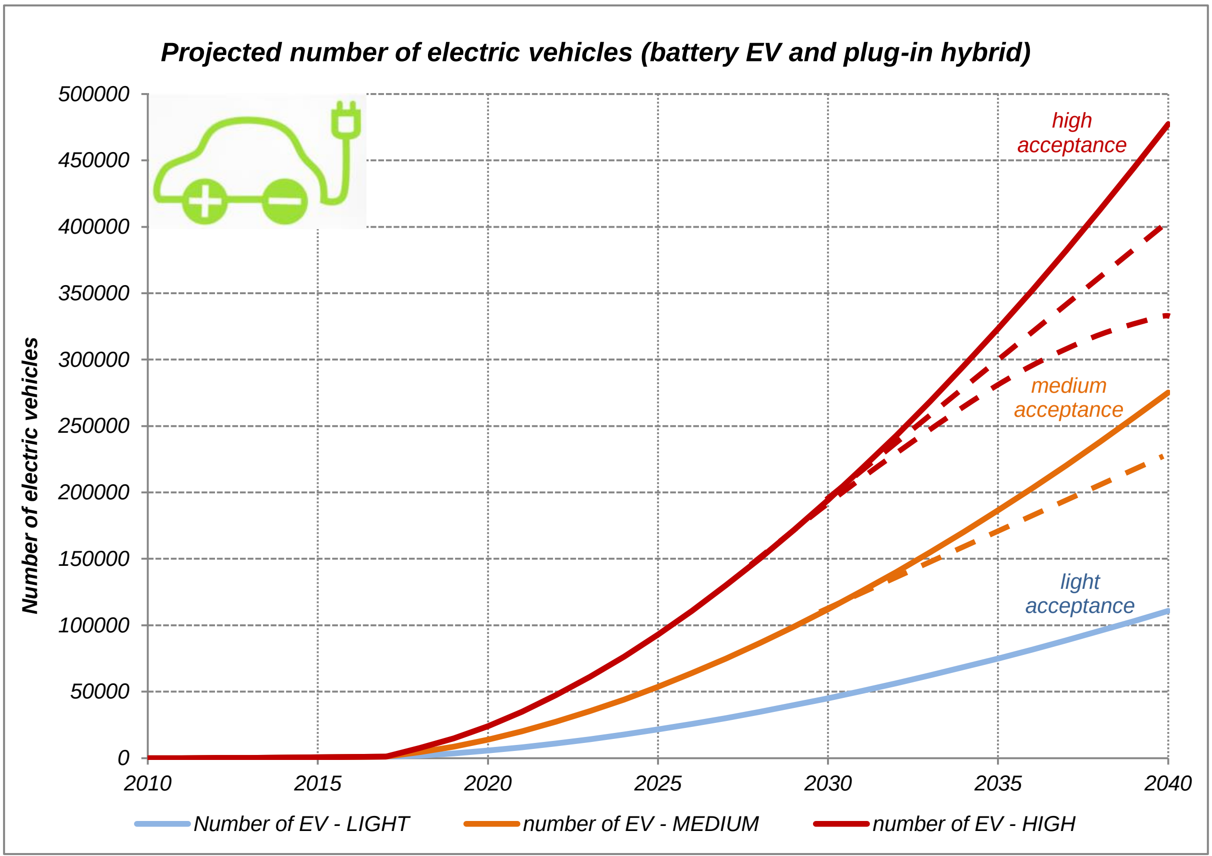
Since January 2017, new tax incentives are offered for the acquisition of electric and hybrid vehicles and even better incentives measures are planned for 2018. The very ambitious, political target of attaining a share of 10% of electric and plug-in hybrid vehicles from the total registrations (that means, over 40000 EV) in 2020 cannot be achieved any more, as the high price and the limited range capabilities of these vehicles thwart the general acceptance. However, the newly offered tax incentives seem to work, **as the registrations for new electric and hybrid vehicles are strongly rising in 2017**. With better range capabilities and better market prices in the future, there may be a broader acceptance with an accelerated growth of the registrations.

As the power demand necessary for the cumulative charging of electric vehicles grows quite severely with the number of EV, a few possible scenarios must be developed and their impact on the grid has to be analysed. The future number of rechargeable vehicles will very likely grow in a non-linear way. For this reason, a projected increase according to a second degree polynomial curve has been assumed.

In this study, three different acceptance levels were taken into account:

- **a light acceptance with a total of about 110.000 EV**
- **a medium acceptance with a total of about 275.000 EV**
- **a high acceptance with a total of about 477.000 EV**






*Source: Creos Luxembourg*

**Cross-border commuters, which would like to recharge the batteries of their electric vehicles on their work place in Luxembourg or with the help of superchargers, have been partly considered in those projected figures.**

The current state of technology gives a hint of the future supercharging possibilities of electric vehicles. Anticipating a more pronounced use of electric vehicles, various fast charging stations are already planned:

| ***Superchargers / projects*** | | | |
|---|---|---|---|
| ***Locality*** | ***Street / Place*** | ***Partner / Customer*** | ***Installed power (kVA)*** |
| Munsbach | 11, Rue Gabriel Lippmann | / | 630 |
| Berchem | Aire de Berchem | / | 2400 |
| Livange | | / | 1000 |
| Wasserbillig | Aire de Wasserbillig | / | 2500 |
| Leudelange | 2, Rue Jean Fischbach | / | 650 |
| Howald | 5, rue Peternelchen | / | 1250 |
| | | | |
| Total | | | 8430 |

*Source: Creos Luxembourg*

Attractive inland electricity costs, compared to the prices of electricity in neighbouring countries, could provoke a related extra load on the electrical grid, which would have to be considered additionally. Superchargers on highways during summer travel period could produce important peak loads that could neither be shifted in time, neither be flattened over a certain time period. This could become a major issue on the higher voltage levels as the simultaneous factor will be close to 1. Local energy storage might be favourable to reduce peak demands but the economic viability of such a system is still unsure. **It should be noted, that this speculative additional load has not been included in the projections hereafter.**



The charging of the batteries of the electric vehicles will stress the electrical grids on all voltage levels. In addition to the number of electric vehicles, their charging capacities and the charging time are of importance for the overall additional electric load.

**The highest relative additional load of the E-mobility will occur on the low-voltage grids**, because the simultaneity is much higher when a few EV are recharging during the same time at home or on a public charging station on the low voltage grid. **For example: a typical electric car with a large battery has a charging capacity of 22kW.**

Medium-voltage grids will benefit from the smaller probability of simultaneous charging of a many EVs, and will therefore be, relatively viewed, less loaded.

The high-voltage grid will be relatively the least loaded, because of the interplay of the numerous, various times of the recharges and of the power demands.

In 2014, the University of Stuttgart released the study ‘Implications of E-Mobility for the energy system analysed with probabilistic grid calculations’ which provides values for common charging capacities. With the analysis of commercial available vehicles (65 available on the market) and their charging capabilities, a stochastically calculated peak power per car has been determined, which can be used to assess the cumulative load on the high-voltage grid.

In fact, this study foresees that, because of frequency and the mix of different vehicles with charging capabilities between 3,7kW and 22kW, the resulting average charging power per car should be about 7,66kW in the year 2030, on the low voltage grid. Most vehicles are expected to use only 3,7kW, roughly a quarter of the vehicles 11kW and about 10 percent a charging power of 22kW or above.

Extrapolated on the high-voltage grid, this should lead a simultaneously occurring peak power of only 1kW per car per day. According to the study, this rather low power can be explained by a low daily energy consumption and the associated charging time.

In the Master thesis 'E-mobility – Impacts on the energy supply system' from the year 2010 and from the technical university HTW Saar, a higher peak power per car has been determined, by means of a bottom-up analysis. It was supposed that higher charging capacities will be used simultaneously in the future. Depending on the scenario, an additional, average peak load, on the high voltage grid, of 1,66kW per car has been calculated (with an average daily route of 50km).

**Today, the real effects of the E-mobility on the electrical grids are still unknown, because there are no practical experiences with high numbers of electric vehicles charging simultaneously.** For this reason, we decided to take the average peak load of both impact studies to calculate the total peak power necessary for charging large numbers of electric vehicles in Luxembourg **(about 1,33kW peak power per car on the HV grid).**

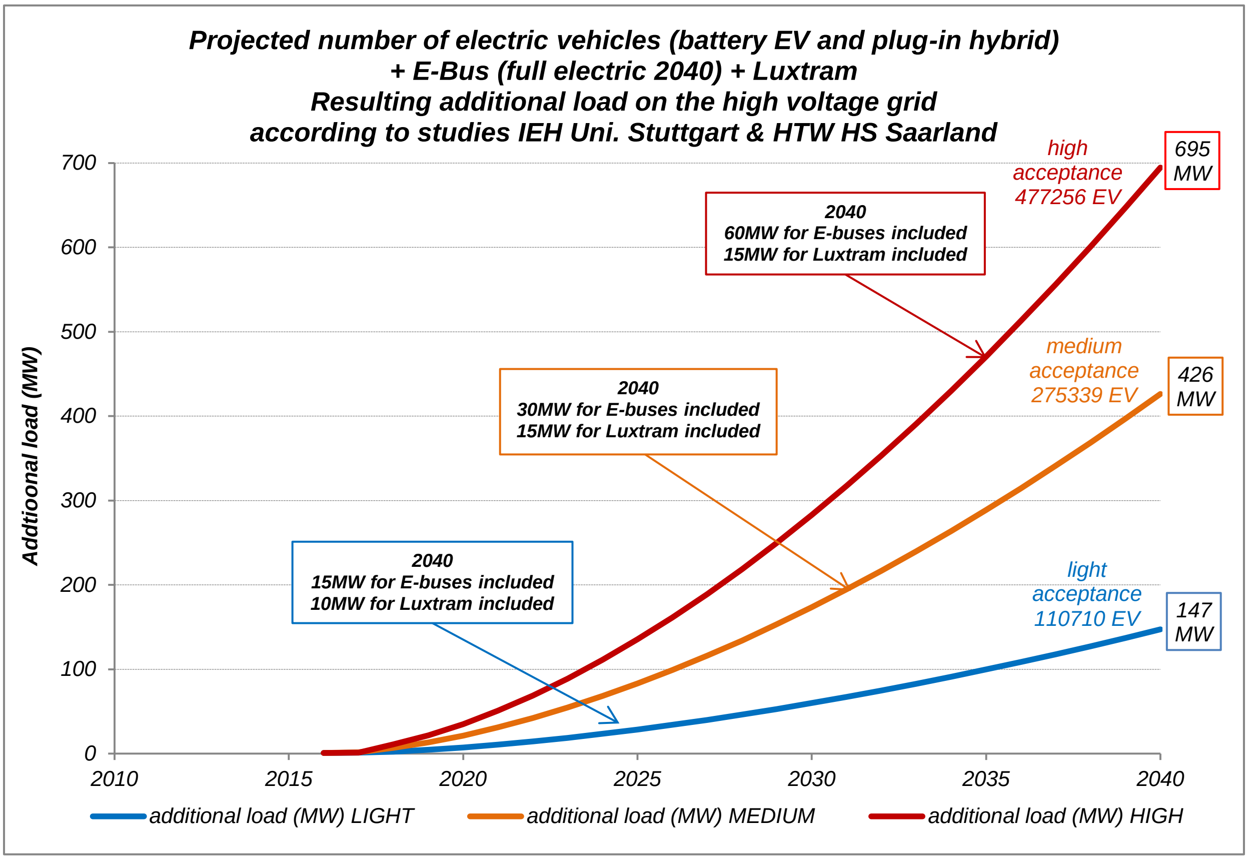
**Recent studies and calculations from 2017 have determined** that with a homogeneous distribution of the charging points and electric vehicles, and with a mix of charging capacities as available today**, a light acceptance of electric vehicles should lead to very few or no overloads on the low and medium voltage grids.**



**Nevertheless, the additional load of a light acceptance of electric vehicles would almost use up the entire remaining power reserve of the existing high-voltage grid.**

Without intelligent or coordinated charging management solutions, there will certainly be overloads on the electrical grids with higher acceptances (Estimation: starting from a total of 150.000 to 200.000 EV's).

