LE GOUVERNEMENT
DU GRAND-DUCHÉ DE LUXEMBOURG
Ministère de l'Énergie et de
l'Aménagement du territoire

Long-term renovation strategy for Luxembourg

Long-term renovation strategy (LTRS)

In accordance with Directive (EU) 2018/844 of the European Parliament and of the Council of 30 May 2018 amending Directive 2010/31/EU on the energy performance of buildings and Directive 2012/27/EU on energy efficiency.

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1. Executive summary

This document contains Luxembourg's long-term renovation strategy (LTRS) for residential and non-residential buildings, both private and public, in line with the requirements of Article 2a of Directive (EU) 2018/844. According to the Directive, the LTRS is intended to support the renovation of the national stock of buildings to an extremely high standard of energy efficiency and to replace fossil fuels for heating with renewable energies, in both cases as cost-effectively as possible. The buildings sector is responsible for approximately 36% of all CO2 emissions in the Union (Directive on the energy performance of buildings (EPBD), 2018), and the long-term renovation strategy is accordingly a key factor in progress towards the EU's target of achieving a socially just transition to net-zero greenhouse gas (GHG) emissions by 2050.

Luxembourg's LTRS clarifies in greater detail the goals and measures set out in Luxembourg's National Energy and Climate Plan (NECP) 2020(NECP, 2020) for the buildings sector and describes how the sector – in particular through the renovation of buildings – can help to achieve the national targets of a 55% reduction in GHG emissions and a 40–44% reduction in final energy demand compared to EU PRIMES 2007 (DGET, 2008) by 2030, and the more ambitious long-term targets by 2050 at the latest.

According to the NECP, energy savings associated with building renovations hold the joint second-largest potential for cumulative energy savings by 2030 (together with energy savings in the Transport sector).

Sector	GWh	%
Transport	9 618	66.4%
Industry	863	6.0%
Commerce, trade and services	986	6.8%
Private households	3 013	20.8%
- of which regulatory provisions governing new builds	*834*	*5.8%*
- of which regulatory provisions governing existing buildings	*532*	*3.7%*
- funding for building envelope	*944*	*6.5%*
- funding for heating system	*702*	*4.8%*
Total	14 480	100.0%

Figure 1: Cumulative energy savings by 2030, broken down by sector (NECP, 2020)

The LTRS contains an up-to-date analysis of the country's building stock and outlines recent developments in relation to strategic planning and the design of implementing measures. It is intended to consolidate previous work performed in these areas. The most important stakeholders have been involved in its drafting, and the measures it describes will be implemented on a gradual basis over the coming months.

Luxembourg’s new-build and demolition rates are well above those of other EU Member States. This can be attributed to the strong economic growth recorded by the country and the resulting strong population growth (in relative terms, Luxembourg has the strongest population growth of any OECD country, outpacing even Mexico). To ensure that this large stock of new builds is constructed using ‘climate-friendly’ methods, Luxembourg – as the first country in the EU – introduced the ‘near zero energy building’ (NZEB) standard on a mandatory basis for residential buildings on 1 January 2017. Early introduction of this demanding standard has allowed Luxembourg to achieve CO2 emission reductions in the residential buildings sector in spite of population growth. In summer 2020, this successful policy will be supplemented by a new regulation that introduces climate-neutral standards on a mandatory basis for new builds in both the residential and non-residential sector; these standards will be rolled out gradually between 2020 and 2023.

Although the combination of a high demolition rate and a high standard for new builds means that a larger proportion of energy and climate reductions are achieved in Luxembourg’s buildings sector than in other EU Member States, the country still faces substantial renovation-related challenges. To remain within the target corridor for the 2030 and 2050 climate targets, Luxembourg must significantly increase both the redevelopment depth (the amount of energy saved compared to the pre-redevelopment condition) and the redevelopment rate (how many buildings are renovated per year). ‘Business as usual’ alone will not suffice.

To accelerate progress in this area, a whole range of well-integrated implementing tools will need to be put into practice, including the following:

- regulatory provisions (regulations and standards),
- promotional and funding instruments,
- tax instruments,
- training,
- awareness raising and publicity work,
- research and model projects.

The various tools will be aligned with each other in such a way that the combination of their impacts is mutually reinforcing.

From a technical perspective, emphasis is placed on energy-related improvements to the building envelope (insulation) and improvements to the energy efficiency of technical installations, with a particular focus on fossil-free energy sources (replacement of old heating systems based on fossil fuels). Accompanying measures such as further training, awareness raising and research are aimed at identifying and foregrounding savings potentials, and at highlighting possible improvements and supporting measures.

Alongside the impact on energy savings and climate, a further key indicator for assessing the mix of measures is the impact on those individuals who live in and use the buildings, in particular those who are at risk of energy poverty because their incomes are low but their energy consumption is relatively high. An analysis of energy poverty in Luxembourg is thus a key component of this LTRS. The analysis reveals that Luxembourg is among the EU Member States with the lowest rates of energy poverty. According to Eurostat, around 5 000 households in the country are unable to heat their homes appropriately or need to rely on State benefits to pay their fuel bills. An analysis of the energy poverty situation also reveals that the problem is caused not by energy prices (price per litre of heating oil or per cubic metre of gas), since Luxembourg has some of the lowest energy costs in the EU in terms of absolute value, and particularly in terms of purchasing power parities; but rather the main cause of an inability to pay fuel bills is the fact that rents have been rising at a significantly faster rate than purchasing power in recent years, particularly in the lower income brackets.

Based on the analyses carried out in connection with the drafting of the LTRS, the following implementing measures have been identified as priorities:

Regulatory provisions:

- introduction of stricter minimum requirements in terms of thermal insulation for individual components in the form of new energy efficiency regulations (for non-residential buildings from 2021 and for residential buildings from 2023);
- checks to ensure that renovation works comply with the requirements (energy passport checks) (revision of existing system of checks);
- introduction of ‘renovation passports’ (renovation roadmap) to ensure that the overall sum of individual measures gradually results in full renovations with a sufficient depth (‘deep renovation’);
- obligation to build up financial reserves for the renovation of owner-occupied and rented apartments (based on the example of Austria’s ‘Maintenance and Improvement Contribution’);
- reduction in the quorums for majority decisions in co-owned multi-family dwellings;
- hiatus in the expansion of gas networks in residential areas;
- requirement to install photovoltaic systems on all public buildings by 2030 (with the exception of buildings protected as historical monuments);
- preparatory measures for the installation of photovoltaic systems on the roofs of other non-residential buildings during redevelopments (with the exception of buildings protected as historical monuments and heavily shaded buildings) from 2023.

Promotional and funding instruments

- revision of the PRIMe House scheme for residential buildings: funding of individual measures for building envelope components in combination with a tightening up of minimum efficiency standards (heavily scaled to promote high levels of performance);
- ‘zero-interest climate loan’ for renovations under the PRIMe House scheme to be rolled out to all households (instead of just low-income households);
- access to the PRIMe House funding scheme for certified tradespeople who carry out individual measures; access to a bonus for full renovations provided that a certified energy consultant is consulted, with a significant increase in the funding available for consultation costs;
- funding for energy-efficiency measures in buildings protected as historical monuments;
- PRIMe House funding in combination with a switch to renewable energy carriers (‘mazut replacement scheme’).

Tax law

- gradual introduction of CO2 pricing from 2021 onwards;
- harmonised reduced VAT rate of 3% for energy renovations that comply with the requirements of the PRIMe House scheme for residential buildings;
- further incentives for renovations by owners, such as accelerated depreciation allowances.

Training

- training on the energy-efficient optimisation of non-residential building redevelopments;
- training on ways to reduce demand for cooling energy as a means of adapting to future climate change.

Awareness raising and publicity work

- further development of the existing ‘myrenovation’ app for residential buildings;
- information campaign on energy efficiency in non-residential buildings in connection with the introduction of the new regulations.

Research and model projects

- prefabrication of the components required for renovations with a view to shortening the time frame of renovations and combating labour shortages, in cooperation with other countries;
- model projects for the redevelopment of residential developments with poor energy ratings and heating systems based on fossil fuels:
  - trial of funding schemes based on energy performance contracting;
  - opening up of the PRIMe House funding scheme to cover measures implemented by contractors;
  - more generous recognition of CO_2 savings achieved through renovations carried out by energy suppliers (measure currently under consideration);
  - strict energy-related requirements under the PRIMe House funding scheme;
- model projects involving highly energy efficient and economical renovations of non-residential buildings.

Success stories in the new residential buildings sector can be used as a foundation for implementing the aforesaid measures. Luxembourg has succeeded in introducing one of the most ambitious standards in Europe in this market segment within a period of around 10 years.

As noted above, the LTRS is intended to serve as a basis for summarising, clarifying and further developing implementing measures. The most important stakeholders in the sector are involved in this process by means of regular workshops.

A ‘Renovation Day’ event was planned for May 2020 for the purpose of allowing public participation, but this event could not take place as a result of COVID-19 restrictions. Since a comprehensive public participation process in relation to the topics covered in the LTRS was carried out when drafting the previous version of the building renovation strategy 3 years ago and when drafting the NECP in 2019, it was decided that a similar process involving events aimed at providing information on forthcoming implementing measures (e.g. details of the revised PRIMe House funding scheme) should be carried out in autumn 2020 (subject to COVID-19 restrictions), and at the latest in spring 2021.

Additional key steps during the drafting of the renovation strategy included a detailed analysis of the current non-residential building stock and systematic evaluations of energy-related data from the energy passport database and other sources. Energy demand/consumption data and energy generation data are to be localised in a geographic information system on this basis.

2. Background, objective, procedure and structure of the document

2.1. Background

The Union is committed to developing a sustainable, competitive, secure and decarbonised energy system by 2050. In its strategic long-term vision for Europe, the Commission describes a cost-effective method of achieving a socially just transition to net-zero GHG emissions by 2050 (Kommission, 2018).

Since the buildings sector is responsible for approximately 36% of all CO_2 emissions in the Union(EPBD, 2018), the LTRS is a key factor in progress towards this target. In order to decide on the measures to be taken, Member States and investors alike require clear visions with national and sectoral targets and milestones that can be used as a basis for preliminary quantifications and ex-post evaluations of the short-term (2030), medium-term (2040) and long-term (2050) effects.

Article 2a of Directive (EU) 2018/844 of the European Parliament and of the Council of 30 May 2018 states the following; '*Each Member State shall establish a long-term renovation strategy to support the renovation of the national stock of residential and non-residential buildings, both public and private, into a highly energy efficient and decarbonised building stock by 2050, facilitating the cost-effective transformation of existing buildings into nearly zero-energy buildings.'* (EPBD, 2018), (Berichtigung, 2018). The term 'decarbonised building stock' is not defined in Directive (EU) 2018/844 (EPBD), but is clarified in the Commission Communication of 20 June 2019 as follows: *'A "decarbonised" building stock is not defined in EU legislation, but it can be considered as one whose carbon emissions have been reduced to zero, by reducing energy needs and ensuring that remaining needs are met to the extent possible from zero-carbon sources'* (EU, 2019).

2.2. Objective of the document

The objective of this document is to outline Luxembourg's long-term renovation strategy for residential and non-residential buildings, both private and public, in accordance with the requirements set out in Article 2a of Directive (EU) 2018/844. According to the Directive, the LTRS is intended to support the cost-effective renovation of the national stock of buildings into a highly energy efficient and decarbonised building stock (nearly zero-energy buildings).

Based on an analysis of the country's current building stock, a roadmap with measures and progress indicators must be produced as a foundation for preliminary impact assessments and ex-post evaluations. The strategy should be aimed at achieving the EU's long-term target of reducing total GHG emissions in the Union across all sectors by 80–95% (target year: 2050, reference year: 1990). According to the Directive, the long-term renovation strategy must contain a roadmap with milestones for 2030, 2040 and 2050.

A further aim of the document is to analyse the current progress in developing a coherent long-term renovation strategy and implementing measures aligned with this strategy for the entire building stock, with a view to identifying any questions that have not yet been resolved and any sectors or market segments where action is still required.

2.3. Data reporting limitations

The LTRS outlines Luxembourg's long-term strategy for renovating buildings. Unless otherwise indicated, the figures for final energy consumption referred to in this document therefore relate to the following energy uses:

- residential buildings: heating, hot water, auxiliary power for building services (pumps, ventilators, etc.), domestic electricity;
- non-residential buildings: heating, cooling, hot water, lighting, electrical consumers such as lifts, IT equipment, etc.

Demand/consumption in non-residential buildings for non-building-related uses (process heat, power (electricity) for production processes) included under the 'commerce, trade and services' sector or the 'tertiary' heading in Luxembourg's statistics are irrelevant in terms of the LTRS and will not therefore be examined.

2.4. Specific features of Luxembourg

In order to gain a better understanding of the long-term renovation strategy outlined in this document and the way it fits into Luxembourg's overall strategy for the buildings sector, it is important to acknowledge certain specific features of Luxembourg which mean that the new builds sector in this country is significantly more important than in other EU Member States.

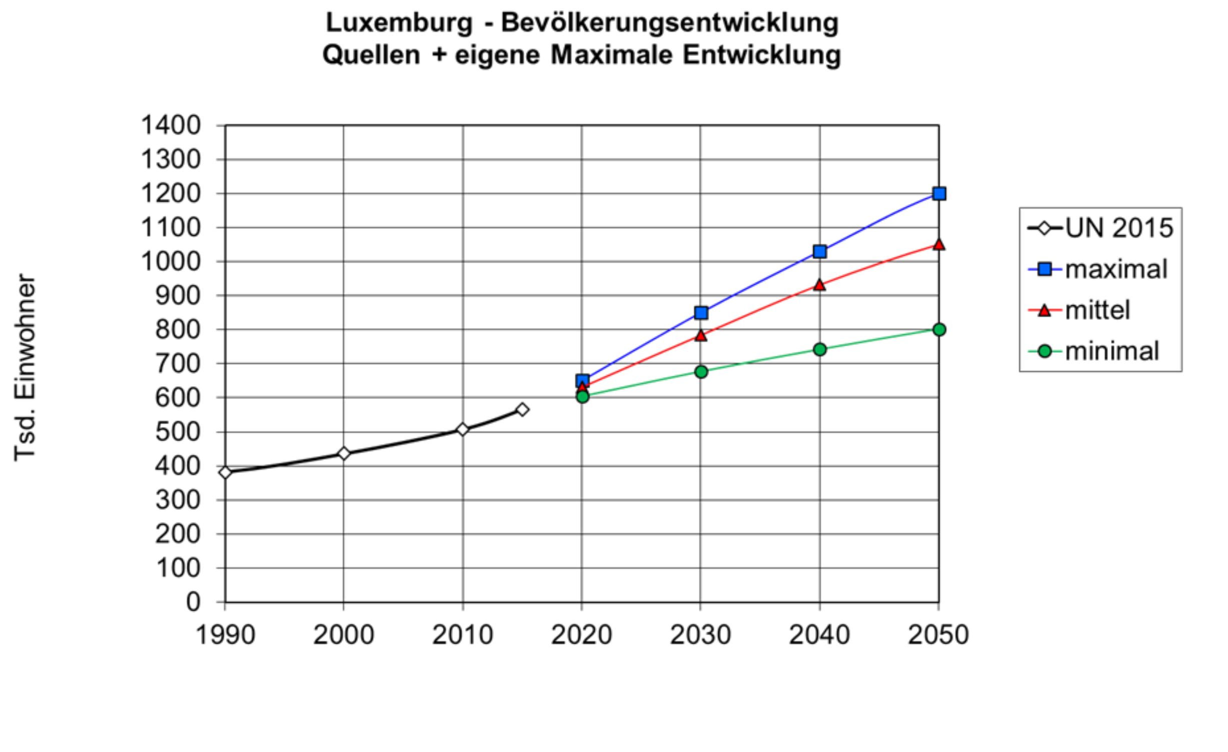
2.4.1. Strong economic growth

Average real gross domestic product (GDP) growth was very high in Luxembourg between 2000 and 2018 (over 3.1%)(STATEC, 2019).