**The total additional load on the high-voltage grid can be seen in this chart:**






*Source: Creos Luxembourg*

**Smart-charging solutions could reduce the power needed during peak times, with a better usage throughout the day.**

In regard to 'vehicle to grid' approaches, it has to be taken into consideration that E-vehicles owners may not agree with a third-party use of the battery packs of their EVs for energy storage purposes. Network operators could theoretically use the stored energy of the batteries of the EVs to counter brief shortages or avoid possible overloads. But the durability of the expensively acquired batteries of the E-vehicles owners, would suffer from the additional charging cycles. Legal aspects would also have to be considered.

**The ability of a bidirectional use of these storage capacities remains questionable.**

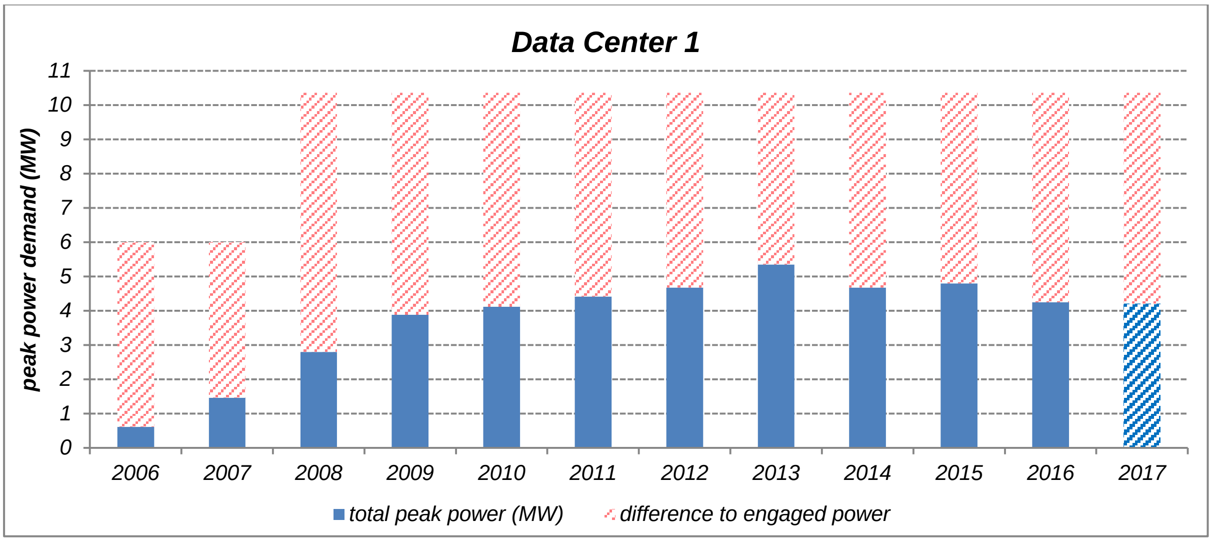
# Extraordinary loads

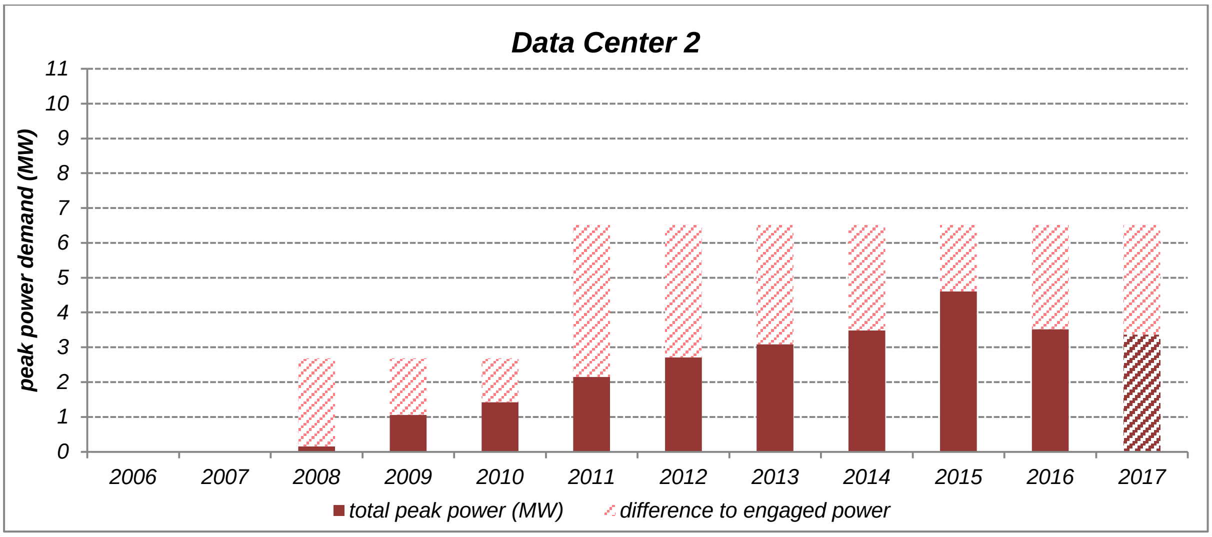
## Data Centres with high energy needs

### *Contractually agreed power and actual peak power of the existing data centres*

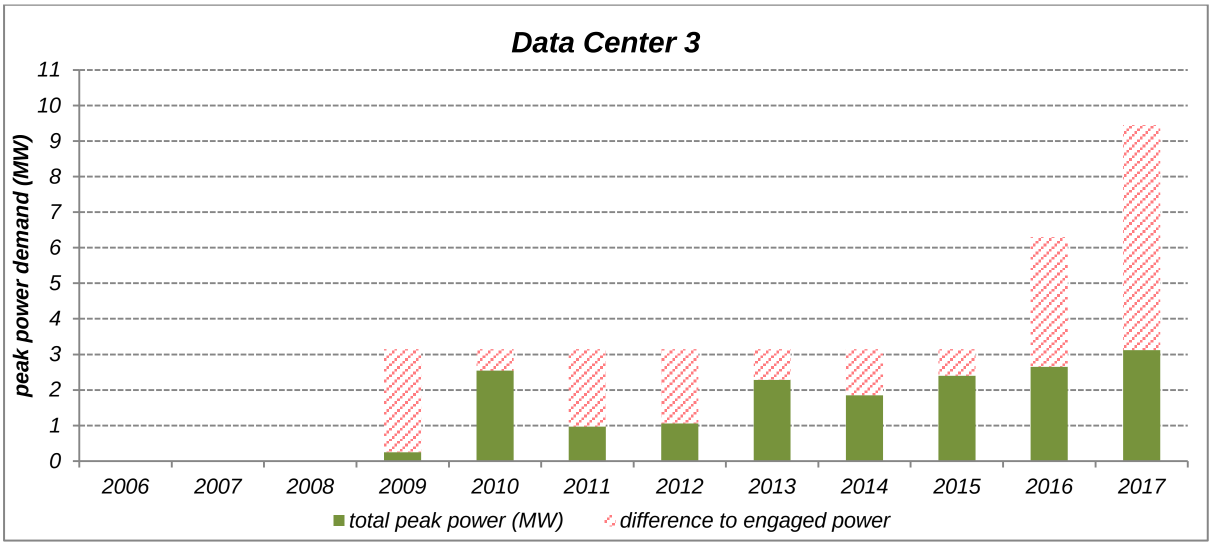
Since 2006, five major data centres, labelled as such, have been connected to the Creos electrical grids. The consumption of other smaller data centres, which are integrated in administrative or commercial buildings and banks, cannot be isolated clearly enough to be considered here. The operators and the exact locations are not mentioned for confidentiality reasons.

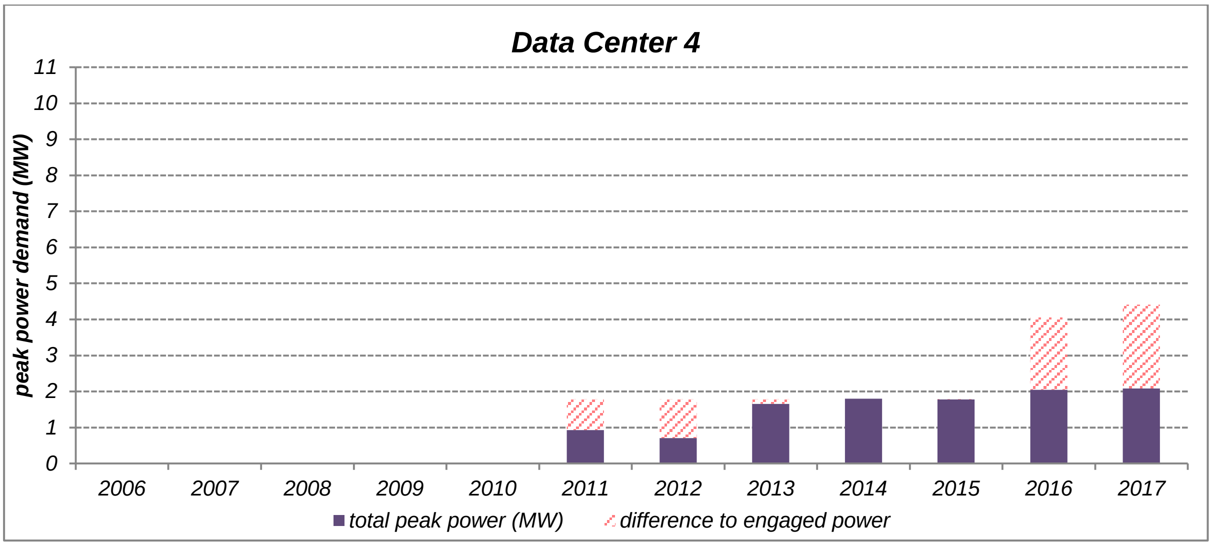
The high power demands, which the customers requested initially, do not match with the more moderate actual power needs and the contractually agreed powers of these data centres. We experienced that the initial high power requests and the contractually agreed power demands have not (or not yet) been reached or used. However, Creos must still be able to provide the agreed powers at any time and consider these given values during the future grid planning.



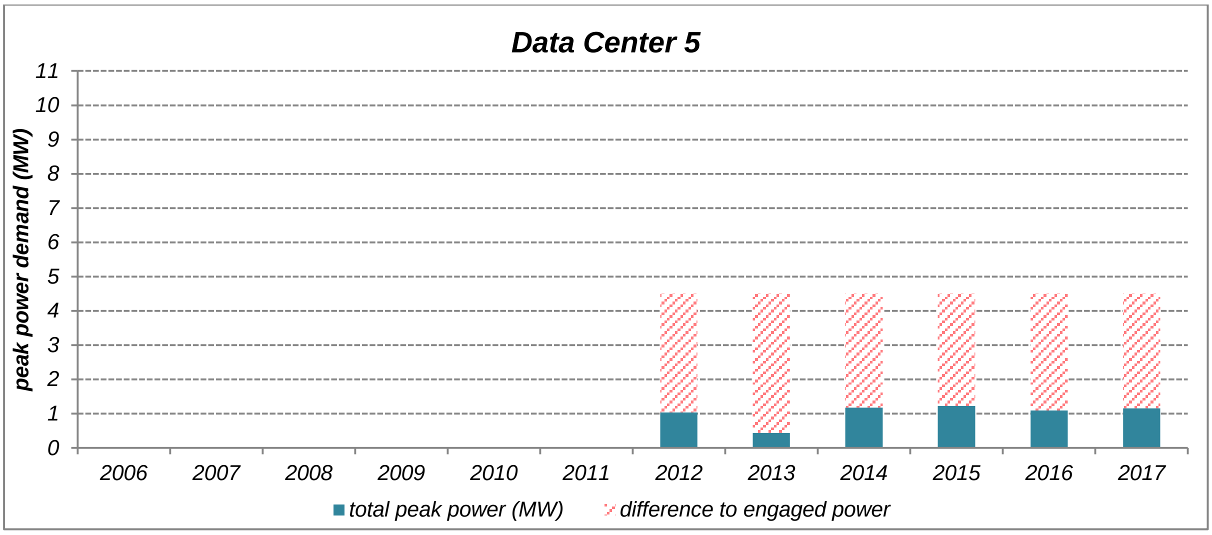




*Source: Creos Luxembourg*






*Source: Creos Luxembourg*

Summarising, the existing data centres have the following power needs:

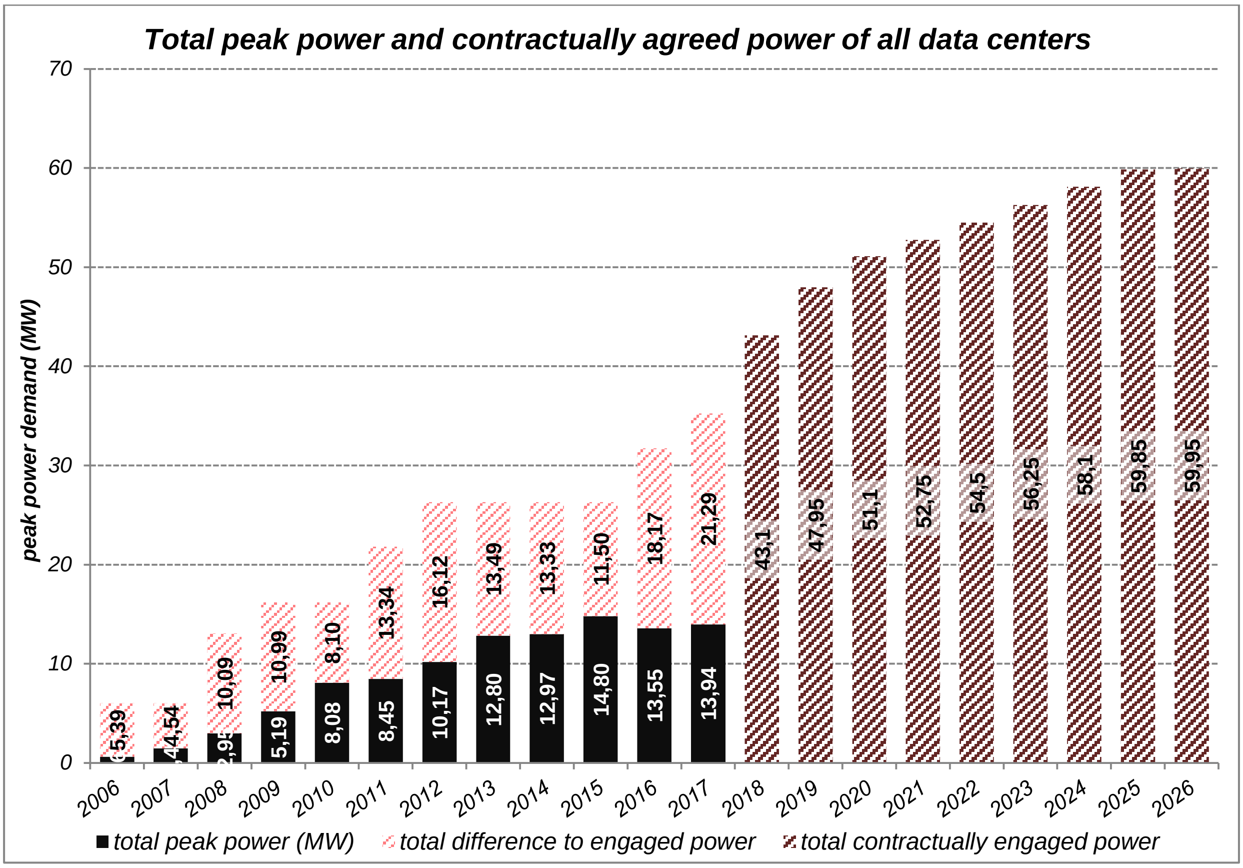
| Existing data centre | In operation since | Requested power | Contractually agreed power | Peak power 2006 - 2017 |
|---|---|---|---|---|
| N°1 | October 2006 | 10,5 MW | 10,35 MW | ~ 5,3 MW |
| N°2 | March 2008 | 10 MW | 6,51 MW | ~ 4,6 MW |
| N°3 | December 2009 | 21 MW | 9,45 MW | ~ 3,1 MW |
| N°4 | August 2011 | 13,5 MW | 4,4 MW | ~ 2,1 MW |
| N°5 | February 2012 | 21 MW | 4,5 MW | ~ 1,2 MW |

*Source: Creos Luxembourg*

Common power densities of the existing data centres in Luxembourg vary between 0,8 – 2,5 kW/$m^2$, with a rising tendency. A better energy efficiency, for instance for the cooling, should counter this tendency.

As already mentioned, Creos must be able to provide the contractually agreed powers at any time. The original high requests must not be forgotten, as these powers needs could occur later on, with full operational readiness and extensive use or due to upgrades and expansions.






*Source: Creos Luxembourg*

## *Future mega data centre*

A project to install a massive data centre with very high energy needs is still unofficial and unconfirmed. Based in Bissen / Roost, the projected surface should be close to 25 hectares and the power request plan looks as follows:

| *Phase of project* | *Requested power* | *Desired date of power supply readiness* |
|---|---|---|
| *Phase 1* | ***100 MW** (120 MVA)* | ***from 2020*** |
| *Phase 2* | ***180 MW** (210 MVA)* | ***from 2025*** |
| *Phase 3* | ***260 MW** (280 MVA)* | ***from 2030*** |

*Source: Creos Luxembourg*

**Such an enormous single power demand will considerably reduce the remaining power reserves of the existing high voltage grid and will make extensive reinforcements necessary to ensure a reliable future power supply.** Even if this project is still unconfirmed, this data should be included in the total projected peak power demand as a possible scenario.

## *Additional data centres projects*

In order to consider other future data centres, which are also planned (see list hereafter), a total amount of 100MW of additional load has been projected.

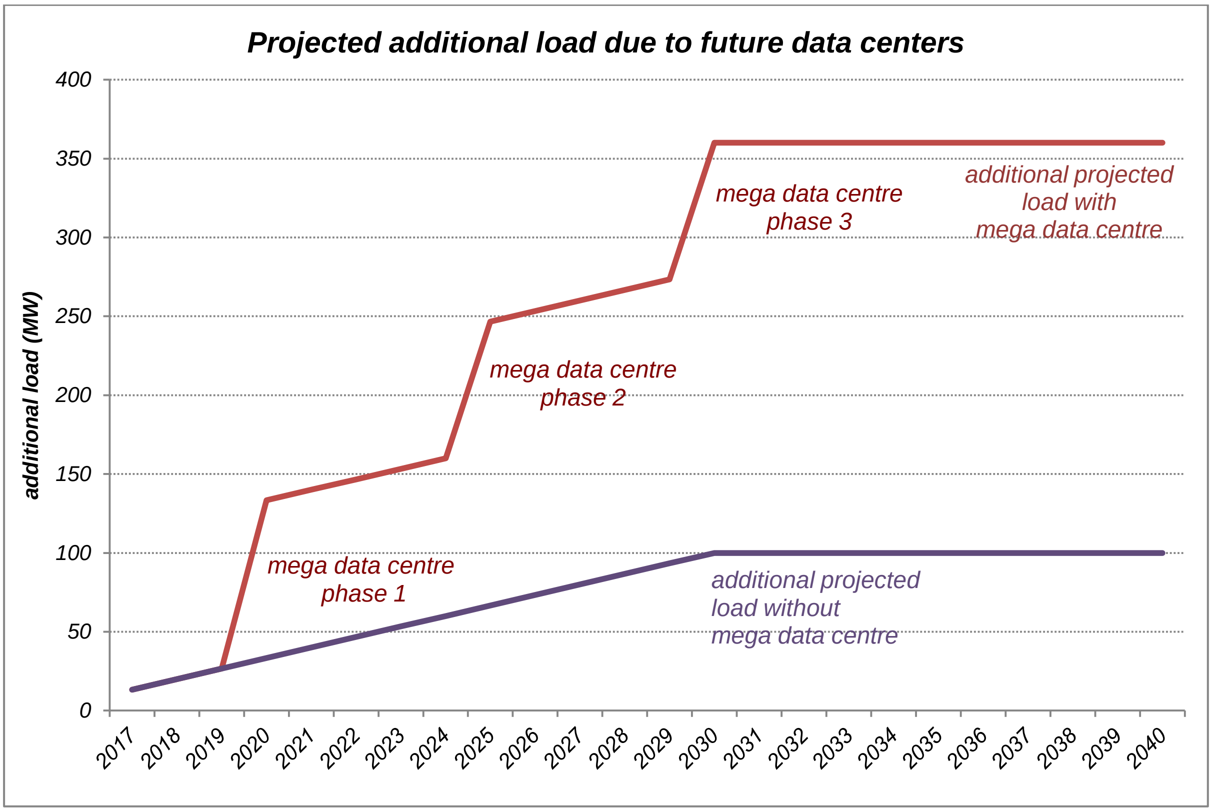


| **Data Centers** | | | | | | |
|---|---|---|---|---|---|---|
| *Voltage level* | *Locality* | *Adress* | *Name of partner or project* | *power requested* | *n° project* | *Comments* |
| *220kV* | *Roost* | */* | */* | *120MVA phase 1*<br>*210MVA phase 2*<br>*280MVA phase 3* | | *mega datacenter*<br>*on hold / awaiting confirmation* |
| *65kV* | *Bissen ou Bettembourg* | *Z.A.C. Klengbousbierg*<br>*Z.I. Krakelshaff* | */* | *10MVA phase 1*<br>*20MVA phase 2* | | *datacenter* |
| *65kV* | *Bofferdange* | *164, Rte de Luxembourg* | */* | *12MVA* | | *datacenter* |
| *65kV* | *Findel* | *Parking Aerogare* | */* | *20MVA* | | *datacenter*<br>*oral inquiry* |
| *20kV* | *Grass* | *Z.I. Zaro* | */* | *1,25MVA phase 1*<br>*2,5MVA phase 2* | *17-00017* | *datacenter* |
| ***Subtotal*** | | | | ***163,25MVA short term***<br>***334,5MVA long term*** | | |

*Source: Creos Luxembourg*

That value of 100MW includes the remaining, still unused power of the existing data centres and a certain amount of new facilities. (mega data centre excluded)

The full operational readiness of the existing data centres and the construction of future ones have been taken into account with the following additional load projections:

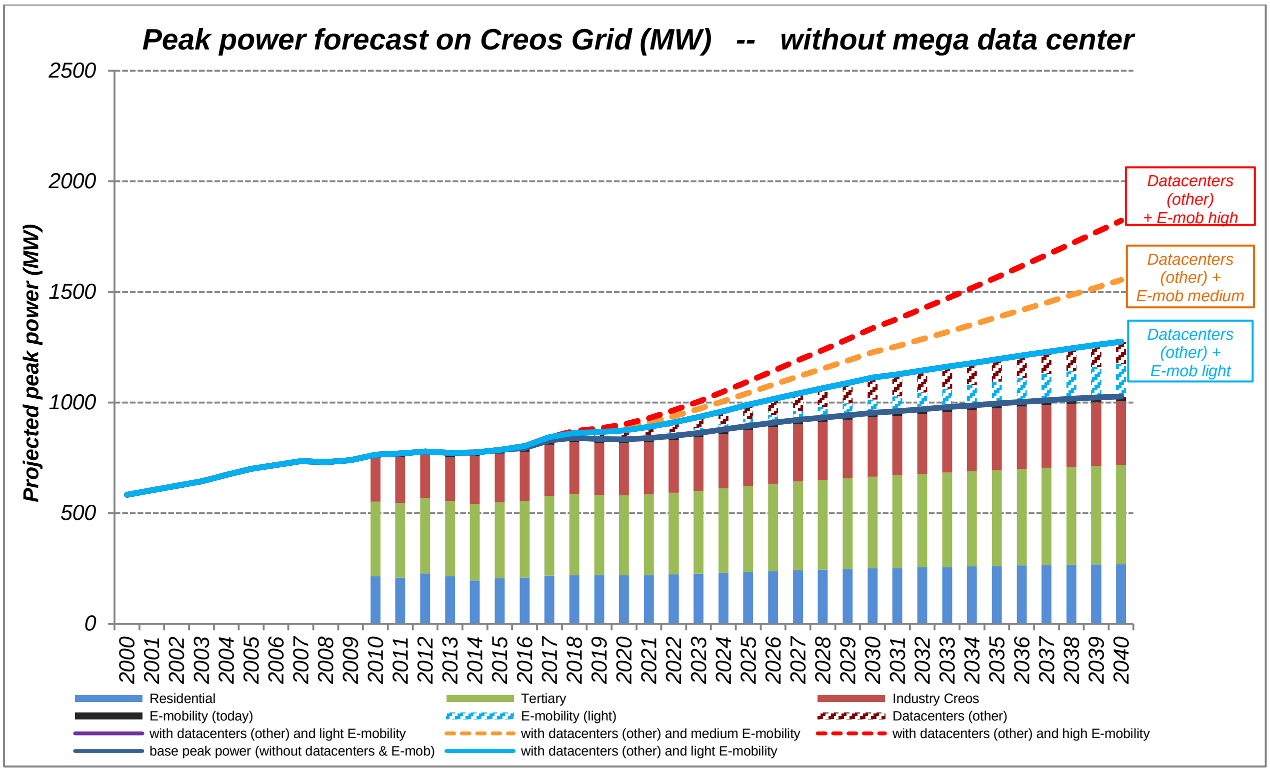



*Source: Creos Luxembourg*

## Forecast of the future electricity need and peak power demand (p.2)

## Ordinary and Extraordinary loads

**The future peak power can be calculated with the projected future electricity need and with given average usage hours. The peak powers for the e-mobility scenarios and for data centres can then be added to that base peak power curve.**