2.4.2. Rapid population growth and rapid increase in living space and useful floor area

The population of Luxembourg is expanding very quickly as a result of strong economic growth and high demand for labour. A very rapid upturn in total living space has been observed as a consequence of this population growth, and the same is true for the non-residential building stock.

The data relating to population growth and the increase in total living space were investigated in detail and on the basis of official statistics in a study published in 2017 (Ploss, 2017). Figure 2 shows population trends to date and the changes forecast by various studies over the period until 2050.

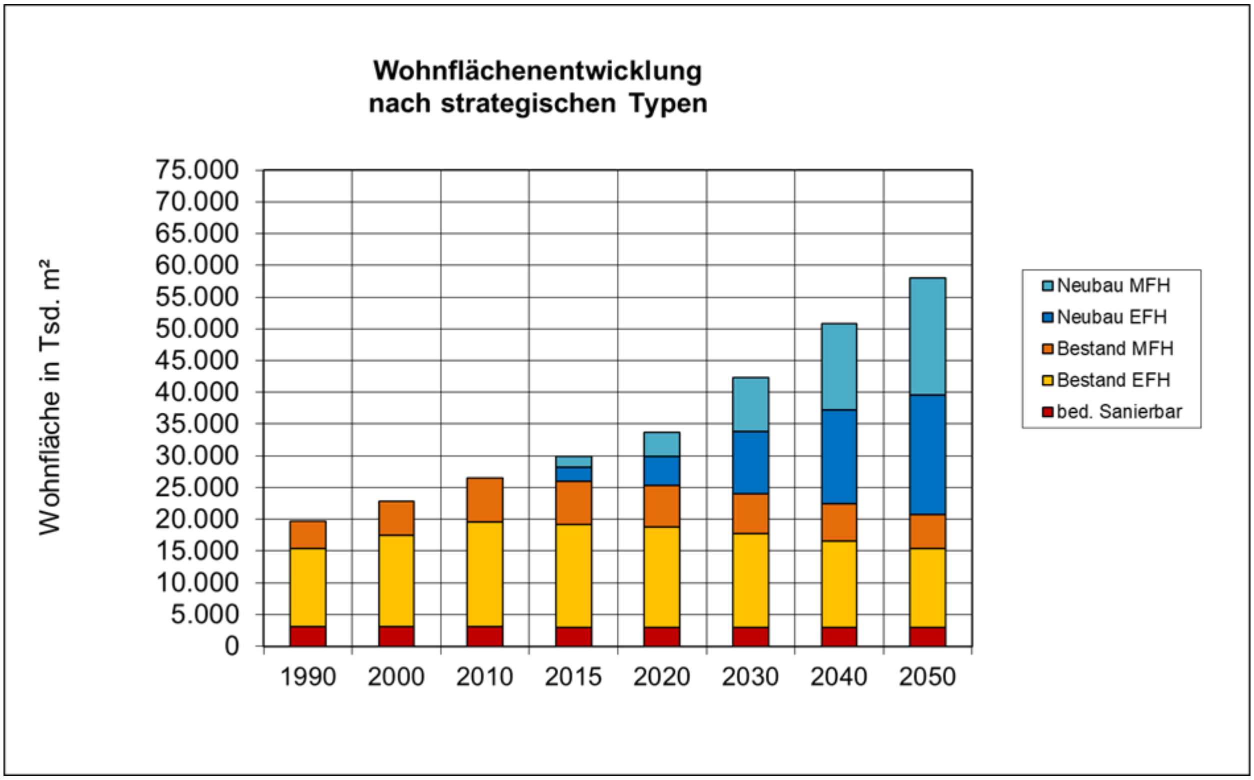


Luxemburg – Bevölkerungsentwicklung Quellen + eigene Maximale Entwicklung	Luxembourg – Population trends Sources + own calculations for maximum growth
Tsd. Einwohner	Thousand inhabitants
UN 2015	UN 2015
maximal	maximum
mittel	average
minimal	minimum

Figure 2: Population trends in Luxembourg over the period 1990–2050 (Ploss, 2017)

Luxembourg's population rose from just under 400 000 in 1990 to 567 000 in 2015; it topped 600 000 for the first time in 2018. According to current forecasts, population growth will continue to be extremely strong, and it is anticipated that the population in 2050 will be between 800 000 and 1 200 000.

Figure 3 shows the impact of population growth and demographic trends (e.g. the trend towards smaller households) on changes in total living space (Ploss, 2017). The data are broken down into five strategic residential building types. As well as the increase in area resulting from new builds, account has also been taken of the decrease in area resulting from the demolition of existing buildings. The annual demolition rate is assumed to be 0.85% of the total building stock, in line with the figures taken from the Third NEEAP, which was published in 2014 (NEEAP3, 2014). A lower demolition rate of 0.1% per annum has been used for the sub-segment of buildings that can only be redeveloped to a limited extent (buildings protected as historical monuments or listed groups of buildings, etc.), by way of derogation from the Third NEEAP.



Wohnflächenentwicklung nach strategischen Typen	Changes in living space, broken down by strategic types
Neubau MFH	New-build multi-family dwellings
Neubau EFH	New-build single-family dwellings
Bestand MFH	Stock of multi-family dwellings
Bestand EFH	Stock of single-family dwellings
bed. Sanierbar	Buildings that can only be renovated to a limited extent

Figure 3: Changes in living space in Luxembourg between 1990 and 2070, broken down by strategic types *(Ploss, 2017)*

Total living space in Luxembourg was around 30 million m^2 in 2015. Owing to strong population growth, it will increase to around 57 million m^2 by 2050(Ploss, 2017).

Based on the assumed demolition rate, the area covered by the building stock that was present in 2015 will account for around 35% of the total building stock present in 2050. In terms of area, a large majority (65%)

of the residential building stock present in 2050 will have been constructed after 2015, i.e. after the introduction of extremely ambitious and mandatory new-build standards in Luxembourg.

The latest research by STATEC corroborates the trend described above; depending on GDP growth, the annual demand for new builds will range from 7 310–5 881 residential units/year (GDP growth 1.5%) to 7 310–6 567 residential units/year (GDP growth 3%) between 2020 and 2050 (Peltier, 2019). Demand for new builds is expected to drop slightly between 2020 and 2050. The figures predicted by STATEC are 1.5 times higher than the historical maximum for new residential builds (around 4 400 residential units per year). Given that the population currently stands at around 610 000, this corresponds to approximately 7.2 residential units/1 000 inhabitants.

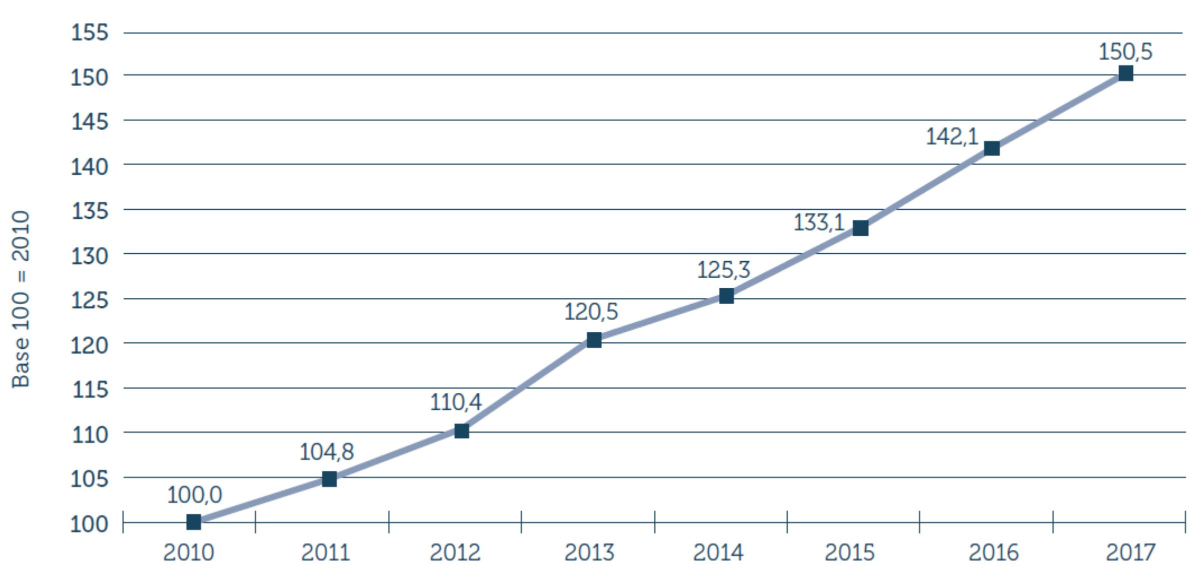
As a result of very strong economic growth, a similar trend has emerged in respect of useful floor area. This too will continue to increase rapidly, meaning that the current building stock will account for a significantly lower proportion of the total non-residential building stock in 2050 than in other EU Member States.

No attempt will be made to quantify potential changes in the floor area of non-residential buildings, since the data available regarding the current situation are significantly less accurate than the data available for the residential buildings sector.

2.4.3. Rapidly increasing land prices

As can be seen from Figure 4, the prices for plots of land rose by 50% between 2010 and 2017.

Graphique 6 – Evolution de l'indice des prix des terrains à bâtir en zone à vocation résidentielle

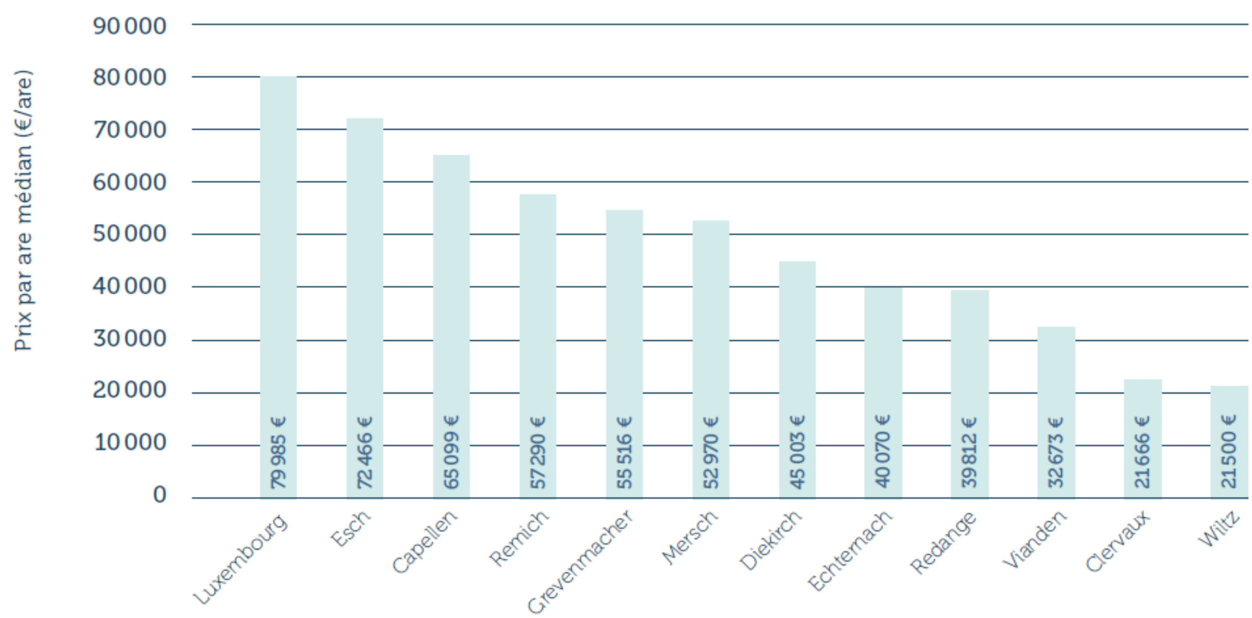


Graphique 6 – Evolution de l'indice des prix des terrains à bâtir en zone à vocation résidentielle	Figure 6 – Price index changes for plots of land designated for residential use

Figure 4: Price index changes for plots of land designated for residential use (Observatoir, 2019)

The following figure shows prices in a number of different municipalities.

Graphique 7 – Prix médians des parcelles situées essentiellement en zone résidentielle par canton, entre le 01.01.2016 et le 31.12.2017



Graphique 7 – Prix médians des parcelles situées essentiellement en zone résidentielle par canton, entre le 01.01.2016 et 31.12.2017	Figure 7 – Average price of plots located mainly in residential zones, by canton, between 1 January 2016 and 31 December 2017

Figure 5: Prices in EUR/100 m2 for plots of land designated for residential use in various municipalities (Observatoir, 2019)

Rapidly increasing prices, particularly in more urban areas, mean that there is rising pressure to demolish existing buildings and to replace them with new builds in denser developments. This suggests that the demolition rate is likely to continue its upward trend.

2.4.4. High purchasing power

In 2017, Luxembourg's per capita GDP was equivalent to around 250% of the EU-28 index (STATEC, 2019). This means that purchasing power is very high, even taking into account the price level index of 127%.

This high purchasing power meant that all of the residential units completed over the past few years were sold, despite a sharp rise in construction and land costs.

2.4.5. Summary: above-average importance of the new-build sector in Luxembourg

Owing to the specific features of Luxembourg, which include:

- strong economic growth;
- rapid population growth and rapid increase in living space and useful floor area;
- trend towards high demolition rates due to steeply rising land prices;
- high purchasing power;

new builds (constructed between 2020 and 2050) will account for a much higher proportion of the total residential and non-residential building stock by 2050 in Luxembourg than in other EU Member States. This will increase yet further the importance of the new-build market segment compared to that of the existing building stock.

This comparison is not intended to downplay the significance of the existing building stock and the long-term renovation strategy. However, it confirms that the strategic decision to start by introducing ambitious standards for new builds was correct given the rapid increase in living space.

These standards for residential buildings (which are extremely stringent compared to those in force in other EU Member States) were successfully implemented as minimum standards in 2017, and similarly ambitious standards will be introduced from 2021 onwards for non-residential buildings. This means that a policy shift towards the development of strategies and measures targeting the various market segments covering the existing building stock is appropriate. The interim outcomes of this process are reported in this document where available.