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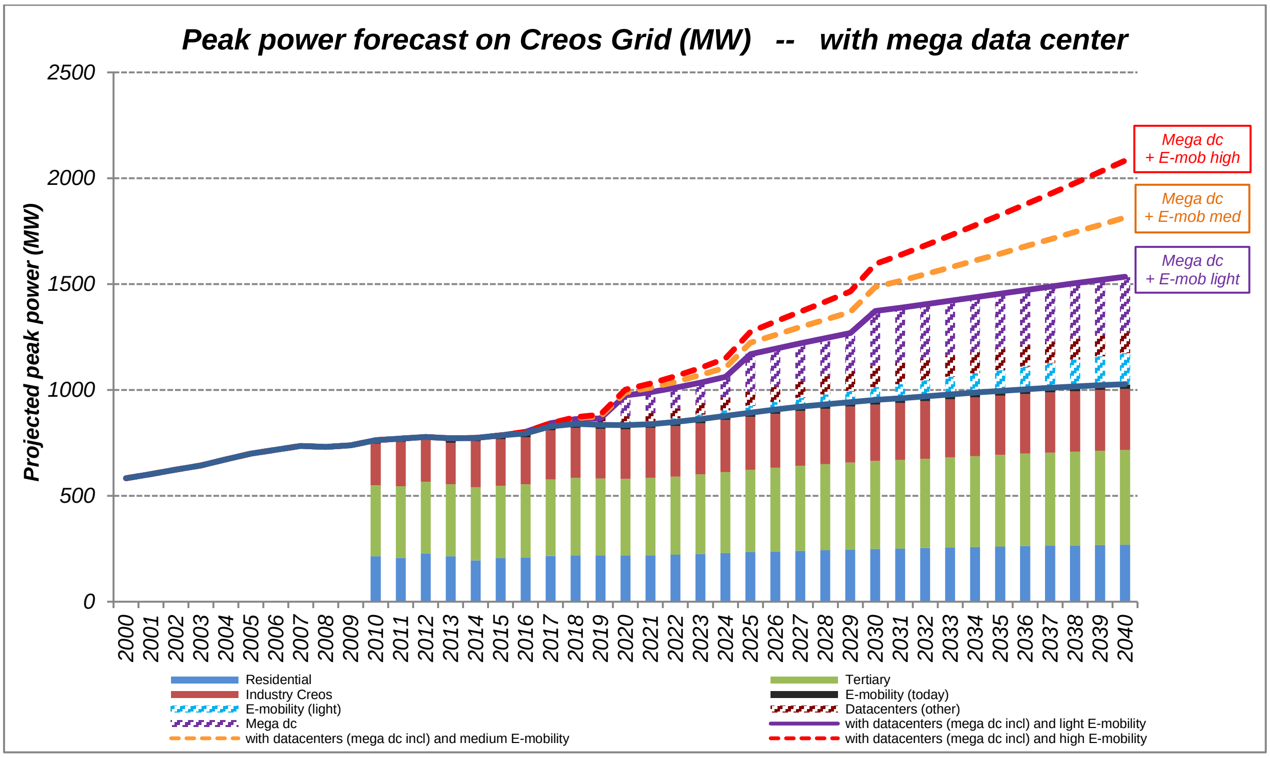



*Source: Creos Luxembourg*

**The loads considered in this study do not include potential additional loads presently connected via the Sotel grid to Belgium and France. Furthermore, the interconnection capacity between Creos and the Belgian grid is not considered in the study. Both together represent an additional load of 480 MW to 680 MW. This additional load has to be considered in any major grid extension project as it would allow the Sotel load to be switched away from the BE and FR markets to the more attractive DE-LU market and avoid costly redispatch measures on cross border flows in case of high flows from Germany through Luxembourg to Belgium. Furthermore, these additional loads and flows are likely to contribute to the financing of such new infrastructure.**

With a forecast of the future inland electrical energy generation, an assessment of the remaining import can be established.

# Electrical energy generation and renewables energies

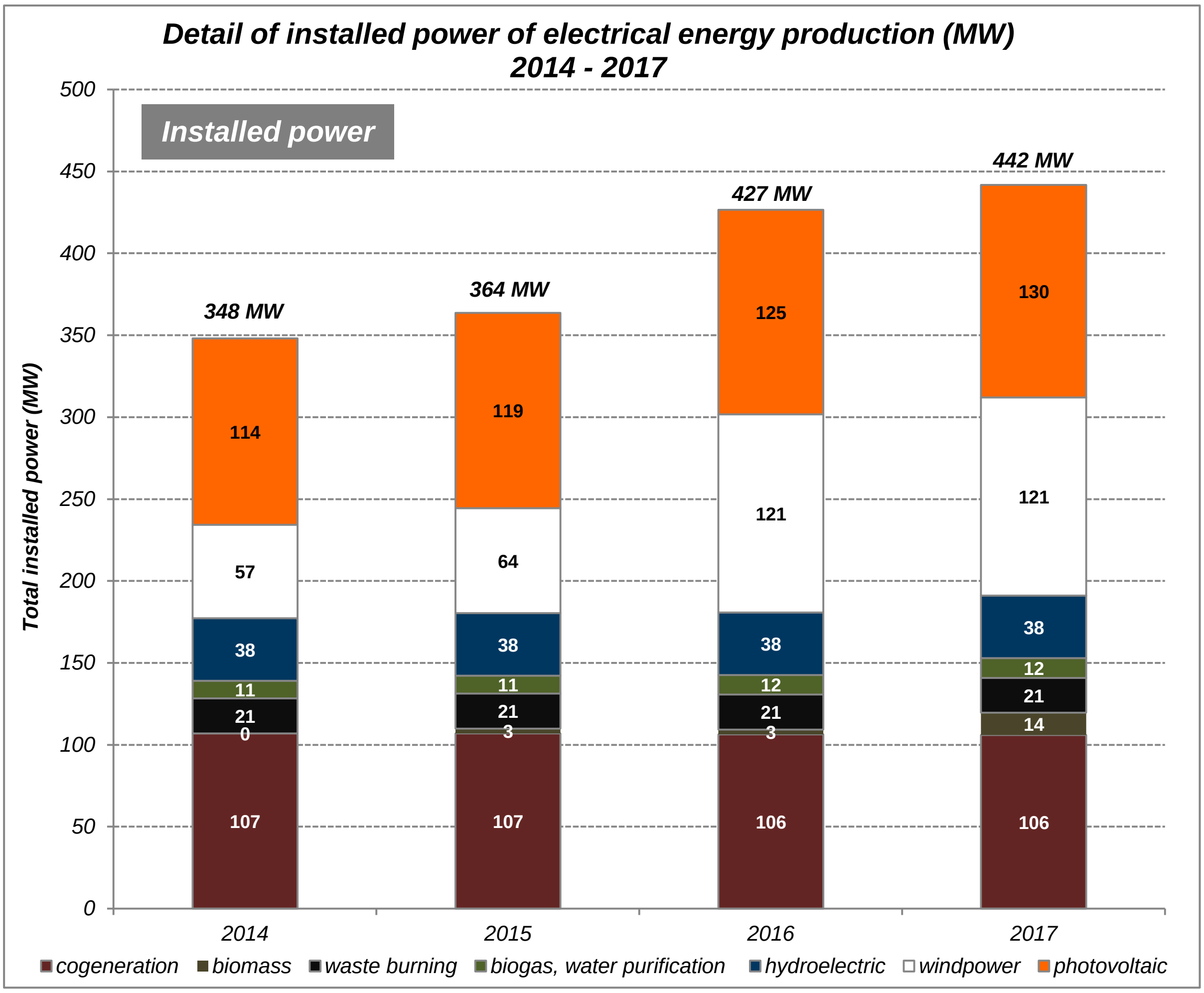
## *Current electricity generation and its contribution during peak demand*

The evolution of the annual electricity volume which was generated and its source is interesting, but of secondary importance for the dimensioning of the electrical grid. **The generation at the moment of the peak demand is the most important.** The dimensioning of the electrical lines is dictated by the moment, during which the greatest currents occur on those lines.

In this chapter, the influence of the generation during the peak demand shall be analysed and which remaining power must be imported.

The total installed power of all generation units on the Creos grid has risen from 348MW in 2014 to 442MW to this day, with the following segmentation:

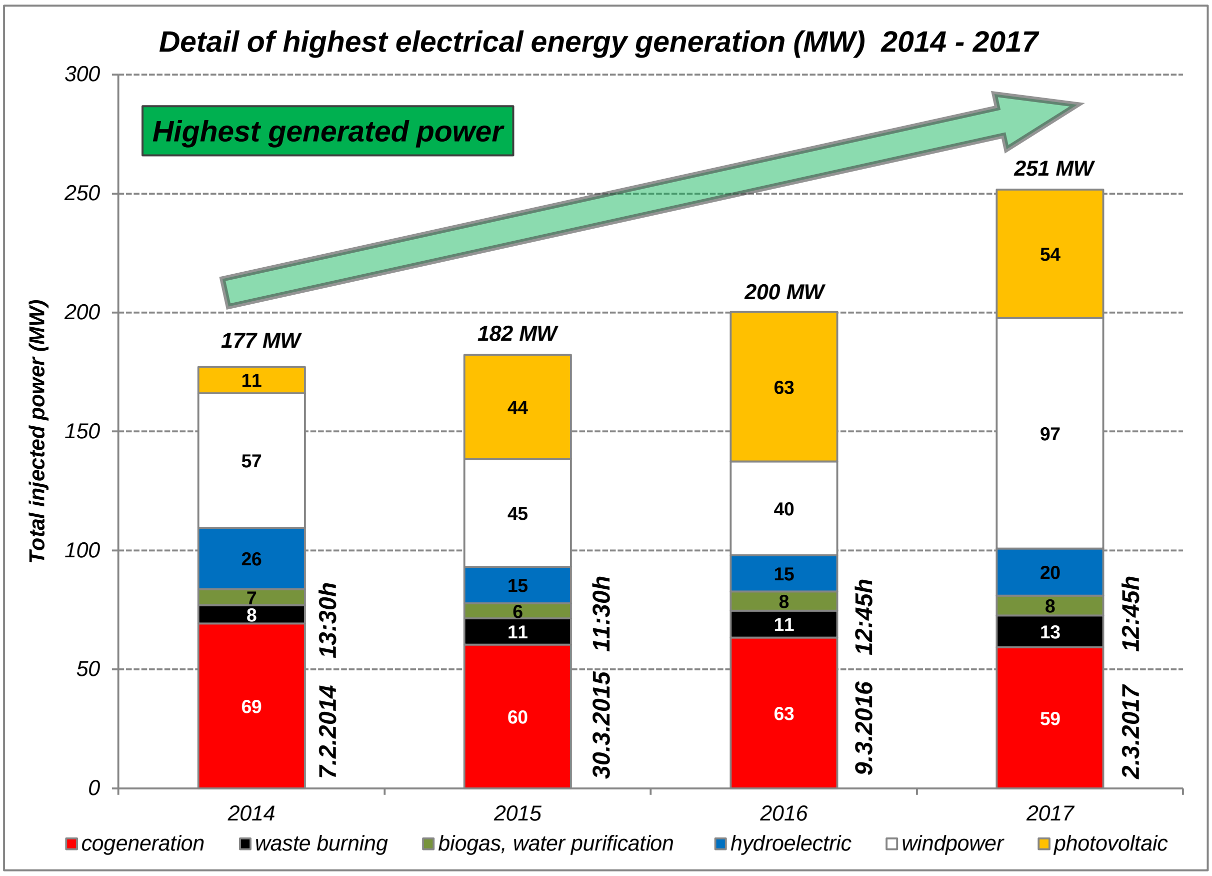




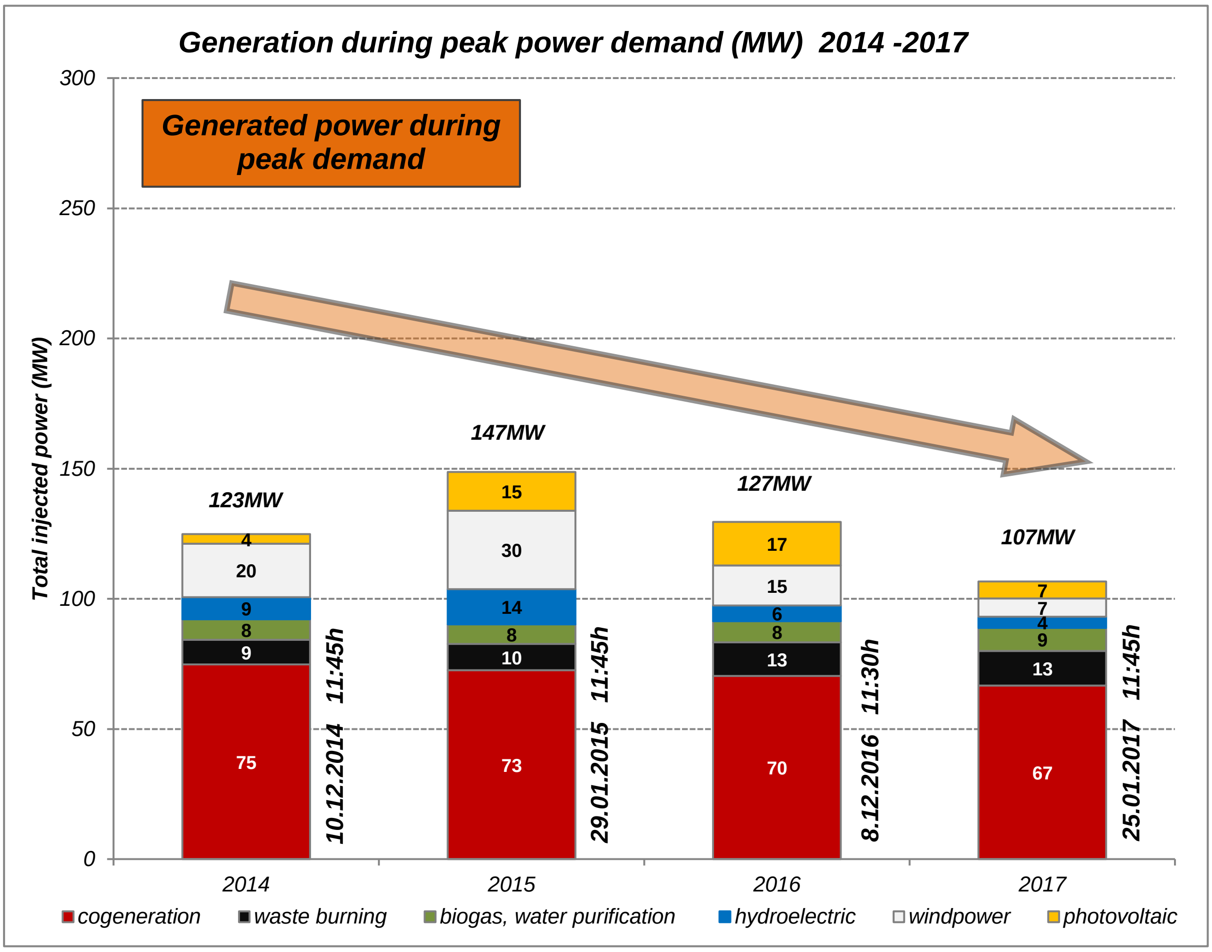

*Source: Creos Luxembourg*

The share of the installed generation capacity based on renewable energy sources passed from 63 percent in 2014 to 71 percent nowadays.

**Although, the real, delivered power of all generation units combined is rising, the total generation during the peak demand is decreasing, as can be seen in the following charts:**






Source: Creos Luxembourg

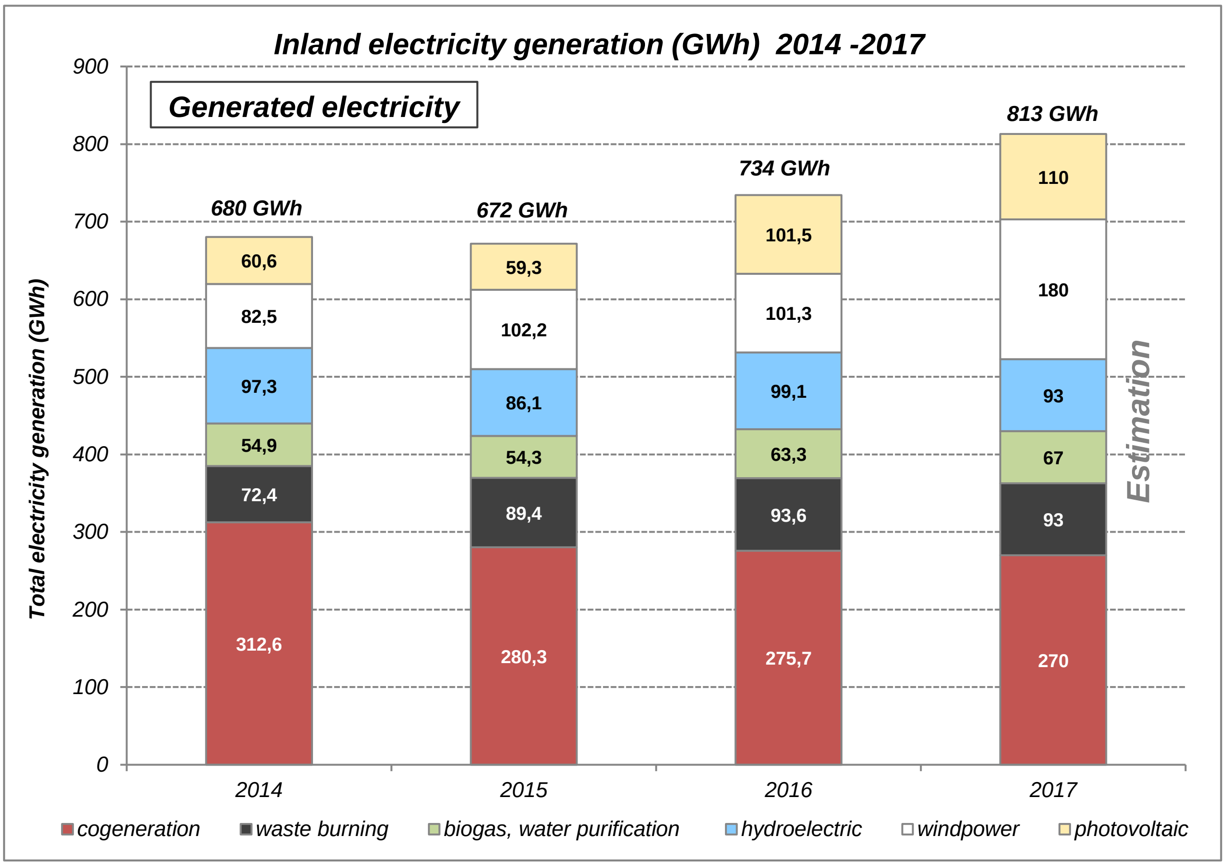
As can be seen, the increase of the installed generation capacity during the last years, which was mainly an increase of wind power and photovoltaic generation, did not help reduce the import need during the peak demand. **The day of the greatest electrical power demand is typically a cold winter day, during which there is no wind and no sunshine.** The only remaining reliable electrical generation on those days comes from cogeneration units.

The difference in generation between the day with the highest electrical generation and the day with the highest electrical demand is enormous. **The part of the generation based on renewables energies is highly volatile** and about 6.5 times smaller during the day of the peak demand than on the day with the highest generation. In fact, during the last years, volatile generation (wind, hydro, pv) contributed between 17 and 38 percent to the lowering of the total peak; generation units with high yield (cogeneration, waste burning, biogas, biomass) contributed up to 72 percent to the reduction of the peak demand.

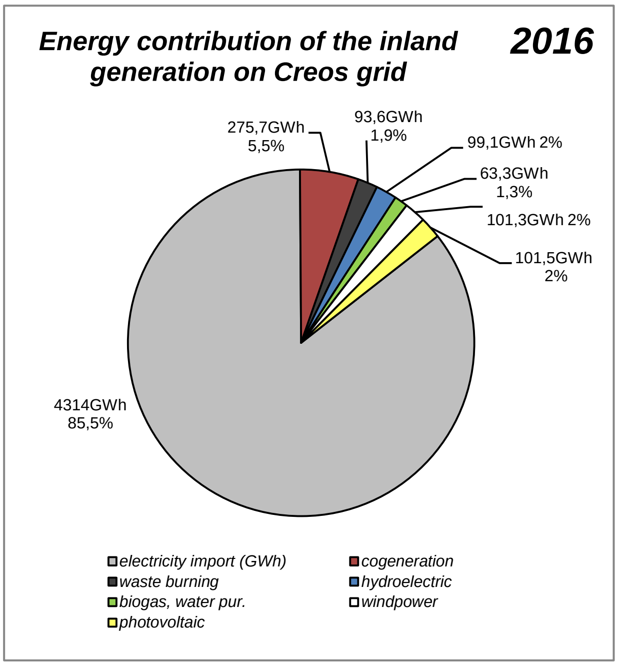
**So, the expansion of renewable energy sources is not preventing grid reinforcements, but could make them even necessary on all voltage levels**. For example, if the generation capacities exceed the grid capacities of the electricity demand.

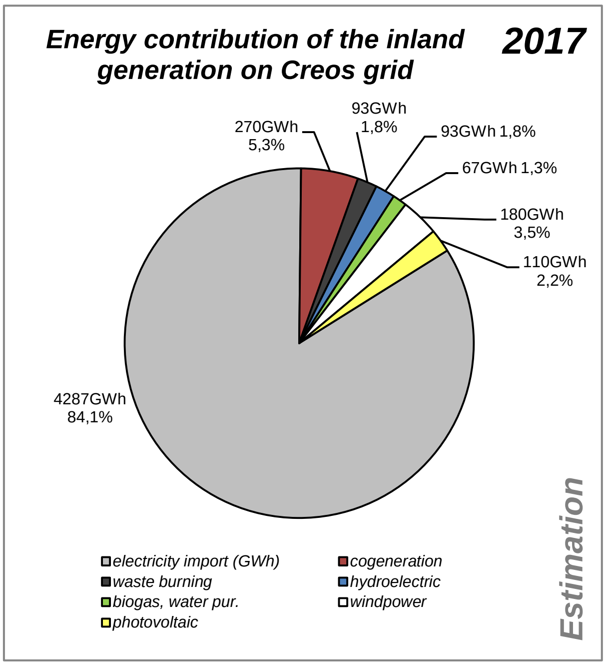
The generation varies strongly throughout the year, and is generally greatest during spring and summer months, at times where the electricity demand is not at its peak. **'Smart grids', with intelligent communication and energy storage capabilities could help smooth the discrepancy between highest generation and highest demand, but cannot prevent it completely.**

The inland electricity generation has increased during the past 4 years, with a total share from renewable energy sources surpassing the conventional generation for the first time in 2016. Even so, compared to the total electricity consumption, the yearly contribution of the total inland generation was only 14.5 percent in 2016 and is estimated to be 15.9 percent in 2017. The rest of the consumed electricity has to be imported. Please note that recent cogeneration units using biomass as primary energy form are included in the cogeneration figures.