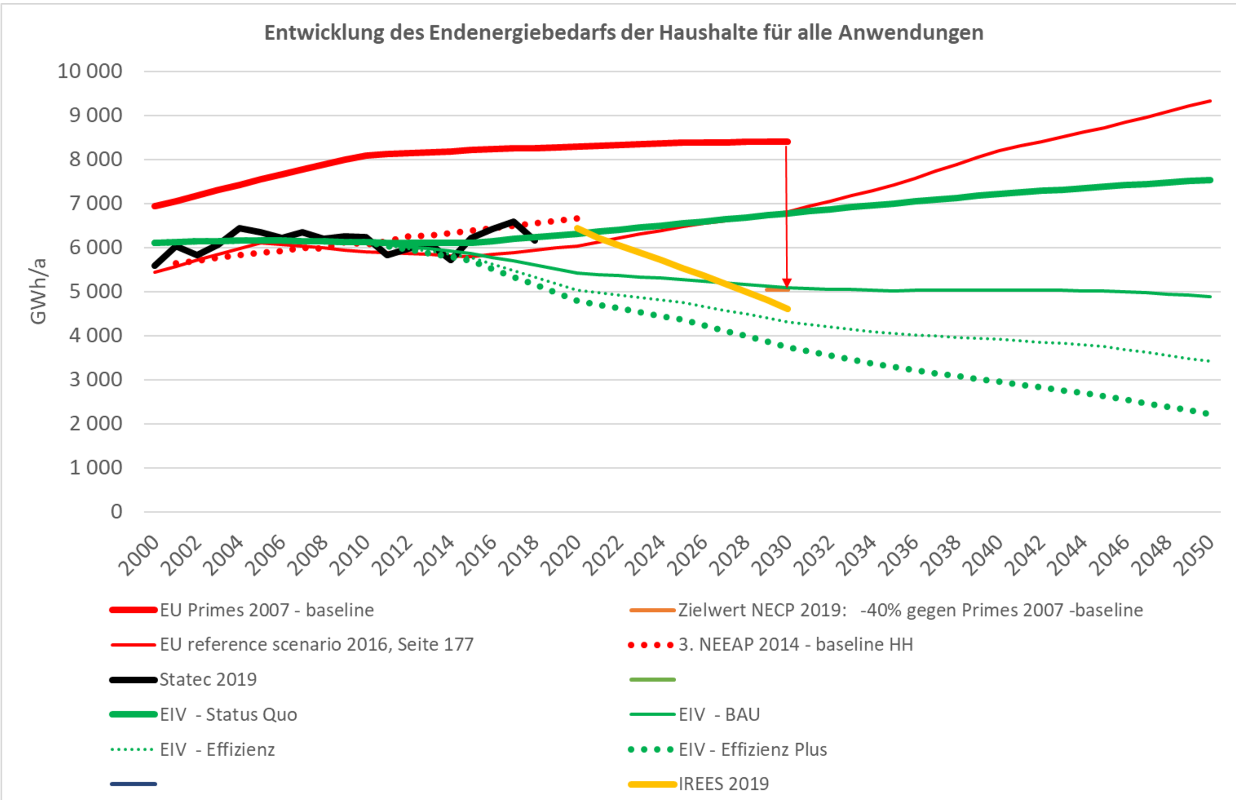
2.5. National energy efficiency targets

2.5.1. Residential buildings (households sector)

The current national energy efficiency targets for 2030 are set out in the NECP 2019 (NECP, 2020). Demand in the households sector and the commerce, trade and services sector is of decisive importance for the long-term renovation strategy.

The following figure shows the pattern of real final energy consumption by household for heating, hot water, auxiliary power and domestic electricity (STATEC, 2019). For comparison purposes, the target value specified in the NECP 2019 is also shown (-40% compared to the baseline figure in EU PRIMES 2007) (DGET, 2008).

The EU's most recent projections (dating back to 2016) (Capros, 2016) and the results of the four scenarios investigated in a study carried out by the Vorarlberg Energy Institute in 2017 are also included(Ploss, 2017).



Entwicklung des Endenergiebedarfs der Haushalte für alle Anwendungen	Changes in final energy demand by households for all uses
GWh/a	GWh/a
EU Primes 2007 – baseline	EU PRIMES 2007 – baseline
EU reference scenario 2016, Seite 177	EU reference scenario 2016, Page 177
Statec 2019	STATEC 2019
EIV – Status Quo	Vorarlberg Energy Institute – Status Quo scenario
EIV Effizienz	Vorarlberg Energy Institute – Efficiency scenario
Zielwert NECP 2019: -40% gegen Primes 2007 – baseline	Target under NECP 2019: -40% compared to PRIMES 2007 – baseline
3. NEEAP 2014 – baseline HH	Third NEEAP 2014 – baseline for households
EIV – BAU	Vorarlberg Energy Institute – BAU scenario
EIV Effizienz Plus	Vorarlberg Energy Institute – Efficiency Plus scenario
IREES 2019	IREES 2019

Figure 6 Changes in total final energy demand by household for heating, hot water, auxiliary current and domestic electricity, compared to real consumption *(DGET, 2008) (Capros, 2016) (Ploss, 2017) (NECP, 2020) (STATEC, 2019)*

Real final energy consumption in residential buildings rose from around 5 600 GWh/a in 2000 (with a population of around 434 000) to between 6 200 and just under 6 450 GWh/a in the period between 2004 and 2010 (with a population of around 455 000 to 502 000). Over the period up to 2015, it was possible to reduce final energy demand slightly in spite of continued population growth; it then rose again slightly between 2016 and 2018 (with a population of 602 000 in 2018). The most recent consumption value available is 6 154 GWh/a for 2018 (STATEC, 2019).

According to the projected figures in EU PRIMES 2007 (baseline), final energy demand by households will rise to almost 8 400 GWh/a by 2030 (DGET, 2008). To achieve the savings target of -40% compared to the EU PRIMES baseline by 2030 (i.e. the target set in the NECP 2019), final energy demand would need to be reduced to 5 038 GWh/a.

According to the Paris Agreement trajectory outlined in the NECP, final energy demand will drop to 4 611 GWh/a by 2030 and to 2 715 GWh/a by 2040 (NECP, 2020).

The value calculated on a top-down basis for the 2040 Paris Agreement trajectory in the NECP therefore corresponds approximately to the value calculated by the Vorarlberg Energy Institute on a bottom-up basis for the Efficiency Plus trajectory (Ploss, 2017). In the Vorarlberg Energy Institute's scenarios, however, actions were assumed to take place at an earlier date than in the projections used as a basis for the NECP trajectory; these included the actions relating to building redevelopments.

2.5.2. Non-residential buildings ('tertiary' heading or 'commerce, trade and services')

The national targets for non-residential buildings are outlined below. It should be noted when interpreting the data that the official statistics do not include any figures for building-related energy demand in non-residential buildings. Non-residential buildings are included under the 'tertiary' heading of Luxembourg's energy consumption statistics. This heading covers all energy consumers that do not fall under the sectors of industry, transport, households or agriculture. The 'tertiary' heading therefore corresponds to the 'commerce, trade and services' sector and not to the 'tertiary (services) sector', as might be assumed from the name.

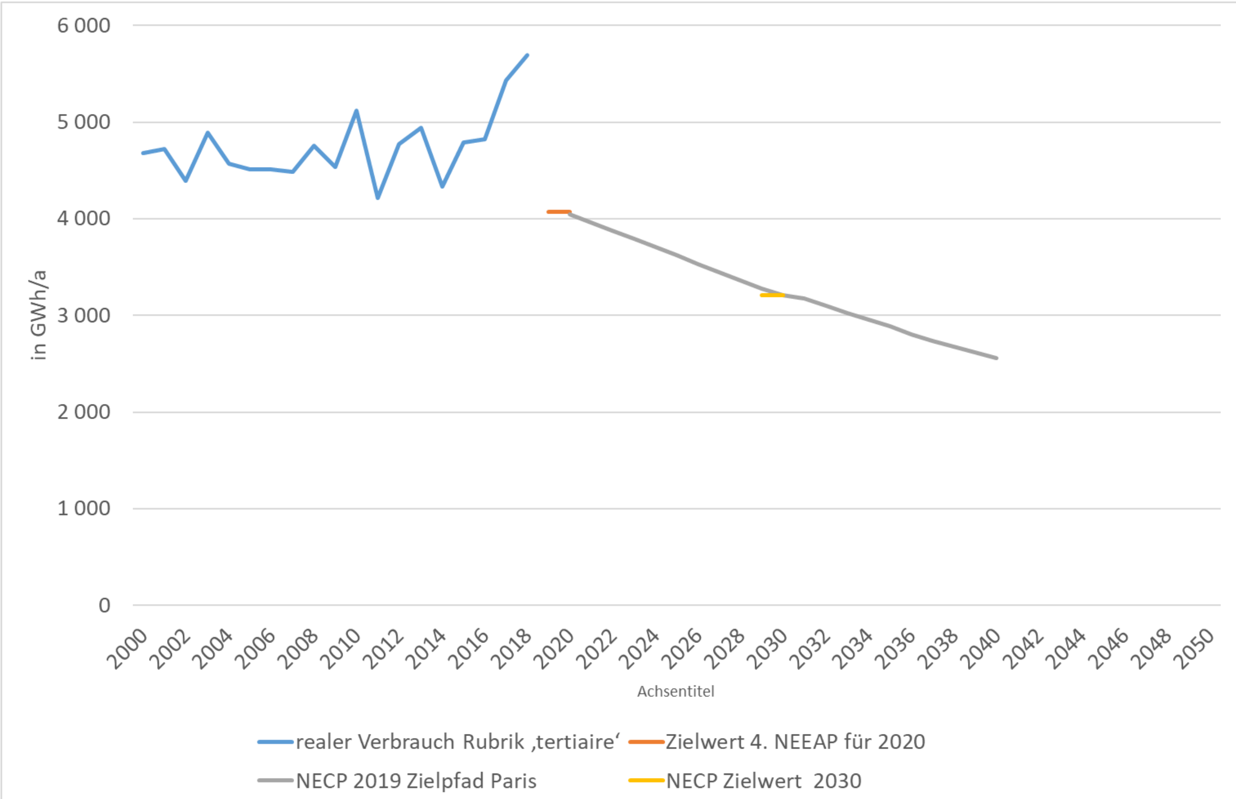
For example, since the studies used as a basis for Luxembourg's NECP (target scenario) were produced by a German consortium, they use the term 'commerce, trade and services'. This differentiates them from other sources (STATEC's official statistics, etc.), in which the term 'tertiary' is more common. Although both terms are assumed to encompass the same scope within the framework of the long-term renovation strategy, the term 'commerce, trade and services' is used most frequently.

Both the data for the 'tertiary' sector and the data that fall under the heading of 'commerce, trade and services' typically include non-building-related energy consumption, e.g. for process heat or power. Since many businesses only have a single electricity and/or gas meter, to date it has only been possible to obtain rough estimates of the share of demand accounted for by building-related and non-building-related energy consumption.

These problems relating to the lack of statistical data for building-related energy consumption are not unique to Luxembourg, but are instead typical of many European countries.

With a view to improving the data used as a basis for identifying dependable saving potentials for building-related energy consumption in the 'commerce, trade and services' sector, it is expected that a comprehensive study will be commissioned in 2021 for the purpose of calculating in detail area-related and building-related energy consumption in non-residential buildings according to use and in different building categories (offices, schools, retail, etc.).

The following figure shows previous changes in final energy consumption under the 'tertiary' heading until 2018, the target value under the Fourth NEEAP for 2030 (NEEAP4, 2017) and the Paris Agreement trajectory outlined in the NECP for 2030 and 2040 (NECP, 2020).



realer Verbrauch Rubrik ‚tertiaire‘	Real consumption under the 'tertiary' heading
Zielwert 4. NEEAP für 2020	Target for 2020 under the Fourth NEEAP
NECP 2019 Zielpfad Paris	Paris Agreement trajectory outlined in the NECP 2019
NECP Zielwert 2030	Target for 2030 under the NECP

Figure 7: Changes in final energy demand under the 'tertiary' heading, in GWh/a *(STATEC, 2019)*, *(NEEAP4, 2017)*, *(NECP, 2020)*

As shown in the figure, real final energy consumption under the 'tertiary' heading rose from around 4 700 GWh/a in 2000 to 5 697 GWh/a in 2018 (STATEC, 2019). Owing to the strong economic growth and substantial increase in useful floor area experienced by Luxembourg, the country will fall a long way short of the target of 4 068 GWh/a by 2020 stipulated in the Fourth NEEAP.

When interpreting the data, it should be noted that the 'tertiary' heading for statistically recorded energy consumption does not include solely demand for heating and cooling and electricity demand for building-related energy uses; instead, it also includes demand for production processes (machines, ovens, etc.) in the skilled trade businesses in question.

This energy demand is not calculated separately and is not known; when setting the NECP targets, the impacts of the different measures (‘regulatory provisions governing new builds’, ‘regulatory provisions governing existing buildings’ and ‘funding for building envelope and heating systems’) were determined in respect of the total number of buildings in the ‘commerce, trade and services’ sector (a number which increased from around 8 900 in 2017 to around 10 200 in 2030). The data in these sections of the LTRS remain subject to a certain degree of uncertainty, particularly in cases where the share of energy consumption for production processes (which is not reported separately) varies over time and may therefore obscure any energy-saving measures implemented.

Taking into account this statistical uncertainty (and other factors), the changes in consumption to date reveal that the significant reduction of final energy demand under the ‘tertiary’ heading (to 3 205 GWh/a in 2030 and to 2 557 GWh/a in 2040, as described under the NECP trajectory) is a highly ambitious goal given the very rapid growth.

2.6. Method followed when drafting the long-term renovation strategy

The long-term renovation strategy is based on previous versions of the building renovation strategy, as described in the Fourth National Energy Efficiency Action Plan, for example, and updates these versions by taking into account the outcomes of a number of different investigations and studies published over the past few years that analyse individual aspects or market segments in detail. The most important investigations and studies of this kind are summarised in the table below.

Title	Author	Date	Main areas of focus
Third National Energy Efficiency Roadmap for Luxembourg (NEEAP3, 2014)	Luxembourg Ministry of the Economy	December 2014	
Fourth National Energy Efficiency Action Plan for Luxembourg (NEEAP4, 2017)	Luxembourg Ministry of the Economy	June 2017	
Further development of the building renovation strategy – more ambitious strategic approaches and measures (Gebäuderenovierungsstrategie, 2017)	Luxembourg Ministry of the Economy	July 2017	Residential building stock – analysis of the status quo Analysis of challenges and obstacles List of measures Broad participation process TNS Ilres survey on redevelopment behaviour

Energy perspectives for Luxembourg 2010–2070 (Ploss, 2017)	Vorarlberg Energy Institute/Vallentin Reichmann Architects	November 2017	Scenarios for future energy demand within Luxembourg's residential building stock by 2070
Calculation of cost-optimal levels of minimum energy performance requirements for new and existing residential and non-residential buildings (KostOpti, 2019)	Luxembourg Ministry of the Economy/Goblet Lavandier & Associés S.A.	May 2019	
Assessment of potential for the use of high-efficiency cogeneration and efficient district heating and cooling (Klobasa, 2016)	Luxembourg Ministry of the Economy/Fraunhofer ISI	June 2016	
Luxembourg's Fifth Annual Monitoring Report pursuant to Article 24(1) of Directive 2012/27/EU, dated 2017 (Monitoring, kein Datum)	Luxembourg Ministry of the Economy	2017	Including information on central government buildings
Scientific advice on issues relating to Luxembourg's energy strategy, with a particular focus on renewable energies (Schön, 2016)	Ministry of the Economy		
Study by energieagence on non-residential buildings (energieagence, 2020)	Agence de l'Energie SA (energieagence)	2020	Preliminary study, overview of the energy saving potential of non-residential buildings, as a basis for the development of a de-risking tool

Figure 8: Overview of the investigations and studies carried out in preparation for the LTRS

A 'Renovation Day' event was planned for May 2020 for the purpose of allowing public participation, but this event could not take place as a result of COVID-19 restrictions. Since a comprehensive public participation process in relation to the topics covered in the LTRS was carried out when drafting the previous version of the building renovation strategy 3 years ago and when drafting the NECP in 2019, it was decided that a similar process involving events aimed at providing information on forthcoming implementing measures (e.g. details of the revised PRIMe House funding scheme) should be carried out in autumn 2020 (subject to COVID-19 restrictions), and at the latest in spring 2021.

The key elements and guiding principles of the long-term renovation strategy were outlined and discussed back in 2015/2016 as part of a broad participation process focused on the further development of the building renovation strategy, during workshops centring around the following five topics:

- architectural requirements and solutions,
- legal obstacles and solutions,
- encouragement for owners,
- financial obstacles,
- opportunities for the building sector.

A separate workshop was also held in 2016 for representatives of municipalities.

Luxembourg's long-term renovation strategy has been drafted in parallel with the country's integrated National Energy and Climate Plan. Both documents complement one another, with the long-term renovation strategy focusing in greater depth on the topic of building renovation.

Since the integrated National Energy and Climate Plan was finalised around 3 months before the long-term renovation strategy, it has been possible to incorporate a number of recent findings into the latter that could not be included in the NECP.

2.7. Impact of the COVID-19 crisis on implementation of the strategy

A slight delay in the final stages of drafting the long-term renovation strategy resulted in the final version being presented in June 2020, against the backdrop of the unprecedented challenges caused by the COVID-19 pandemic. It is impossible to predict the economic, social and political consequences of this crisis at the current point in time, and so any adjustments that might be required to the timeline for implementation (which was developed before the outbreak of the crisis) have not been attempted.

2.8. Structure of the document

The structure of this document is aligned with the substantive description of a long-term renovation strategy provided in Article 2a (EPBD, 2018).

The following points referred to in Article 2a(1) EPBD are covered in **Chapter 3**:

- **Chapter 3.1**: overview of the national building stock – residential buildings (Article 2a(1)(a));
- **Chapter 3.2**: overview of the national building stock – non-residential buildings (Article 2a(1)(a));
- **Chapter 3.3**: identification of cost-effective approaches to renovation (Article 2a(1)(b));
- **Chapter 3.3**: policies and actions to stimulate cost-effective deep redevelopment of buildings (Article 2a(1)(c));
- **Chapter 3.4**: policies and actions to stimulate cost-effective deep redevelopment of buildings (Article 2a(1)(c));

- **Chapter 3.5:** overview of policies and actions to target the worst performing segments of the national building stock (Article 2a(1)(d));
- **Chapter 3.6**: policies and actions to target all public buildings (Article 2a(1)(e));
- **Chapter 3.7**: overview of national initiatives to promote smart technologies and well-connected buildings, as well as skills and education in the construction and energy efficiency sectors (Article 2a(1)(f));
- **Chapter 3.8**: evidence-based estimate of expected energy savings and wider benefits, such as those related to health, safety and air quality (Article 2a(1)(g)).

The following points referred to in Article 2a(2) are covered in **Chapter 4**:

- **Chapter 4.1**: roadmap with measures and domestically established progress indicators. The measures should be designed with a view to achieving the long-term 2050 goal of reducing greenhouse gas emissions by 80–95%, ensuring a highly energy efficient building stock and facilitating the cost-effective transformation of existing buildings into nearly zero-energy buildings. The roadmap should include indicative milestones for 2030, 2040 and 2050;
- **Chapter 4.2**: specification of how the milestones contribute to achieving the Union's energy efficiency targets in accordance with Directive 2012/27/EU.

The following points referred to in Article 2a(3) relating to the mobilisation of investments into renovation are covered in **Chapter 5**. More specifically, an explanation is provided of how Luxembourg intends to facilitate access to appropriate mechanisms for:

- **Chapter 5.1**: the aggregation of projects, including by investment platforms or groups (Article 2a(3)(a));
- **Chapter 5.2**: the reduction of the perceived risk of energy efficiency operations for investors and the private sector (Article 2a(3)(b));
- **Chapter 5.3**: the use of public funding to leverage additional private-sector investment or to address specific market failures (Article 2a(3)(c));
- **Chapter 5.4**: guiding investments into an energy efficient public building stock, in line with Eurostat guidance (Article 2a(3)(d));
- **Chapter 5.5**: accessible and transparent advisory tools on relevant energy efficiency renovations and financing instruments (Article 2a(3)(e)).

Chapter 6 explains how the public consultation on the long-term renovation strategy was carried out, and the outcomes it delivered (Article 2a(3)(d)).

Chapter 7 provides a summary of information on the implementation of the long-term renovation strategies, including the planned policies and actions.

To make this document easier to follow, the relevant sections from Commission Recommendation (EU) 2019/786 of 8 May 2019 on building renovation (Q 4) have been placed at the start of each chapter as a guide to the expected content. These sections are highlighted in grey.

3. Overview of the national building stock (Article 2a(1)(a))

Article 4(a) of the Energy Efficiency Directive (EED) already provided that the starting point of the LTRSs was an overview of the national building stock. Article 2a(1)(a) of the Energy Performance of Buildings Directive (EPBD) provides that each LTRS shall encompass 'an overview of the national building stock, based, as appropriate, on statistical sampling and expected share of renovated buildings in 2020'.

The expected share of renovated buildings may be expressed in various ways, for example: (a) as a percentage (%); (b) as an absolute number; or (c) in m2 of renovated space per type of building. Renovation depth (e.g. 'light', 'medium' and 'deep') could also be used for greater accuracy. Transformation into NZEBs could be another indicator. (4) More generally, 'deep renovation' should result in both energy and greenhouse gas efficiency. The 'expected share' is not intended to be a binding target, but rather a figure that realistically represents the likely rate of completed building renovation in 2020. Member States can also mention the expected share of completed renovation for 2030, 2040 and 2050, in line with the requirement to provide indicative milestones for those years.

3.1. Residential buildings

The current status of the national building and housing stock was analysed in detail on the basis of STATEC's evaluations of the 2011 census, in an interpretative document published in 2015 concerning the further development of the building renovation strategy (Gebäuderenovierungsstrategie, 2017). As well as the energy carrier mix, each building type was analysed in terms of unit numbers and area covered.

The outcomes of the status quo analysis were also used as a basis for a study commissioned by the Ministry of the Economy, which investigated the changes in final energy demand and GHG emissions for the residential building stock between 1990 and 2070 on the basis of four different scenarios (Ploss, 2017). The study followed a very detailed bottom-up approach, according to which the building stock in 2010 was represented by 40 building types of different age classes and size types based on the STATEC classification.

Detailed calculations concerning changes in the residential building stock after the 2011 census (building stock in 2011 + new builds from 2011 onwards – demolition from 2011 onwards) are not available, since the next census will only take place in 2021. The figures available for new builds since 2011 will be combined with the data from the 2011 census. A distinction is only made between the single-family dwelling/semi-detached house/terraced house, multi-family dwelling and semi-residential building (the term 'semi-residential' refers to buildings that are used partly for residential purposes and partly for non-residential purposes).

Since the buildings built over this period will play a secondary role from the perspective of renovations over the next two decades, this approximate distinction is sufficient.

3.1.1. Residential building stock broken down by size types and age classes

STATEC's statistics break down the residential building stock into four size types (and the category 'Other/not specified') and eight age classes up to construction year 2010, i.e. 40 types altogether. Figure 9 shows the number of residential units per size type and age class as at 2011, i.e. when the last census was carried out.

Absolute figures

	Single-family	DH	RH	Multi-family	Other/not specified	Total per age class
	Number of residential units	Number of residential units	Number of residential units	Number of residential units	Number of residential units	Number of residential units
before1919	4 267	4 363	4 787	5 066	1 990	20 473
1919-1945	2 849	5 321	7 996	7 501	903	24 570
1946-1960	4 003	5 278	5 165	8 481	577	23 504
1961-1970	4 712	3 378	2 255	7 908	319	18 572
1971-1980	8 484	3 717	1 934	9 583	272	24 090
1981- 1990	8 427	2 595	1 197	6 757	216	19 292
1991- 2000	8 899	3 034	1 266	13 584	287	27 070
2001-2010	5 575	4 114	1 758	16 876	376	28 599
Not specified	3 085	2 599	2 584	12 220	1 101	21 589
Total per type	50 301	34 499	28 942	88 176	6 041	207 959

Figure 9: Number of residential units according to building age class and size class. Data prepared by myenergy on the basis of official statistics (Gebäuderenovierungsstrategie, 2017)

In 2011, Luxembourg's residential building stock included almost 208 000 residential units, of which around 88 000 were multi-family dwellings and almost 114 000 were single-family dwellings, semi-detached houses and terraced houses.

The share of residential units built since 1960 fluctuates between 8.9% and 13.8% per decade; the degree of variation is therefore low. It is significant that the construction output for each decade is relatively uniform, since it suggests that the distribution over time of future renovations will also be relatively uniform, taking into account the technical lifespans of building components and building service components.

Figure 10 shows the individual size types and age classes as percentage shares of the total number of residential units.

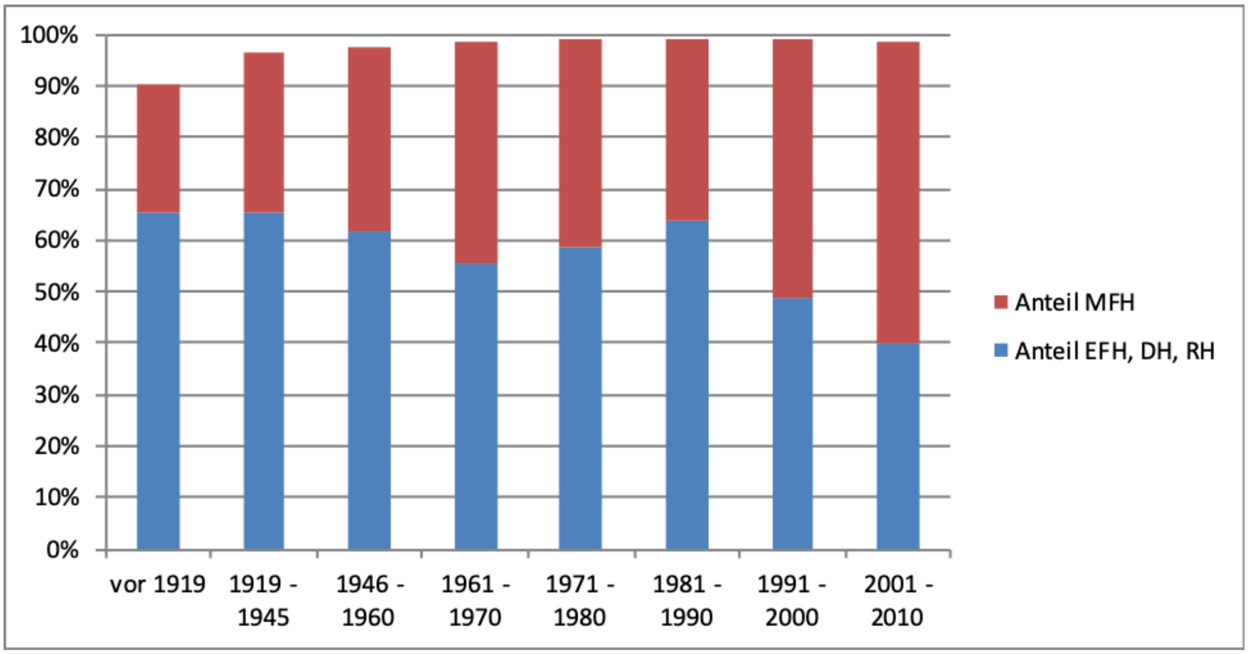
Percentage shares

	Single-family dwellings	DH	RH	Multi-family dwellings	Other/not specified	Total per age class
Before 1919	2.1%	2.1%	2.3%	2.4%	1.0%	9.8%
1919-1945	1.4%	2.6%	3.8%	3.7%	0.4%	11.9%
1946-1960	1.9%	2.5%	2.5%	4.1%	0.3%	11.3%
1961-1970	2.3%	1.6%	1.1%	3.8%	0.2%	8.9%
1971-1980	4.1%	1.8%	0.9%	4.7%	0.1%	11.6%
1981-1990	4.1%	1.3%	0.6%	3.2%	0.1%	9.3%

1991-2000	4.3%	1.5%	0.6%	6.5%	0.1%	13.0%
2001-2010	2.7%	2.0%	0.8%	8.1%	0.2%	13.8%
Not specified	1.5%	1.2%	1.2%	5.9%	0.5%	10.4%
Total per type	24.2%	16.6%	13.9%	42.4%	2.9%	100.0%

Figure 10: Residential units in various building age and size classes as percentage shares of the total number of residential units. Data prepared by myenergy on the basis of official statistics (Gebäuderenovierungsstrategie, 2017)

The number of apartments in multi-family dwellings as a share of the total number of residential units is 42.4% across all age classes, while the share of single-family dwellings, semi-detached houses and terraced houses is much higher, at 54.7%. No data are available for 2.9% of the building stock existing in 2011. Figure 11 shows the changes over time in the shares of single-family dwellings and multi-family dwellings.



Anteil MFH	Share of multi-family dwellings
Anteil EFH, DH, RH	Share of single-family dwellings, semi-detached houses, terraced houses
Vor 1919	Before 1919

Figure 11: Residential units in single-family dwellings and semi-detached and terraced houses as well as multi-family dwellings as percentage shares of the total number of residential units, broken down by the various age classes. Data prepared by myenergy on the basis of official statistics (Gebäuderenovierungsstrategie, 2017)

The share of apartments in multi-family dwellings is rising continuously, while the share of single-family dwellings, semi-detached houses and terraced houses is falling. The share of single-family dwellings, semi-detached houses and terraced houses was between 55% and 65% until 1990, but has fallen to below 40% of residential units since 1990.

The majority of residential units in multi-family dwellings are in buildings with 4 to 10 residential units; only a very small proportion are in buildings with up to three residential units.

The following figure shows the area-based proportions accounted for by the various size types and age classes. The values relate to the residential units for which area-related data are available (approximately 169 000). Area-related data were not available for almost 40 000 residential units.

Percentage shares

	Single-family dwellings	DH	EH	Multi-family dwellings	Other/not specified	Total per age class
Before 1919	2.8%	2.6%	2.4%	1.2%	1.3%	10.3%
1919-1945	1.7%	2.9%	3.8%	1.7%	0.4%	10.5%
1946-1960	2.5%	2.9%	2.6%	2.1%	0.3%	10.3%
1961-1970	3.1%	2.0%	1.2%	2.2%	0.1%	8.6%
1971-1980	6.1%	2.3%	1.0%	2.8%	0.2%	12.4%
1981-1990	6.5%	1.8%	0.7%	2.1%	0.1%	11.2%
1991-2000	7.1%	2.0%	0.8%	4.3%	0.2%	14.4%
2001-2010	4.8%	3.0%	1.1%	5.9%	0.2%	15.0%
Not specified	1.8%	1.2%	1.1%	2.8%	0.4%	7.3%
Total per type	36.4%	20.6%	14.7%	25.2%	3.2%	100.0%

Figure 12: Different building age classes and size classes as a percentage share of the total living space in residential units for which area-related data are available. Data prepared by myenergy on the basis of official statistics (Gebäuderenovierungsstrategie, 2017)

Single-family dwellings account for 71% of the total area but a smaller proportion of the number of residential units; this is because the average living space per single-family dwelling (175 m^2) is significantly higher than that per apartment in a multi-family dwelling (83 m^2).

New residential units constructed since 2011

The following table shows the new residential units constructed since 2011, broken down by single-family dwellings (including semi-detached and terraced houses) as well as multi-family dwellings and semi-residential buildings.

	Total	Single-family dwellings	Multi-family dwellings	Semi-residential	Share of single-family dwellings

2011	2 162	845	1 072	229	39%
2012	2 304	1 013	1 062	223	44%
2013	2 642	1 078	1 238	319	41%
2014	3 357	1 277	1 744	331	38%
2015	3 091	1 194	1 329	568	39%
2016	3 856	1 182	2 233	414	31%
2017	4 319	1 302	2 241	712	30%
Total	21 731	7 891	10 919	2 796	36%
Average per annum	3 104	1 127	1 560	399	36%

Figure 13: Number of residential units completed between 2011 and 2017 by building type (STATEC, 2018)

The number of completed residential units dropped to around half of the former high (4 444 units in 2008) in 2011 as a result of the global economic crisis, but returned to pre-crisis levels in 2017. The share of residential units in multi-family dwellings continues to rise, and was 64% on average in the period between 2011 and 2017.

3.1.2. Energy carrier mix

Around 98% of the residential units constructed in Luxembourg during the period up to 2010 have central heating systems (STATEC, 2013).

The energy carrier mix (as at 2011) is broken down by single-/multi-family dwelling in Figures 14 and 15.