*Source: Creos Luxembourg*

### *Future electricity generation and its contribution during peak demand*

Possible expansion scenarios of renewable energy sources have been taken over from the study 'Analysis of the potential for renewable energies' (IREES & Fraunhofer ISI institute), which was commissioned by the ministry of economy of Luxembourg. Recent projects and requests addressed to Creos Luxembourg have also been considered, especially concerning the connection requests of wind farms and turbines.

#### *Wind power*

Luxembourg will experience an exceptional high growth in wind power during the next years. If all the projects are realized as planned, at the end of the year 2020, there may be nearly three times as much wind power installed as today, passing from about 120MW to 345MW in total.

| *Year* | *2018* | *2019* | *2020* | *Up to 2040* |
|---|---|---|---|---|
| *Additionally projected power* | *+24MW* | *+149 - 158MW* | *+42MW* | *+122MW* |
| *Total installed power* | *145MW* | *294 - 303MW* | *336 - 345MW* | ***~450MW*** |

*Source: IREES/Fh-ISI / Creos Luxembourg*

#### *Photovoltaics*



The IREES study assumed a theoretical possible increase of photovoltaics of about 30$MW_{peak}$ per year until 2020. But since 2010, there have been only smaller increase figures on the Creos-Grid, except during the year 2012:

| *Year* | *2011* | *2012* | *2013* | *2014* | *2015* | *2016* |
|---|---|---|---|---|---|---|
| *Installed power per Year* | *11,8$MW_p$* | *56,2$MW_p$* | *8,9$MW_p$* | *6,8$MW_p$* | *5,6$MW_p$* | *5,6$MW_p$* |
| *Total installed power* | *41,7$MW_p$* | *97,9$MW_p$* | *106,8$MW_p$* | *113,6$MW_p$* | *119,2$MW_p$* | *124,8$MW_p$* |

*Source: IREES/Fh-ISI / Creos Luxembourg*

The annual average increase of PV was about 15$MW_{peak}$ per year in the past, with an extra total of about 14$MW_{peak}$ in project.

The long-term growth of the photovoltaics in Luxembourg is hard to predict, because the progression is still strongly influenced by government incentives.

For this study, a yearly increase of ***15$MW_{peak}$*** up to the year 2040 has been assumed.

| *Year* | *2017* | *Up to 2040* |
|---|---|---|
| *Additionally projected power* | | *+345$MW_p$* |
| *Total installed power* | *~126$MW_p$* | ***~470$MW_p$*** |

*Source: IREES/Fh-ISI / Creos Luxembourg*

### *Hydroelectric power*

According to the IREES/Fh-ISI study, an increase of the electricity generated by hydroelectric power plants up to 137GWh per year may be possible. The existing power plants with a total installed power of 38MW are generating about 121GWh of energy per year. That should make a growth of 13 percent. (+ 5MW power)

Currently there are no specific projects or inquiries to build new hydroelectric power plants or to modernize existing plants.

| *Year* | *2017* | *Up to 2040* |
|---|---|---|
| *Additionally projected power* | | *+5MW* |
| *Total installed power* | *38MW* | ***43MW*** |

*Source: IREES/Fh-ISI / Creos Luxembourg*

### *Cogeneration of heat and electricity (conventionally fuelled and solid biomass)*

Besides hydro and biomass plants, conventional thermal plants are usually the major contributors to a secured peak generation capacity. The only major thermal plant in Luxembourg has been shut down recently for economic reasons. Therefore it is unlikely that in the short or medium term, additional conventional thermal capacity will be added to the generation park in Luxembourg. Even if such capacity would be added, at least two plants were required in order to contribute to security of supply in case of saturated transmission lines. As it is very unlikely that two major conventional plants are being built within the limited timeframe until the available transmission capacity is exceeded, this option has not been further pursued in this study.



Current smaller cogeneration units, fuelled by natural gas or oil, are already getting unprofitable to operate, and are no longer desired, due to ecological aspects and the related political engagements. That’s why more and more older installations are put out of service, when major failures or defects occur.

**Without attractive incentives which encourage the construction and operation of environment friendly cogeneration units, the reliable electricity generation by those units may be decreasing severely and rapidly in near future.**

The simultaneous generation and use of heat and electricity still makes sense, as the primary energy source is optimally exploited. Only a few cogeneration units have recently been replaced by units using renewable energy sources, like biomass (for ex.: waste wood or pellets).

According to the IREES/Fh-ISI study, the feasible potential for energy generation using solid or liquid biomass is supposed to be about 1800$GWh_{th}$ per year. Between 25 and 38 percent of that thermal energy could be used electrically, which means about 500$GWh_{el}$ per year. That represents 1.7 times the current electricity generation by cogeneration units, and just as much installed power in the future.

At this day, specific projects for new biomass cogeneration units with a total power of about 30MW exist. On middle and long term, the installed power of newly build units could counterbalance the power of the units which are put out of service.

| Year | 2017 | Up to 2040 |
|---|---|---|
| Additionally projected power | | +30-75MW |
| Total installed power | 106MW (+14MW biomass) | **136-180MW** |

*Source: IREES/Fh-ISI / Creos Luxembourg*

### Biogas

The total installed power of all biogas installations is about 12MW today. The achievable target for this form of energy utilisation is approximately 370GWh$_{th}$ or 111GWh$_{el}$ per year (IREES / Fh-ISI). That corresponds to a final capacity of 22MW.

The full feasible biogas potential may not entirely be used to generate electricity. Bigger collective plants may inject the produced gas directly into the local gas lines. A share of 75 percent of the potential, being used to generate electricity, would correspond to an additional power of 7MW.

| Year | 2017 | Up to 2040 |
|---|---|---|
| Additionally projected power | | +7-10MW |
| Total installed power | 12MW | **19-22MW** |

*Source: IREES/Fh-ISI / Creos Luxembourg*



### Waste incineration

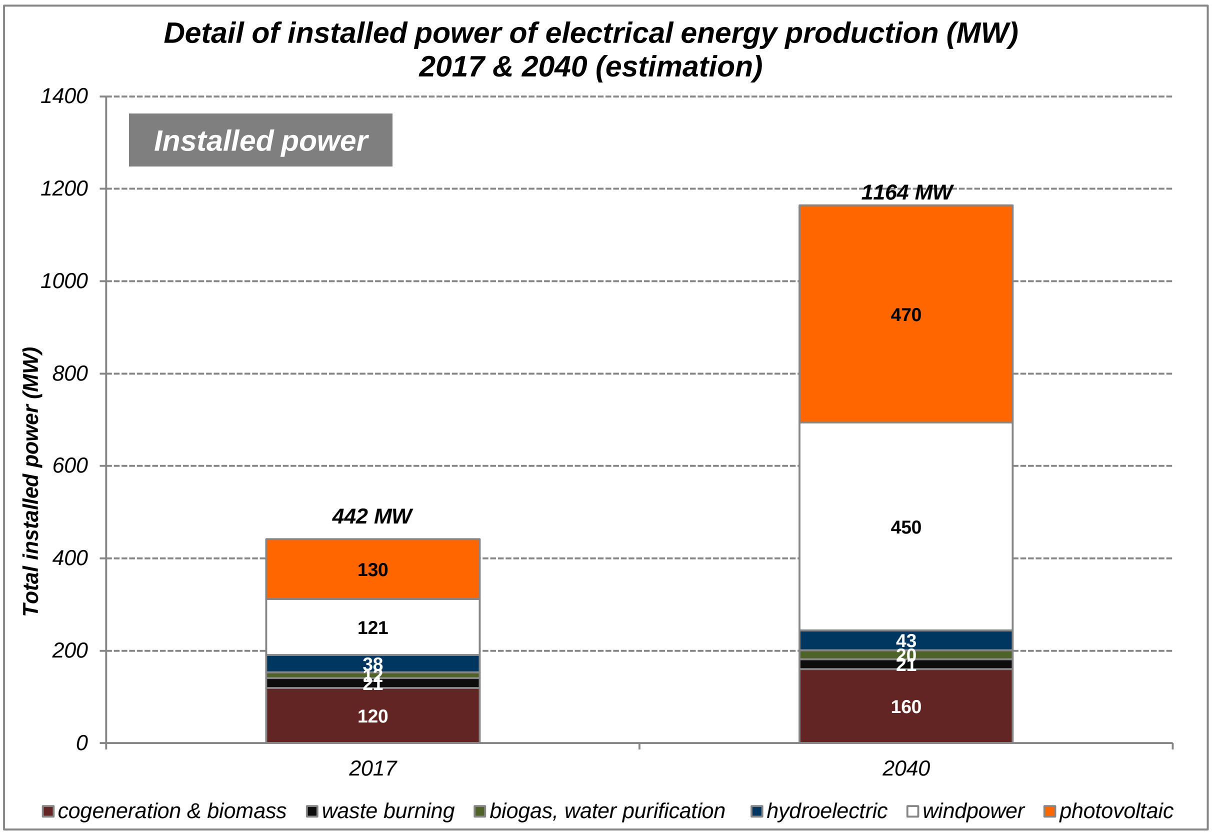
The modernisation of the waste incineration plant Sidor a few years ago has led to an up-to-date waste processing facility with a performant energy recovery system, which fulfils strict environmental regulations. The process heat can be better used and is to be fed into the local heating network. Furthermore, more electricity can be generated.

Despite the clear trend towards more waste prevention and higher recycling rates, it can be assumed that waste incineration will still be unavoidable and necessary in future in Luxembourg. But an expansion or an additional waste treatment facility is currently not planned.

| Year | 2017 | Up to 2040 |
|---|---|---|
| Additionally projected power | | |
| Total installed power | 21MW | **21MW** |

*Source: IREES/Fh-ISI / Creos Luxembourg*

Theoretically, assuming all the feasible potential from the IREES study would be realized, the total installed power of all the generation units could rise considerably until 2040:




*Source: Creos Luxembourg*



According to the IREES study, a possible inland potential of over 1100MW generation capacity in the year 2040 could suffice to cover a big part of the consumption needs, provided that all those generation units would actually inject 100 percent of their capabilities at the same time.

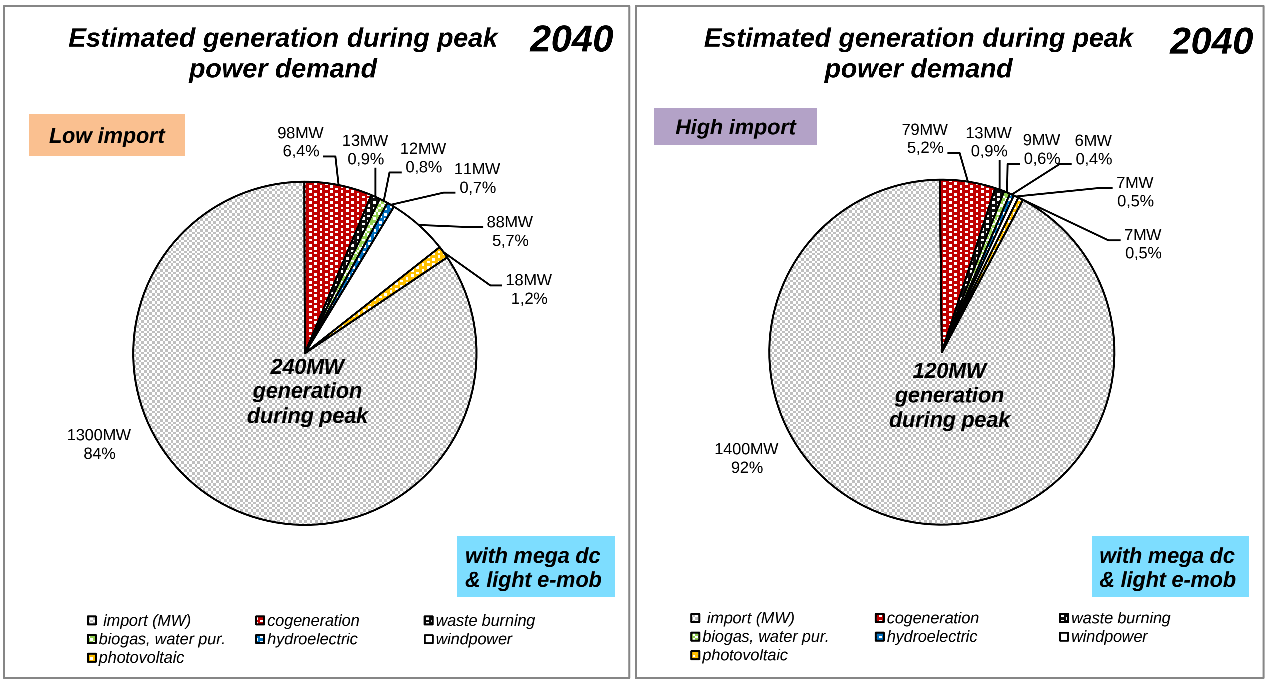
As all generation units are not injecting with their maximum power at the same time (i.e. in 2017 maximal of 57 percent of the installed power), it can be assumed that in 2040 the consumption will still be the biggest and most important component, and will be decisive for the network development.