	Single-family dwellings					DH					RH				
	Heating oil	Natural gas	Electricity	Wood	Other	Heating oil	Natural gas	Electricity	Wood	Other	Heating oil	Natural gas	Electricity	Wood	Other
Before 1919	60.6%	19.9%	5.4%	6.7%	7.4%	46.2%	36.4%	5.2%	4.5%	7.7%	34.6%	48.0%	6.2%	2.3%	8.9%
1919-1945	57.2%	28.3%	3.8%	3.8%	6.9%	29.1%	59.4%	3.0%	1.4%	7.0%	18.9%	68.7%	3.8%	0.9%	7.8%
1946-1960	50.9%	38.5%	2.6%	1.9%	6.1%	27.0%	63.7%	2.3%	0.7%	6.3%	22.6%	66.8%	2.9%	0.7%	7.1%
1961-1970	57.7%	32.8%	2.2%	1.8%	5.5%	35.2%	55.7%	2.5%	0.7%	6.0%	26.0%	66.3%	2.3%	0.4%	5.0%
1971-1980	60.3%	27.8%	5.0%	2.0%	4.9%	36.8%	55.1%	3.3%	0.9%	3.9%	26.7%	64.3%	3.5%	0.4%	5.1%
1981-1990	59.6%	29.2%	4.3%	2.3%	4.6%	31.9%	59.4%	2.4%	1.0%	5.3%	23.7%	67.7%	2.3%	0.8%	5.5%
1991-2000	60.4%	32.5%	0.8%	1.5%	4.7%	31.8%	61.3%	0.8%	1.1%	5.0%	25.0%	67.5%	0.9%	0.6%	5.9%
2001-2010	42.6%	33.6%	4.4%	6.2%	13.2%	32.5%	52.4%	2.0%	2.8%	10.2%	26.8%	59.0%	1.9%	1.3%	10.9%
Not specified	46.6%	29.8%	3.0%	2.5%	18.2%	31.3%	46.9%	2.5%	1.2%	18.0%	24.5%	53.6%	3.7%	1.1%	17.1%
Total per type	56.3%	30.3%	3.5%	2.9%	7.0%	33.4%	54.7%	2.8%	1.7%	7.5%	23.0%	63.8%	3.7%	1.1%	8.5%

Figure 14: Percentage shares of heating systems in single-family dwellings, semi-detached houses and terraced houses accounted for by different energy carriers. Data prepared by myenergy on the basis of official statistics (Gebäuderenovierungsstrategie, 2017)

As shown in the figure, around 86–88% of all single-family dwellings, semi-detached houses and terraced houses are heated using fossil fuels. The share of such dwellings and houses heated by means of wood-fired heating systems is very low (1.1–2.9%). The highest proportion of wood-fired heating systems is recorded for buildings that fall under the age class 'before 1919'. It can be conjectured that a large proportion of these wood-fired heating systems do not comply with modern efficiency and environmental requirements. Electrical heating systems account for a very low proportion of the total (2.8% to 3.7%). The highest proportion of electrical heating systems is recorded for buildings that fall under the age class 'before 1919', which means that they are (presumably) inefficient direct electrical heating systems rather than heat pumps.

The data currently available are not sufficient to estimate the share of buildings in the age class 'before 1919' that have already undergone deep energy renovations and may therefore potentially have up-to-date wood-fired heating systems or heat pumps.

	Multi-family dwellings					Other/not specified					Total per age class				
	Heating oil	Natural gas	Electricity	Wood	Other	Heating oil	Natural gas	Electricity	Wood	Other	Heating oil	Natural gas	Electricity	Wood	Other
Before 1919	30.8%	56.0%	4.5%	1.7	7.0%	57.6%	11.8%	7.9%	12.5	10.3%	43.8%	38.1%	5.6%	4.5%	8.0%
1919-1945	23.8%	65.3%	3.6%	0.4	7.1%	41.7%	30.9%	11.1%	6.0%	10.3%	27.9%	59.6%	3.8%	1.3%	7.4%
1946-1960	28.5%	62.7%	2.0%	0.4	6.5%	38.6%	43.3%	2.4%	5.5%	10.1%	31%	59.2%	2.4%	0.9%	6.6%
1961-1970	36.3%	58.2%	1.5%	0.0	4.0%	32.9%	43.9%	2.5%	3.8%	16.9%	40.2%	52.1%	1.9%	0.7%	5.1%
1971-1980	42.5%	52.1%	2.6%	0.1	2.8%	48.9%	33.1%	5.9%	6.3%	5.9%	46.7%	44.7%	3.7%	1.0%	3.9%
1981-1990	27.7%	65.0%	5.2%	0.1	2.0%	48.1%	25.9%	4.6%	8.3%	13.0%	42.2%	48.3%	4.2%	1.3%	3.9%
1991-2000	28.4%	68.8%	0.7%	0.1	1.9%	40.1%	43.2%	0.7%	1.7%	14.3%	39.3%	55.7%	0.8%	0.7%	3.5%
2001-2010	19.0%	76.3%	1.1%	0.6	3.0%	25.8%	46.5%	10.9%	4.8%	12.0%	26.1%	63.1%	2.1%	2.1%	66%
Not specified	28.6%	60.7%	2.7%	0	7.8%	29.2%	31.0%	2.8%	2.5%	34.5%	31.1%	52.2%	2.8%	0.9%	13.0%
Total per type	28.6%	64.4%	2.3%	0.3	4.4%	43.4%	28.0%	6.3%	7.2%	15.2%	36.0%	53.2%	2.9%	1.5%	6.4%

Figure 15: Percentage shares of heating systems in multi-family dwellings and other residential buildings accounted for by different energy carriers. Data prepared by myenergy on the basis of official statistics (Gebäuderenovierungsstrategie, 2017)

The share of multi-family dwellings with heating systems based on fossil fuels stands at 93%. Only 0.2% of residential units have wood-fired heating systems. The highest proportion of wood-fired heating systems is recorded for dwellings that fall under the age class 'before 1919'. It can be conjectured that a large proportion of these wood-fired heating systems do not comply with modern efficiency and environmental requirements.

Electrical heating systems account for a very low proportion of the total (2.7%). The highest proportion of electrical heating systems (4.5%) is recorded for buildings that fall under the age class 'before 1919', which means that they are likely to be inefficient direct electrical heating systems. Only 1.1% of multi-family dwellings built in the decade 2001–2011 have electrical heating systems. It can be assumed that these are buildings heated by means of heat pumps.

Over 89% of the entire residential building stock constructed during the period up to 2011 uses heating systems based on fossil fuels. Wood-fired heating systems account for 1.5% of the total, and electrical heating systems for 2.9%. The highest proportions of wood-fired heating systems and electrical heating systems are recorded for the age class 'before 1919'. It can be presumed that these heating installations do not comply with modern standards.

If the examination is limited to the buildings constructed in the decade between 2001 and 2011 in Luxembourg, the share of fossil fuels remains unchanged at 89%. The number of gas-fired heating systems compared to oil-fired heating systems based on the heating structure of the total building stock increased from 10% to 76%, however. Electrical heating systems and wood-fired heating systems account for 2.1% in each case.

The data concerning the energy carrier mix of the buildings constructed after 2011 have not been systematically evaluated to date. It is to be assumed, however, that the share of fossil fuels has dropped, particularly in the new builds sector, and particularly as a result of the use of heat pumps (with the exception of zones that are connected to the gas supply, where gas-fired systems are still very popular, even in new builds, owing to the significant cost benefits).

3.1.3. Energy performance of building types and energy demand of the building stock in 2011

The energy performance of the residential building stock was investigated in detail in 2017 in the scenario study on changes in energy demand and GHG emissions in the Luxembourg residential building stock from 1990 to 2070, and represented in a building typology with 40 types (corresponding to the eight age classes and five size types of STATEC)(Ploss, 2017).

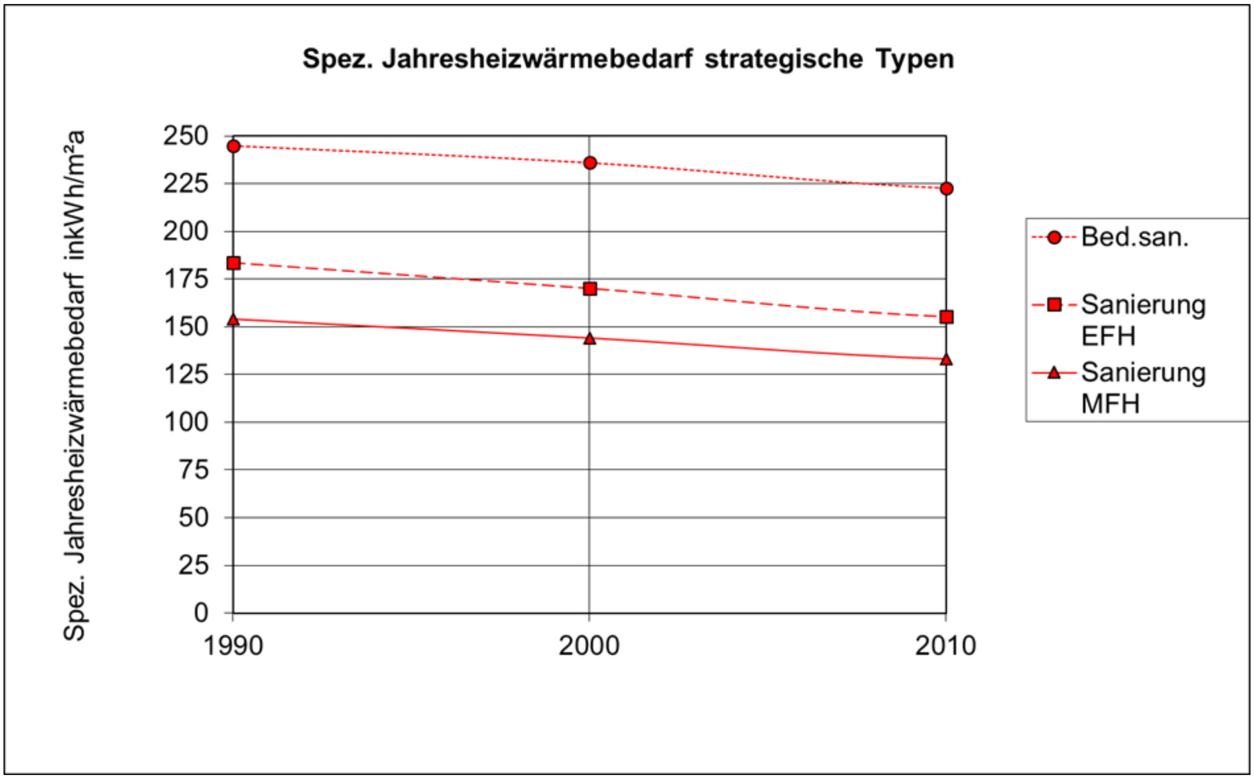
In the typology, each building type is represented by a synthetic model building with characteristic living space and geometry and characteristic energy status. Structural components/U-values of the building envelope are differentiated by age classes and correspond to the average standards that dominate in each case. The same applies to the efficiency of the building services systems used.

Energy balances were calculated for each building type in accordance with ISO 13790. The model produced by the Institute for Housing and Environment in Darmstadt was used to adjust the calculated values based on standard constraints to the anticipated average real consumption figures. Among other things, this involved differentiating the average indoor air temperature on the basis of thermal envelope quality. This correction takes into account effects such as the area-based partial heating of residential units and the drop in temperature overnight, which results in different average indoor air temperatures depending on the building performance (Born, 2003). It results in a reduction in the heating demand calculated arithmetically for worst-performing buildings (a figure that typically exceeds real consumption if standardised calculations are used). The corrected heating demand for high-energy-performance buildings tends to be higher than the value calculated on the basis of standard constraints. If the correction factors are applied, the resulting energy savings are typically lower than in the case of calculations based on standardised constraints. Comparative studies reveal that the corrected values correspond more closely to real energy savings, however.

Heating demand

Changes in the specific heating demand from 1990 to 2010, corrected as described, are shown in Figure 16. The 40 individual types within the building stock are combined into three strategic types:

- single-family dwellings,
- multi-family dwellings,
- buildings that can only be redeveloped to a limited extent (buildings under protection as monuments, listed groups of buildings, etc.).



Spez. Jahresheizwärmebdarf strategische Typen	Specific annual heating demand, broken down by strategic types
Spez. Jahresheizwärmebedarf inkWh/m^{2}a	Specific annual heating demand in kWh/m^{2}a
Bed. san.	Buildings that can only be renovated to a limited extent
Sanierung EFH	Renovation of single-family dwellings
Sanierung MFH	Renovation of multi-family dwellings

Figure 16: Changes in corrected specific heating demand from 1990 to 2010, broken down by strategic types (Ploss, 2017)

The calculations show that energy renovation measures made it possible to reduce the average specific corrected heating demand for the three strategic types between 1990 and 2010. The values for 2010 are around 133 kWh/m$^2_{ERA}$a on average for multi-family dwelling types, 155 kWh/m$^2_{ERA}$a on average for single-family dwelling types and around 223 kWh/m$^2_{ERA}$a for building types that can only be redeveloped to a limited extent. It was possible to reduce the specific demand from 184 to 156 kWh/m$^2_{ERA}$a on average across all strategic types. The majority of energy renovation measures taken as a basis for the scenarios are small, non-subsidised measures such as the replacement of single-glazed windows or the insulation of certain parts of the building.

The value determined on the basis of the bottom-up model corresponds to an average annual reduction in average heating demand of almost 0.8% per annum. If it is assumed that the heating demand over the period between 2011 and 2020 reduced at approximately the same rate, the average value for the building stock in 2020 is around 143 $kWh/m^2{}_{ERA}a$.

Plausibility check:

The average value for the corrected average specific heating demand calculated on the basis of the bottom-up model for the building stock existing in 2020 (around 143 $kWh/m^2{}_{ERA}a$, taking into account renovations between 2011 and 2020) is closely aligned with the value referred to in the 'EU Buildings Datamapper' (Datamapper, 2020).

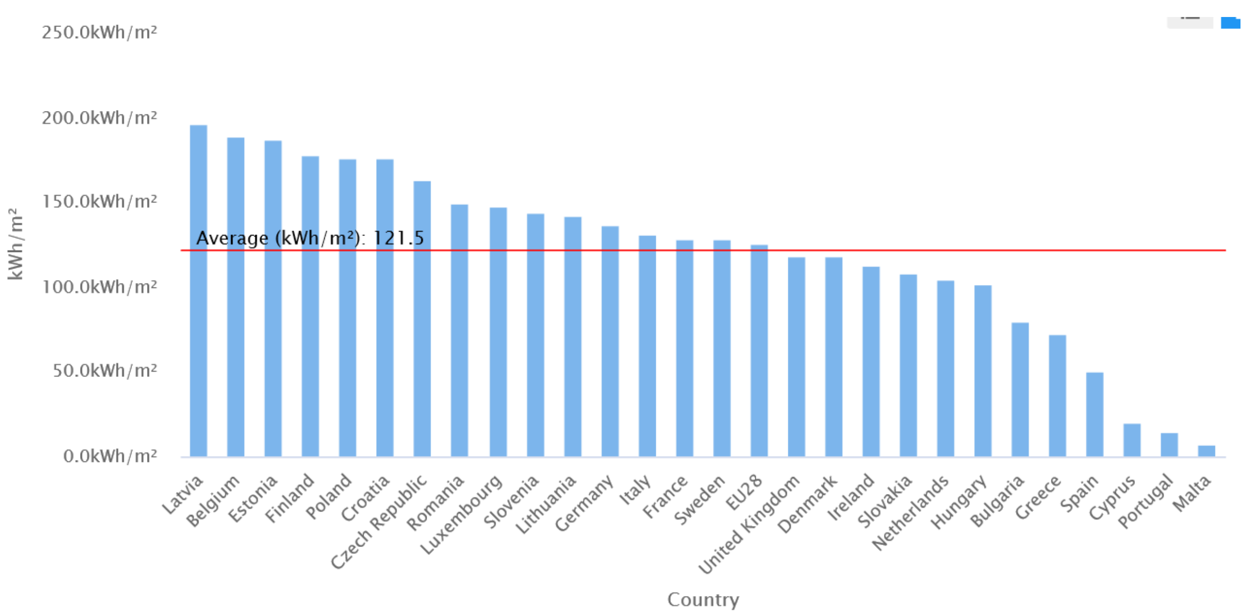


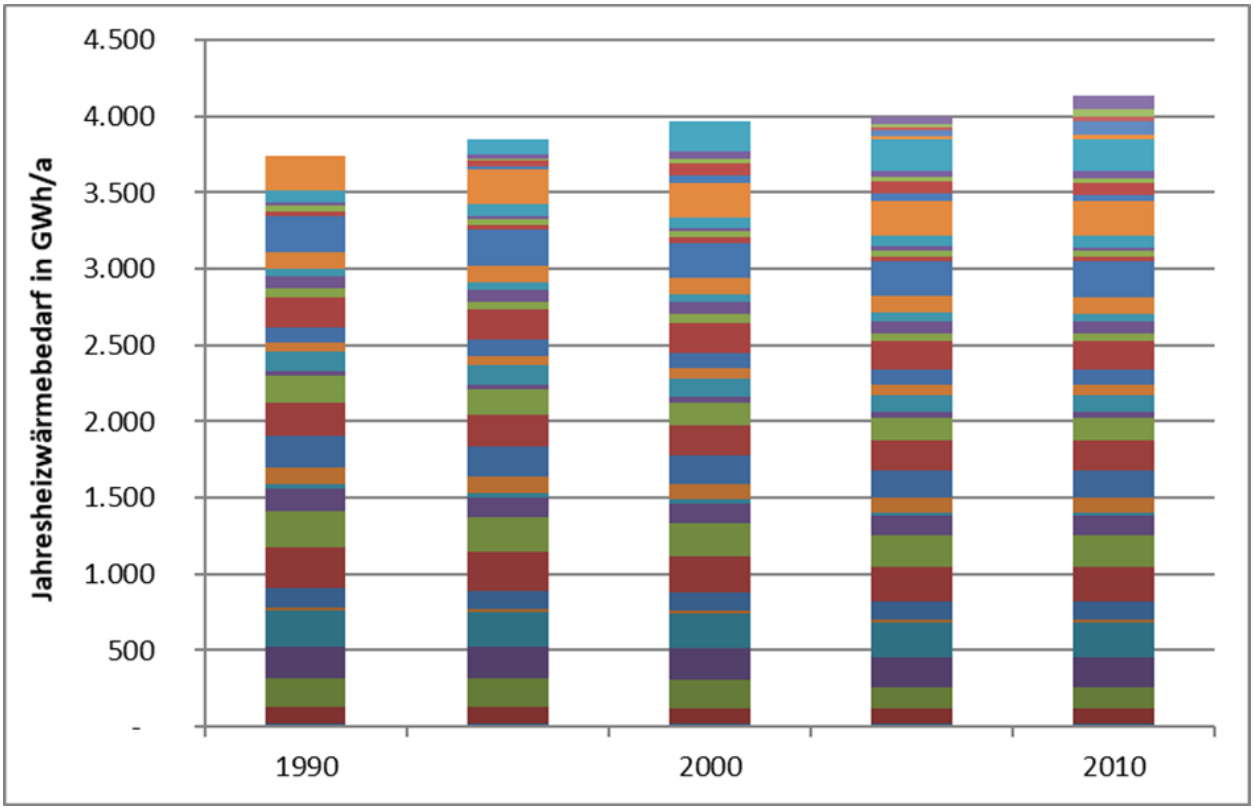
Figure 17: Specific energy consumption for space heating (Datamapper, 2020)

The value specified in the 'EU Buildings Datamapper' is 148 kWh/m^2a. It is referred to as 'energy consumption of residential for space heating per m^2'. It is a calculated value that is not assigned to a particular year and for which the area-specific measurement (m^2) is not further explained.

It is therefore likely to be equivalent to final energy demand (or final energy consumption), i.e. to include losses from the heating system. The value should therefore be higher than the value for specific heating demand calculated using the bottom-up method.

The value for specific heating demand calculated using the bottom-up model applies only to buildings constructed over the period up to 2010, however, whereas the value from the EU source relates to the entire stock, including new builds since 2011 that have a significantly better energy performance, meaning that the value based on the bottom-up model is in the correct order of magnitude.

The following figure shows the changes in the corrected absolute heating demand by the entire residential building stock from 1990 to 2010, broken down by building types and age classes.



Jahresheizwärmebedarf in GWh/a	Annual heating demand in GWh/a

Figure 18: Changes in corrected absolute annual heating demand by residential building stock from 1990 to 2010, in GWh/a, broken down by building types and age classes (Ploss, 2017)

The development over time of the corrected absolute annual heating demand by the residential building stock depends on three factors:

- area and energy performance of buildings newly constructed between 1990 and 2010;
- area and energy performance of buildings demolished between 1990 and 2010;
- changes in the average specific heating demand of the remaining stock.

As shown in the figure, absolute heating demand by the residential building stock increased to just over 4 000 MWh/a as a result of the significant increase in living space.

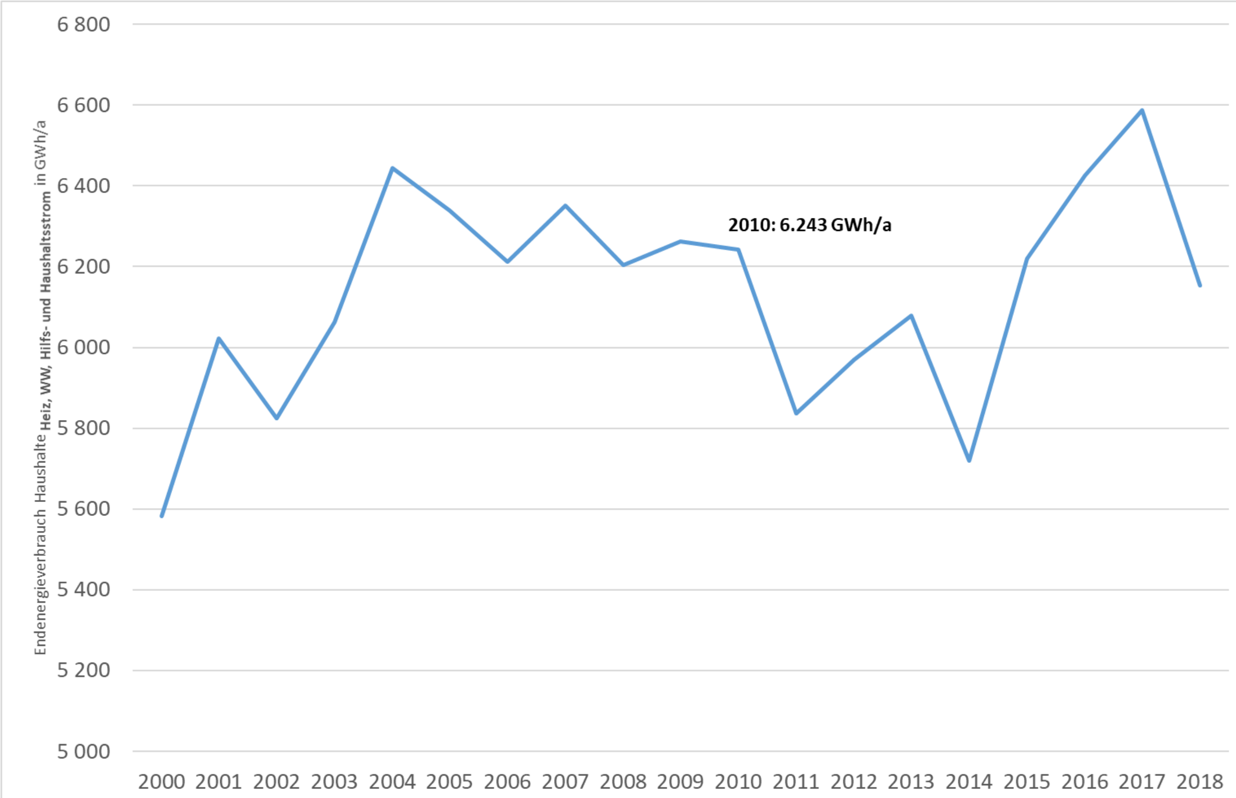
The reduction in heating demand resulting from the demolition of buildings and energy renovations was not able to compensate for the additional demand by new buildings constructed between 1990 and 2010.

The final energy demand for all 40 types of the residential building stock was determined on the basis of the corrected specific heating demand shown, the average efficiency of the building service systems used and the energy carrier mix represented on the basis of statistical data(Gebäuderenovierungsstrategie, 2017). At the same time, a distinction was made between uses for heating, water heating, auxiliary current and domestic electricity.

The total final energy demand by the residential building stock for heating, hot water, auxiliary current and domestic electricity was 6 115 GWh/a based on the bottom-up model of the scenario study in 2010 (scenarios).

Without domestic electricity, the final energy demand by the residential building stock was around 5 500 GWh/a; without auxiliary current and domestic electricity (i.e. only for heating and hot water), it was around 5 400 GWh/a.

The following figure shows the changes in real total final energy consumption by household for heating, hot water, auxiliary current and domestic electricity from 2000 to 2018 (STATEC, 2019).



Endenergieverbrauch Haushalte Heiz, WW, Hilfs- und Haushaltsstrom in GWh/a	Final energy consumption by households for heating, hot water, auxiliary power and domestic electricity in GWh/a

Figure 19: Changes in total final energy consumption of the residential building stock between 2000 and 2018 in GWh/a (STATEC, 2019)

STATEC's evaluation reveals an increase in total final energy consumption by household until 2005, followed by a continuous reduction until 2014 and a significant increase in the years 2015, 2016 and 2017. There was another significant drop in total final energy demand in 2018.

The annual fluctuations in final energy demand are caused by five main influencing factors:

- increase in residential units and living space → increased demand;
- demolition → reduced demand;
- energy renovation of the building envelope → reduced demand;
- higher-efficiency building services through replacement of heat generator → reduced demand;
- average temperature and global radiation during the heating period.

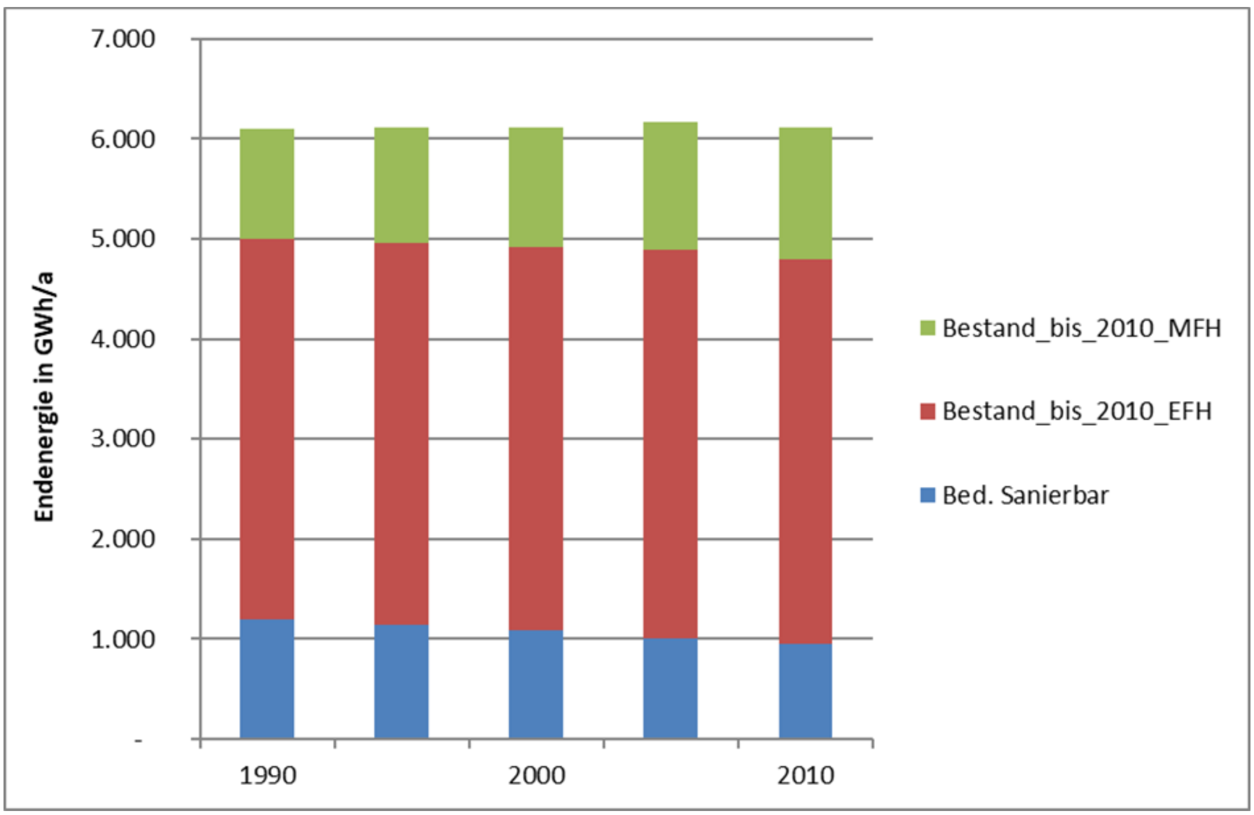
A systematic analysis of the changes in final energy consumption by the total residential stock, corrected for weather, has not been performed to date.

A rough analysis reveals that total final energy consumption increased much more slowly over the period under consideration than the total living space. One important reason for the reduction in final energy consumption from 2006 to 2014 is likely to be the introduction of more stringent minimum standards under building law and accompanying funding programmes for high energy performance. A further reason is likely to be the drop in the annual number of buildings completed, which was a knock-on effect of the financial crisis.

The total final energy demand values calculated in the model for 2010 on the basis of 40 building types (including domestic electricity) are very closely aligned with real consumption, with a deviation of 2.3%. As highlighted in Figure 19, this figure was 6 243 GWh/a (STATEC, 2019).

Inter alia in comparison with the total final energy demand for heating and electricity according to the baseline under the Third NEEAP of 2014 (6 073 GWh/a), the deviation in the modelled final energy demand is very low (NEEAP3, 2014)

As a basis for identifying renovation measures for individual market segments of the residential building stock, Figure 20 shows the breakdown of total final energy demand by the residential building stock (as at 2010) for heating, hot water, auxiliary current and domestic electricity, into three strategic groups.