**The Creos grids must be dimensioned for the maximum total power which could occur at any time. In the year 2040, the maximum total power on the high voltage grid will very probably manifest during a winter day, where only a moderate electricity generation will occur.**

**Regionally or locally, the situation could be quite different: The massive increase in wind turbines in the north of Luxembourg is already dictating the high voltage reinforcements for that region. And the future expansion of photovoltaics will surely require regional and local reinforcements on the low- and medium voltage grids.**

Eventually, the discrepancy between generation and demand could be smoothed out **partially** by an intelligent demand-side management and new storage technologies. **Substantial investments and an appropriate legislative framework would be necessary on those issues.** Considering the vast projected expansion of photovoltaics ($470MW_p$ representing a 100.000 households with a 4 – 5 kWp solar installation), **the vision of a self-sufficient 'prosumer' as mentioned in the Rifkin study has been taken into account.**

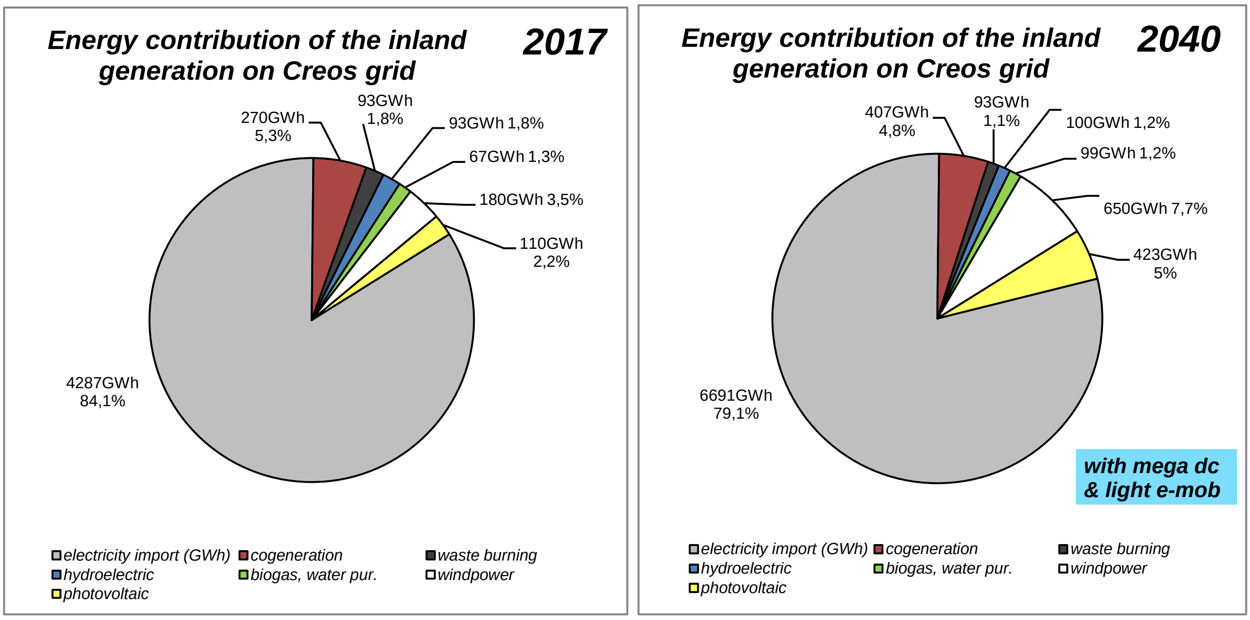
With the projected installed generation capacity for the year 2040, and the actual generation-during-peak values and experiences, the following estimated scenarios have been created:




*Source: Creos Luxembourg*

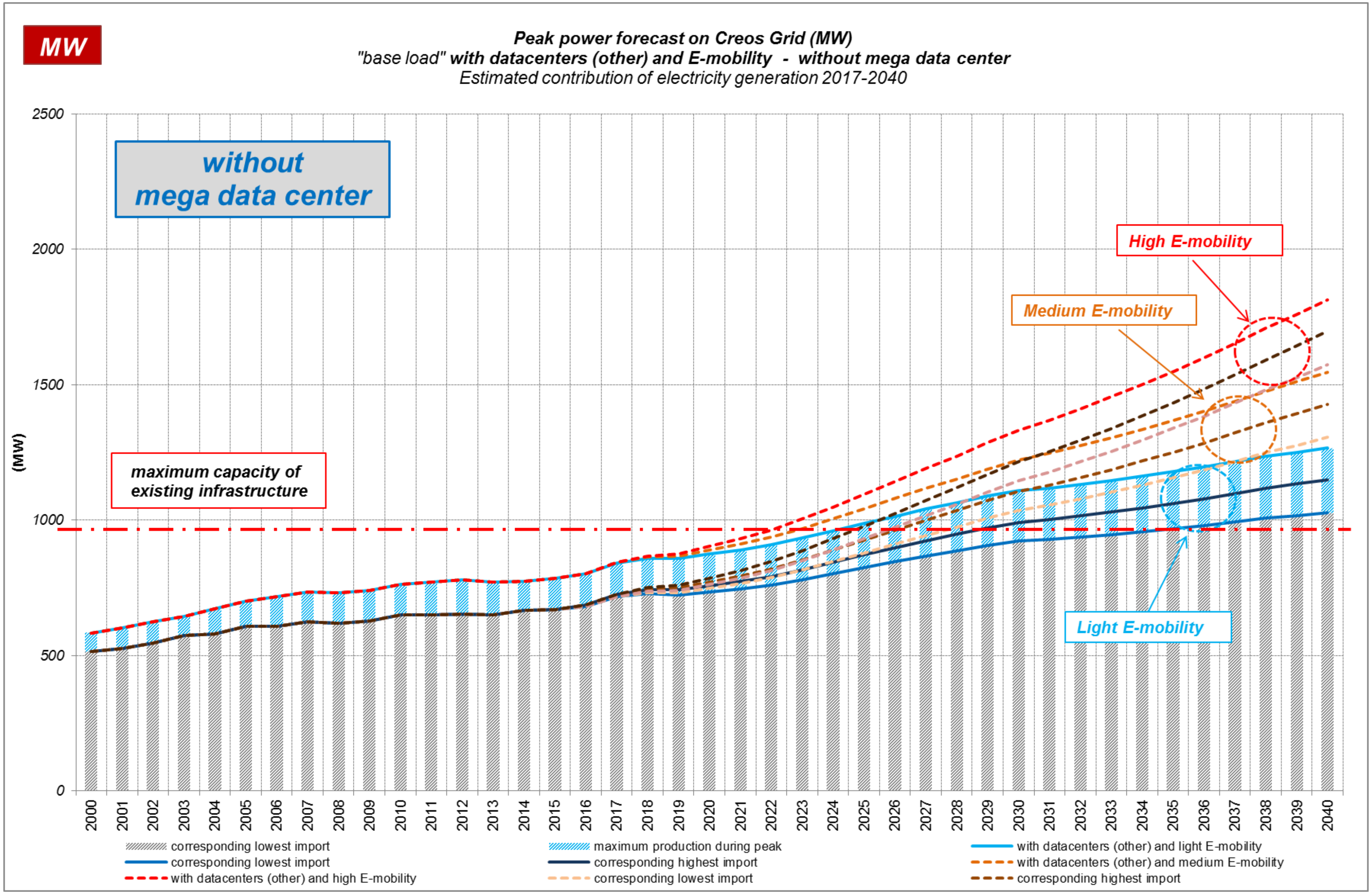
38 According to our estimates, the total generation during peak demand could rise up to 240MW in 2040. Worst case would be that the generation would stay at the same level as it is today, or would even decrease.

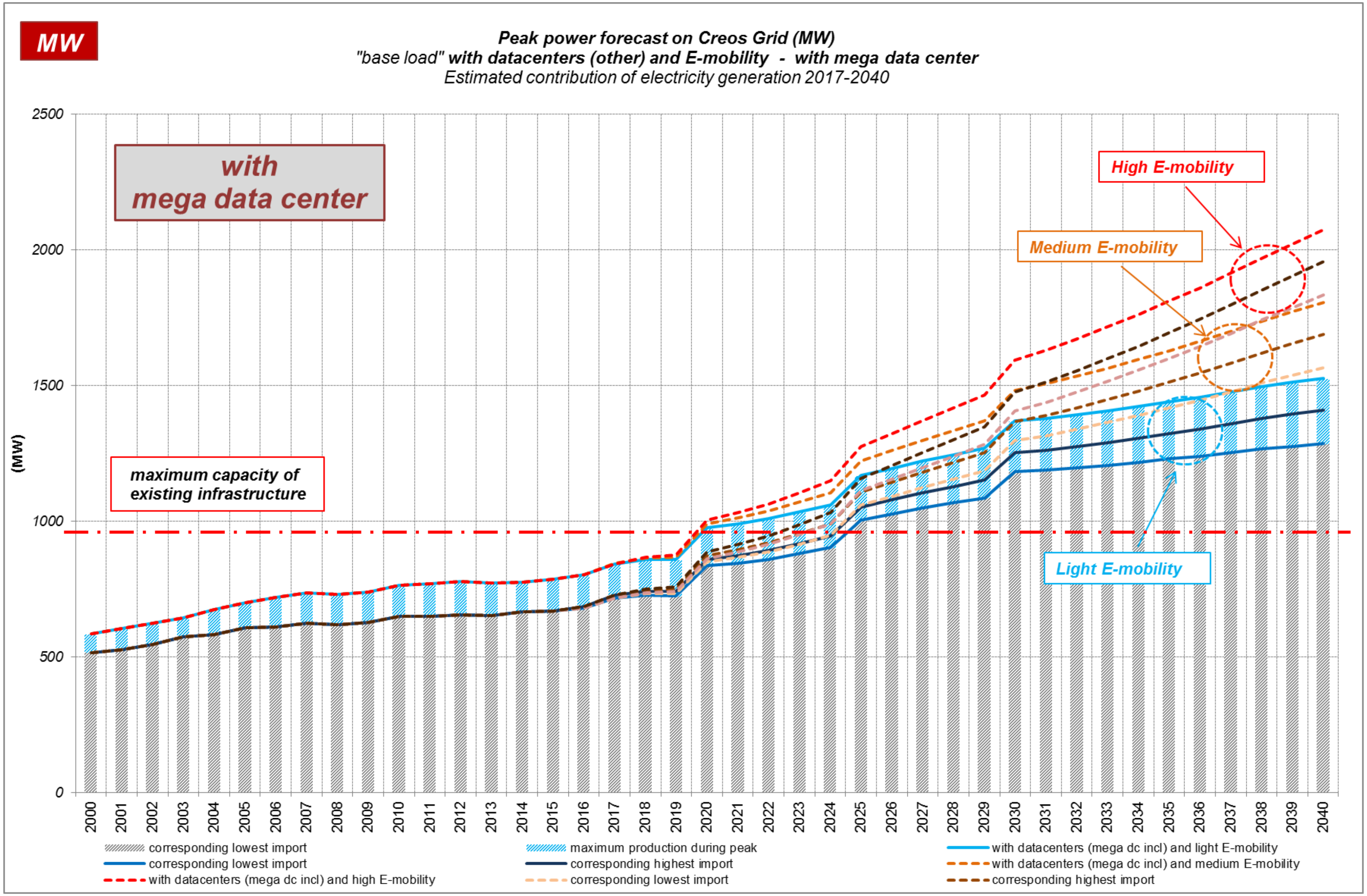
To complement, the projected evolution of the energetic contribution form the year 2017 to the year 2040 is illustrated hereafter:




*Source: Creos Luxembourg*

Finally the import projections up to 2040 have been completed with the estimated contribution of the generation (see next pages):


MW
Peak power forecast on Creos Grid (MW)
"base load" with datacenters (other) and E-mobility - without mega data center
Estimated contribution of electricity generation 2017-2040
without mega data center
maximum capacity of existing infrastructure
High E-mobility
Medium E-mobility
Light E-mobility
(MW)
2500
2000
1500
1000
500
0
2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030 2031 2032 2033 2034 2035 2036 2037 2038 2039 2040
corresponding lowest import
maximum production during peak
with datacenters (other) and light E-mobility
corresponding lowest import
corresponding highest import
with datacenters (other) and medium E-mobility
with datacenters (other) and high E-mobility
corresponding lowest import
corresponding highest import


MW
Peak power forecast on Creos Grid (MW)
"base load" with datacenters (other) and E-mobility - with mega data center
Estimated contribution of electricity generation 2017-2040
with mega data center
High E-mobility
Medium E-mobility
Light E-mobility
maximum capacity of existing infrastructure
(MW)
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1500
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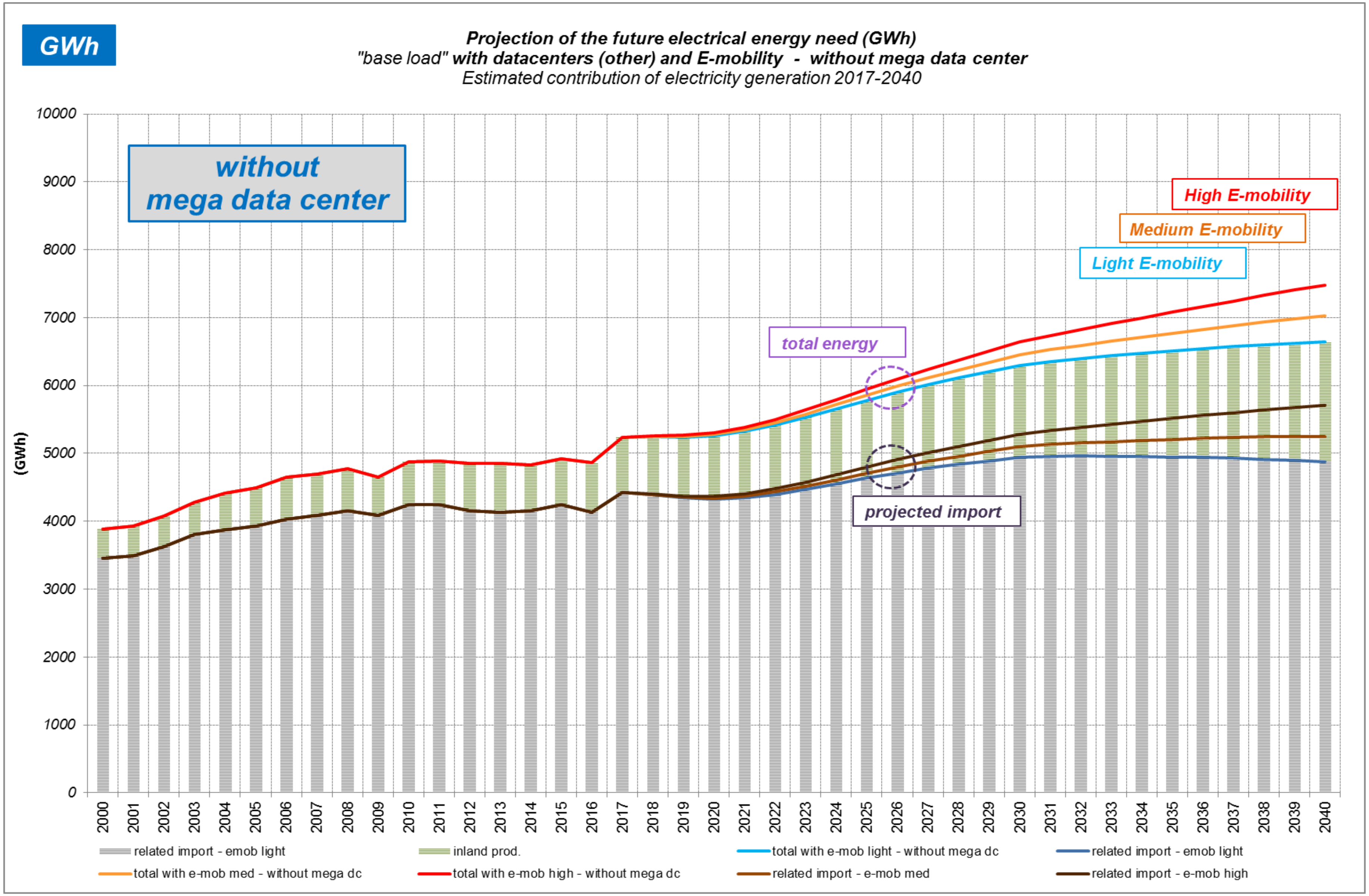
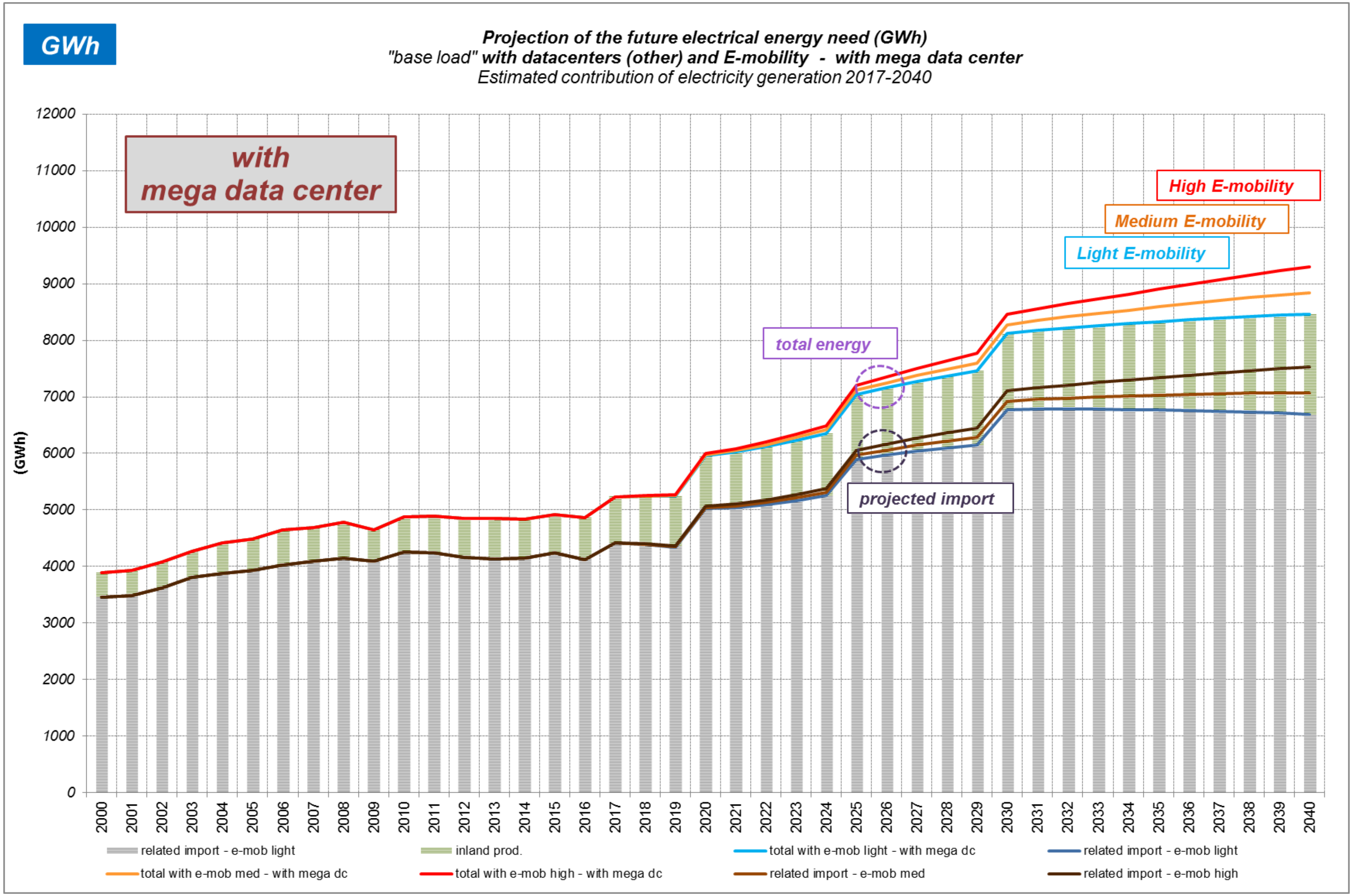
corresponding lowest import
maximum production during peak
with datacenters (mega dc incl) and light E-mobility
corresponding lowest import
corresponding highest import
with datacenters (mega dc incl) and medium E-mobility
with datacenters (mega dc incl) and high E-mobility
corresponding lowest import
corresponding highest import


GWh
Projection of the future electrical energy need (GWh)
"base load" with datacenters (other) and E-mobility - without mega data center
Estimated contribution of electricity generation 2017-2040
without mega data center
High E-mobility
Medium E-mobility
Light E-mobility
total energy
projected import
(GWh)
related import - emob light
inland prod.
total with e-mob light - without mega dc
related import - emob light
total with e-mob med - without mega dc
total with e-mob high - without mega dc
related import - e-mob med
related import - e-mob high


GWh
Projection of the future electrical energy need (GWh)
"base load" with datacenters (other) and E-mobility - with mega data center
Estimated contribution of electricity generation 2017-2040
with
mega data center
High E-mobility
Medium E-mobility
Light E-mobility
total energy
projected import
(GWh)
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2000
3000
4000
5000
6000
7000
8000
9000
10000
11000
12000
2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030 2031 2032 2033 2034 2035 2036 2037 2038 2039 2040
related import - e-mob light
inland prod.
total with e-mob light - with mega dc
related import - e-mob light
total with e-mob med - with mega dc
total with e-mob high - with mega dc
related import - e-mob med
related import - e-mob high

## Summary and Recommendations

The 220kV supply lines coming from Bauler/Niederstedem and Trier/Quint have a secured transmission capacity of about 1000MW.

**Today about 75% to 85% of this total transmission capacity is already used.**

Even with better energy efficiency, **the growth of the economy and of the population will undeniably lead to more electricity needs.**

**The development of electrical transportation will also imply a huge increase of the electrical energy needs.**

According to our projections, a high acceptance of e-mobility could double the peak load on the electrical grid.

**Further investments in renewable energies will not result in relevant reductions of the peak loads on the electrical grids.**

The reliable, steady part of the electricity generation during the peak demand is declining, which further aggravates the situation.

**The extraordinary load due to an interconnection between the Creos high voltage grid and the industrial electrical grid of Sotel, and a surplus load due to an energy transit from Germany to Belgium over the national high-voltage network have not been integrated in the projection curves. Both would be beneficial for transport cost reduction.**

According to our assessment, with the steady increase of the electricity consumption and with the commitment to supply the promised needs of the Mega Datacenter,

**The cross-border interconnection capacities will be depleted from the year 2025 on.**

Without the Mega Datacenter, the capacities will still be depleted 3 to 4 years later.

**So, as the construction and operation of at least two conventionally fuelled, major power plants are not desired, it is clearly necessary to increase the transmission capabilities of the existing high-voltage supply lines and/or to build a new additional supply line with enough capacity for future needs.**

**In order to secure the electrical power supply of Luxembourg in the mid and long term, and to avoid any unnecessary double investments, we therefore propose to:**

- ***Replace the existing 220kV lines from Trier/Quint by stronger higher voltage level lines (400kV)***
- ***Reinforce the existing 220kV lines coming from Bauler/Niederstedem***
- ***Extend, on the long term, the new 400kV grid towards the neighbouring countries (Belgium)***

With a strong additional 400kV injection and a grid extension towards Belgium, the extraordinary load of Sotel with 280MW could be connected and a cross-border transit of 200MW to 400MW could be tolerated. Both would have a positive impact on the network fees.