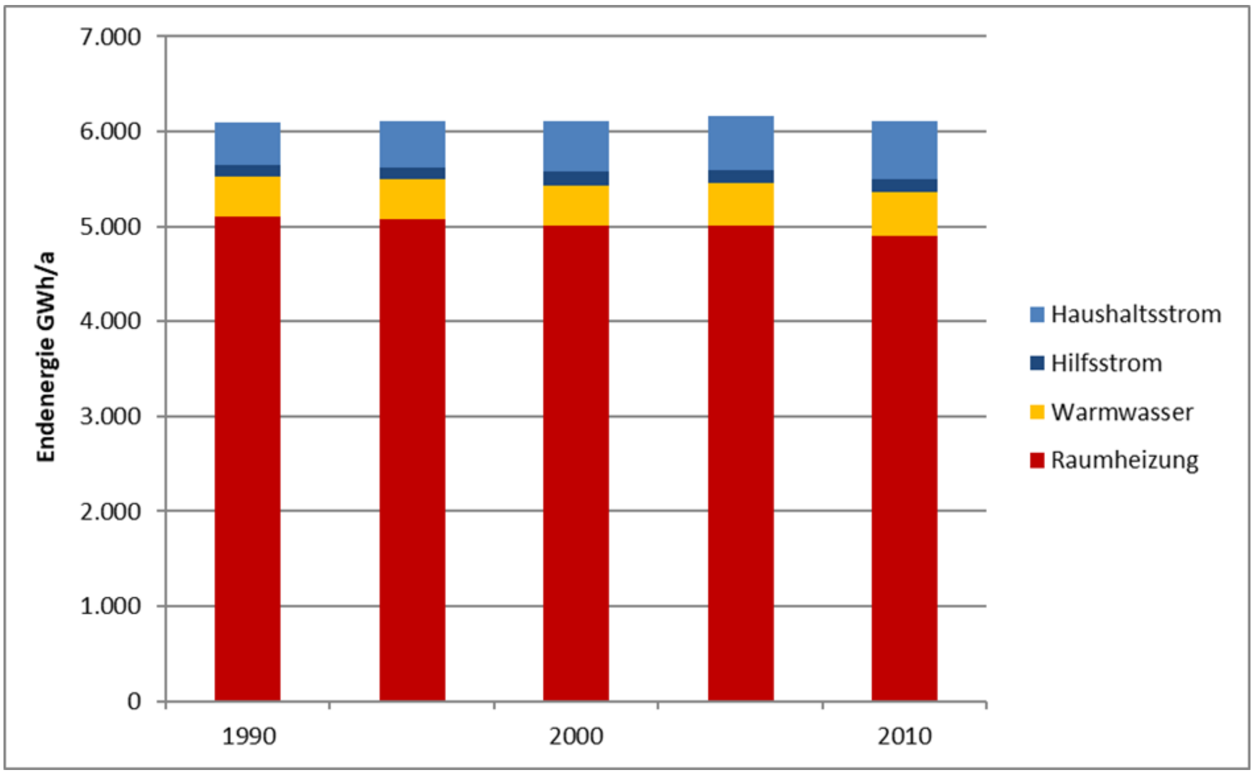
Endenergie in GWh/a	Final energy in GWh/a

Bestand_bis_2010_MFH	Stock of multi-family dwellings until 2010
Bestand_bis_2010_EFH	Stock of single-family dwellings until 2010
Bed. Sanierbar	Buildings that can only be renovated to a limited extent

Figure 20: Changes in final energy demand by the residential building stock from 1990 to 2010 for heating, hot water, auxiliary current and domestic electricity, broken down by strategic types, in GWh/a *(Ploss, 2017)*

Final energy demand by single-family dwellings, semi-detached houses and terraced houses dominates, owing to the larger area covered and the higher specific demand in comparison to multi-family dwellings.

Figure 21 shows the breakdown of total final energy demand in 2010 by different energy uses.



Endenergie GWh/a	Final energy in GWh/a
Haushaltsstrom	Domestic electricity
Hilfsstrom	Auxiliary power
Warmwasser	Hot water
Raumheizung	Space heating

Figure 21: Final energy demand by the residential building stock in 2010, broken down by use, in GWh/a *(Ploss, 2017)*

It can be seen that the most significant use is heating, which accounts for almost 80% of total final energy demand by the residential building stock. Hot water accounts for approximately 7.5% of the demand, and domestic electricity for around 10%. The remainder is accounted for by auxiliary current.

3.1.4. Estimate of the share of the residential building stock subject to energy renovations by 2020, the renovation rate and the renovation quality

A systematic procedure for recording the number of building renovations and their quality on an ongoing basis has not yet been put in place in Luxembourg; similarly, the term 'renovation rate' has not yet been defined on a binding basis.

Quantitative data for renovations of individual building envelope components (based on evaluations of redevelopment funding) are available for the period between 2008 and 2012. The evaluations show an initial increase in renovations, followed by a decrease. The renovation rates for individual building envelope components varied between around 0.11% and 0.34% per annum.

A survey from 2015 reveals that a significant number of additional energy renovations appear to have been carried out without the use of State funding: 28% of those surveyed stated that they had carried out one energy renovation measure or more over the past 10 years (insulation of the building envelope, windows or ventilation system, but not boiler replacement or photovoltaic installations) (ILRES, 2015).

Funding programme evaluations and survey results are not a suitable basis for accurate calculations of renovation rates. The area-weighted renovation rate for the building envelope (see the following section for an explanation) can be roughly estimated at around 0.4% to 1% per annum on the basis of the aforesaid sources.

If it is assumed that the area-weighted renovation rate was somewhere in the region of 0.7% per annum over the period between 2008 to 2020, this means that around 9.1% of the total building stock underwent energy renovations involving the building envelope (full renovation equivalents according to the definition in Infobox 1, see below). Since renovations of the building envelope were also carried out prior to 2008 (albeit in small numbers), the share of residential units whose building envelope has already been renovated can be estimated at around 10–14% of the residential building stock (full renovation equivalents).

The lack of reliable data means that it is impossible to make any statements about the energy performance of the renovations. It is probable that the majority of redevelopments carried out without State funding achieved only moderate levels of energy performance, but that individual renovation projects attained extremely high levels.

Infobox 1: 'Energy renovation rate' (proposed definition) and boiler replacement rate

As a basis for setting political targets and monitoring the implementation of the renovation strategy, it is important to define the term 'energy redevelopment rate' as promptly as possible and on a binding basis within Luxembourg.

It has been proposed that the definition produced by the Institute for Housing and Environment in Darmstadt should be used, and that the following two indicators should be introduced:

- area-weighted renovation rate of the building envelope;
- boiler replacement rate.

Both values are to be reported separately for total residential and non-residential building stock, respectively.

Example 1:

Based on a residential building stock of 250 000 residential units (= total sum of residential units, regardless of their year of construction), an area-weighted building envelope renovation rate of 1% per annum means that complete energy renovations were carried out on the building envelope of 2 500 residential units in the relevant year.

Since not all components are renovated during each energy renovation, the components for which the energy performance has been improved per renovation are taken into account on a pro rata basis according to their average share in the building's total envelope area.

The average area-based weighting of the building envelope components has been specified as follows by the Institute for Housing and Environment in Darmstadt, based on the geometry of sample buildings within Germany's building typology (Cischinsky, 2018):

- exterior wall: 40%,
- roof/top floor ceiling: 28%,
- floor/cellar ceiling: 23%.

- windows: 9%

As an average across Germany's total building stock, the exterior wall thus accounts for 40% of the total building envelope area, the roof or top floor ceiling for 28%, etc.

Example 2:

Based on a residential building stock of 250 000 residential units (= total sum of residential units, regardless of their year of construction), a boiler replacement rate of 4% per annum means that the boilers in buildings containing 10 000 residential units were replaced in the relevant year.

Infobox 2: Calculation of an optimum building envelope renovation rate or boiler replacement rate from an economic perspective

A target weighted renovation rate for all building envelope components which is sound in economic terms can be obtained by calculating the renovation rates for the individual components on the basis of their average technical lifespans.

The following table provides an example.

Component	Average technical lifespan	Resulting renovation rate	Share of total building envelope area accounted for	
	Years	% per annum	%	% per annum
Exterior wall	60	1.67	40	66.80
Roof	50	2	28	56.00
Floor/cellar ceiling	75	1.33	23	30.59
Windows	40	2.5	9	22.50
Area-weighted average building envelope renovation rate				**1.76**
Assumptions: lifespan of pitched roof: 70 years, flat roof: 30 years, pitched/flat roofs each assumed to account for 50% of				

Figure 22: sample estimate of a long-term average area-weighted building envelope renovation rate that is sound in economic terms

Example of how to read the table:

If the average technical lifespan of the outer layer of exterior walls (render, thermal insulation composite system, etc.) is taken to be 60 years, this results in a component-related renovation rate of 1.67% per annum. This (energy) renovation rate is sound in respect of the assumed average technical lifespan, since insulating measures are most cost-effective when they are combined with renovation measures that are due to be carried out in any case (render repairs, etc.).

If the renovation rates for individual components calculated in this way are weighted on the basis of their share of the total building envelope area, this results in an area-weighted average renovation rate of 1.76% according to the example.

Based on realistic technical lifespans, an area-weighted building envelope renovation rate that is sound in economic terms will range from 1.6% to 2.0%.

If a similar procedure is followed to obtain heat generator replacement rates that are sound in economic terms, values of around 3.33% to 5% are achieved for average technical lifespans of around 20 to 30 years.

High renovation rates or boiler replacement rates may also be beneficial in economic terms, for example if the costs of the environmental damage that has been prevented are taken into account in the calculations.

3.1.5. Summary of residential building stock

The most important outcomes of an analysis of the residential building stock from the perspective of energy renovation are as follows:

- total living space stood at around 26 million m^2 in 2010 and around 30 million m^2 in 2015, and is likely to be around 34 million m^2 in 2020;
- single-family dwellings, semi-detached houses and terraced houses account for a very high share of the total area (around 71%), whereas the share accounted for by multi-family dwellings has only risen significantly over the past two decades;
- strong population growth over the past few decades means that Luxembourg's building stock is younger on average (compared to Germany and Austria, for example);
- the number of buildings that can only be redeveloped to a limited extent (buildings under protection as monuments, listed groups of buildings, etc.) has increased significantly over recent years and currently stands at around 13 588; the majority of these buildings are already being used for residential purposes today (SSMN, 2020),
- statistical data on the demolition rate are not available, but it can be assumed to be high based on the rapidly increasing land prices; according to the Third NEEAP (p. 46), it can be estimated at around 0.85% (NEEAP3, 2014). The rate estimated in the Third NEEAP should be corroborated with statistics as soon as possible, however;

- the share of owner-occupied residential units is very high (around 70%), and the share of rented units is low;
- the share of social housing is low compared to neighbouring countries (around 3.6%);
- the average living space across all residential units is high compared to neighbouring countries (130 m^2),
- the average living space in single-family dwellings (175 m^2 as an average across all age classes) is very high, and has increased to more than 200 m^2 over the past decade;
- the average number of people per residential unit is 2.46, and this figure is continuing to drop;
- the share of one-person and two-person households is over 60%, and this figure is increasing;
- the average per capita living space is 52.4 m^2, which is high compared to the rest of Europe;
- the vast majority of Luxembourg's residential building stock is dependent on fossil fuels in terms of the energy carrier mix for heating; almost 90% of all residential units are heated using fossil fuels;
- building envelope renovation rates have not been systematically recorded to date. Based on the available data, the average area-weighted building envelope renovation rate for the years since 2008 can be roughly estimated at 0.4% to 1% per annum of the total stock. Since buildings were also being renovated before 2008, the number of residential units renovated by 2020 can be estimated at around 10–14% of the residential building stock (full renovation rate, see Infobox 1). Lock-in effects resulting from mediocre renovation qualities are therefore only present within a small market segment.

3.2. Non-residential buildings

Luxembourg's non-residential building stock has been analysed in much less detail than its residential building stock to date. The investigations carried out to date have mostly focused on individual building types (e.g. office buildings) or public buildings, for which more accurate details are available from the Public Buildings Administration (Bâtiments Publics, ABP).

Data concerning the total area covered by all non-residential buildings and the relative shares accounted for by the different categories are only available in fragmentary form.

A bottom-up approach to estimating energy demand based on the building typology has not been followed to date.

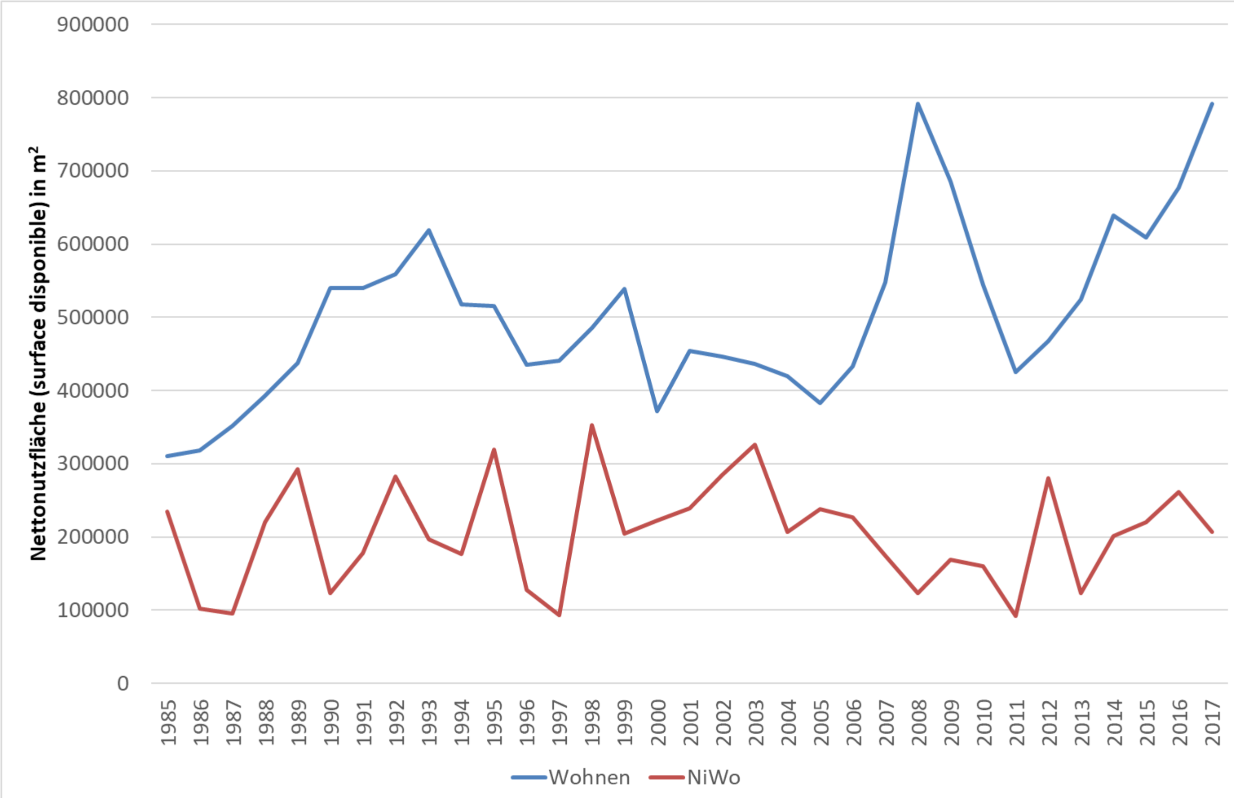
The key available sources for area-related data and energy demand data for non-residential buildings are outlined in the following chapters, and the findings are summarised in the final chapter.

3.2.1. Statistics for buildings completed in 1970, 1975, 1980 and 1985 to 2017 (STATEC)

The statistics published by STATEC on completed buildings include data for the years 1970, 1975 and 1980, and annual data for the period 1985–2017 (STATEC, 2018). Factors evaluated include the number of buildings, their useful floor area and the converted volume. During the evaluation, a distinction is made between residential buildings (single-family dwelling, multi-family dwelling, semi-residential building) and the following types of non-residential buildings:

- commerce and services ('commercial'),
- public administration ('administrative'),
- industry and skilled trades,
- agriculture,
- other.

The following figure shows changes in useful floor area in completed non-residential buildings compared to living space in residential buildings.



Nettonutzfläche (surface disponible) in m²	Net useful floor area in m²
Wohnen	Residential
NiWo	Non-residential

Figure 23: Net useful floor area in completed residential and non-residential buildings in Luxembourg between 1985 to 2017 *(STATEC, 2018)*; non-residential buildings: trade and services, public administration, industry and trade, agriculture, other; residential buildings including STATEC's 'semi-residential' category

As shown by the graph, the area available in non-residential buildings newly constructed since 1985 is significantly less than the area available in newly constructed residential buildings. As a total for the entire period from 1985 to 2017, non-residential buildings accounted for around 29% of the total area of all buildings constructed, and residential buildings for 71%. The values given in the statistics for 1970, 1975 and 1980 show that non-residential buildings accounted for 10%, 8% and 31% of the total, respectively. This proves that the share of non-residential buildings has increased significantly since the 1980s. At the same time, however, it should be noted that the figures for residential buildings also include buildings that fall under STATEC's 'semi-residential' category. This includes a smaller, unquantified proportion that is not used for residential purposes. Buildings in the semi-residential category that were constructed between 1985 and 2017 account for a total area of around 1.9 million m^2. If the area not used for residential purposes is estimated at 20% of the total (e.g. a building with a shop on the ground floor, then four floors of residential units above), this gives a figure of around 380 000 m^2 for non-residential use.

Non-residential buildings completed between 1985 and 2017 account for a total area of around 6.75 million m^2. Adding in the estimated area that is not used for residential purposes under the 'semi-residential' category (380 000 m^2) gives a total area of 6.75 + 0.38 = 7.13 million m^2. Buildings in the trade and services categories ('commercial' and 'administrative' according to STATEC) account for around 4.6 million m^2 of this area.

Buildings in the trade and services categories alone account for around 19% of the total area in all buildings completed between 1985 and 2017.

The useful floor area in non-residential buildings with construction years before 1985 can be estimated approximately from the area of residential buildings. In 1985, this was around 19 million m^2 (Ploss, 2017). If the share of non-residential buildings with constructions years up to 1985 is estimated at between 15% and 25% of the total stock, this would correspond to a useful floor area in non-residential buildings of around 3.4 to 6.3 million m^2.

Based on the total for new builds from 1985 to 2017 and the estimated stock with construction years up to 1985, this results in a total area in non-residential buildings (including the 'semi-residential' category) of between 7.13 + 3.4 = 10.53 million m^2 and 7.13 + 6.3 = 13.43 million m^2. If new builds between 2018 and 2020 are estimated at around 500 000 m^2, this results in a total area of 11.03 to 13.93 million m^2. The demolition of non-residential buildings must however be subtracted from this sum, and no data are available in this respect.

Note: The percentages specified above relate to shares based on area rather than final energy demand or GHG emissions.

3.2.2. EU Building Stock Observatory

The EU Building Stock Observatory states that non-residential buildings accounted for 33.5% of Luxembourg's total building stock in 2013 (datamapper, 2020). It gives an average value for the EU 28 of 26.1%, with comparison values of 31.5% for Germany, 23.5% for France and 32.5% for Belgium.

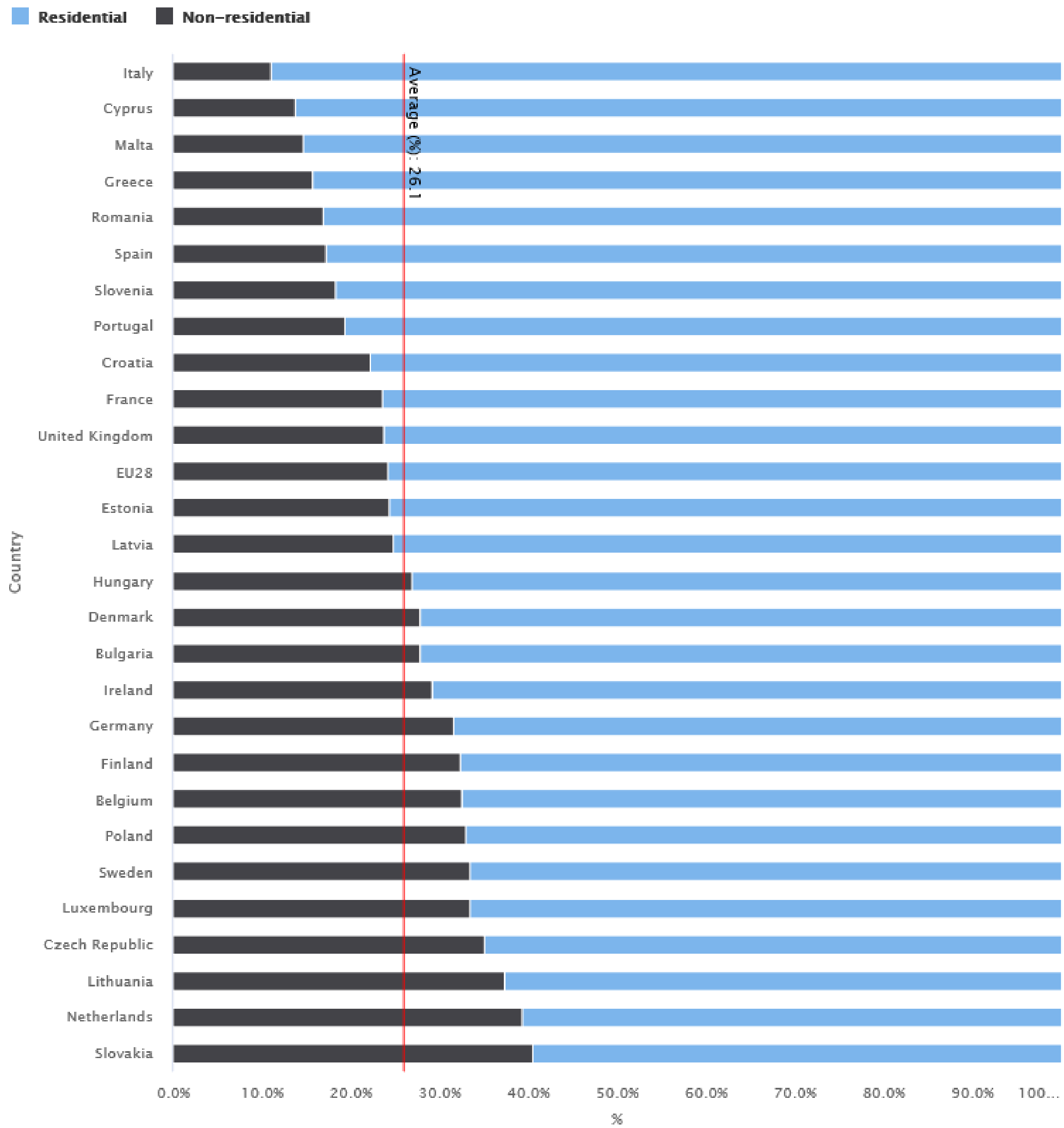


Figure 24: Share of total living space and total useful floor area accounted for by residential and non-residential buildings in 2013 *(datamapper, 2020)*

Based on total living space of around 29 million m^2 in 2013, this would correspond to an area of around 14.6 million m^2 in non-residential buildings. The total area in non-residential buildings constructed since 2014 can be estimated at around 1.4 million m^2 on the basis of the statistics for completed buildings, meaning that the total area in non-residential buildings in 2020 would be around 16 million m^2.

Based on STATEC's area-related figures for non-residential buildings completed between 1995 and 2017 (6.75 million m^2) and the estimated useful floor area of buildings constructed over the period up to 1985 (3.4 to 6.3 million m^2), it would appear that the value tends to be high. The difference may be attributable to variations in the method followed when assigning buildings to categories, however.

The proportions accounted for by the different categories of non-residential buildings are specified as follows in the EU Building Stock Observatory (stock, 2020):

- public buildings 8.17%;
- wholesale and retail 22.85%;
- hotels and restaurants 21.07%;
- healthcare 4.62%;
- education 10.82%;
- private offices 32.48%.

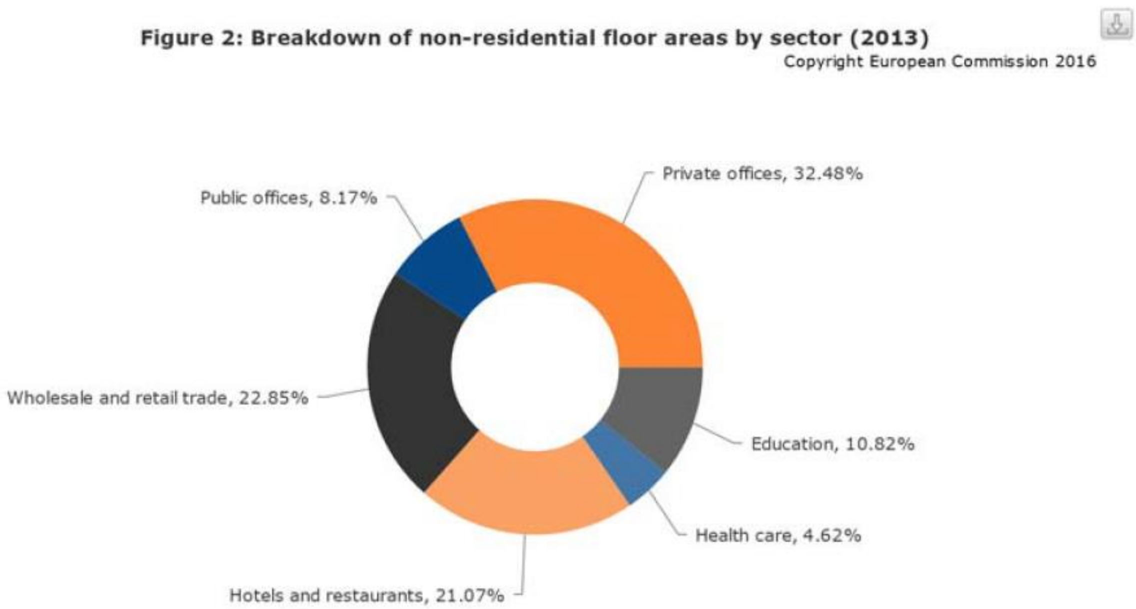


Figure 25: Net useful floor area in Luxembourg's non-residential buildings, as at 2013 *(stock, 2020)*

The specific final energy demand for non-residential buildings is as follows:

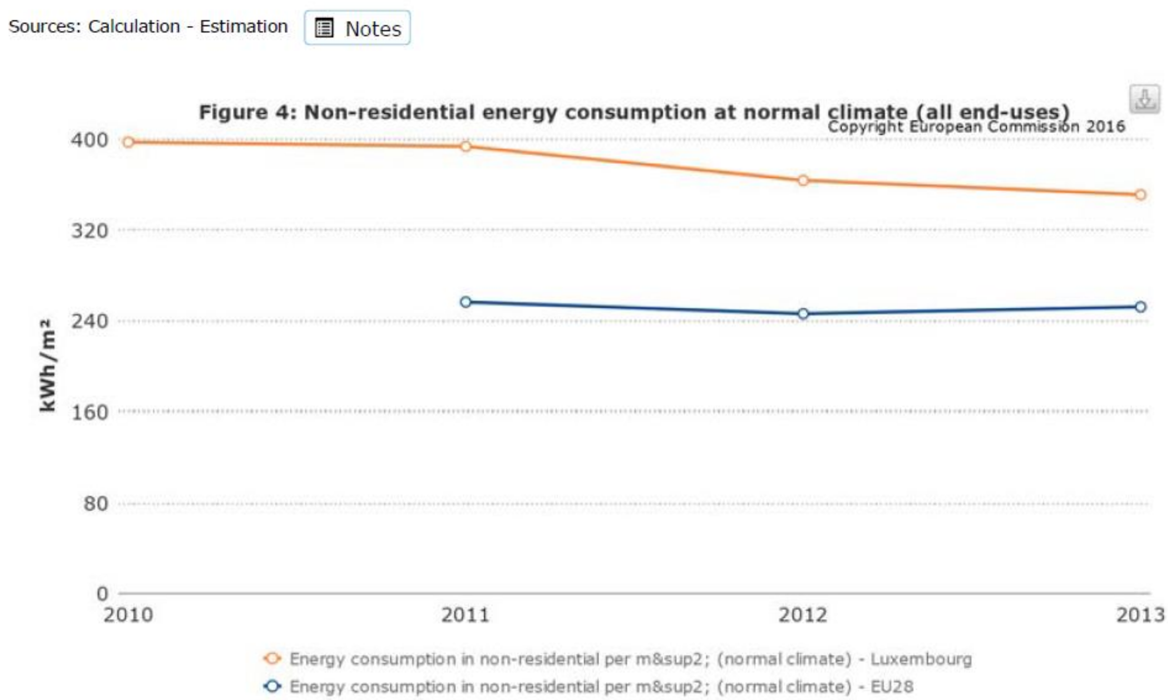


Figure 26: Climate-corrected final energy consumption for non-residential buildings in Luxembourg and the EU 28, as at 2013 *(stock, 2020)*

According to the data, the average specific final energy consumption (around 350 $kWh/m^2_{\text{useful floor area}}a$) is of a similar order of magnitude as the consumption values for office buildings with high electricity consumption (see 3.2.6). They are therefore more likely to be representative of recently constructed and fully air-conditioned office buildings than of the average for the non-residential buildings sector as a whole.

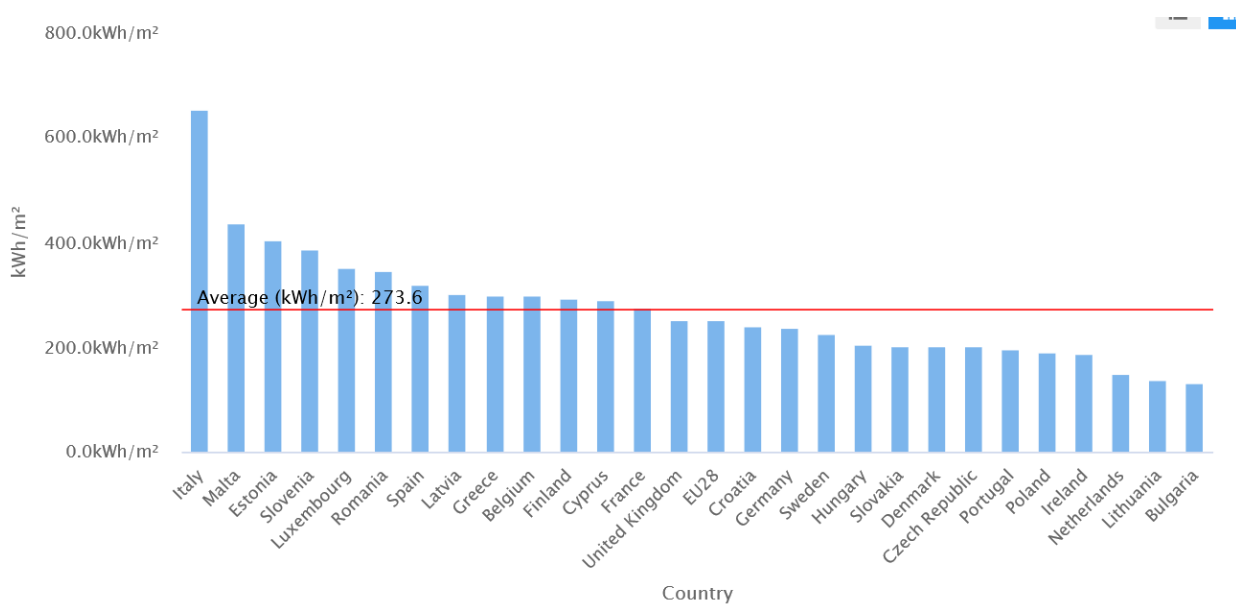


Figure 27: Average specific final energy demand for non-residential buildings across the entire EU *(datamapper, 2020)*

The value specified for non-residential buildings in Luxembourg (350 kWh/m^{2}a) is significantly higher than the average for the EU 28 (273 kWh/m^{2}a), which appears plausible in view of the high proportion of office buildings in Luxembourg's financial sector that are modern and therefore equipped with a higher level of technology.

3.2.3. Third NEEAP (energy)

The Third NEEAP (NEEAP3, 2014) breaks the data for the commerce, trade and services sector down into office-like services (around 70%) and other services (around 30%) (as at 2013). It is not indicated whether the percentages relate to area, number of employees, energy demand or another indicator.

Data concerning the useful floor area for the commerce, trade and services sector or concerning specific energy demand for heating and electricity are not available.

Energy balance for heating in the commerce, trade and services sector (corrected for climate)													
Energy carrier	**Unit**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
Natural gas	GWh	1 447	1 646	1 717	1 528	1 441	1 816	1 777	1 807	1 771	1 577	1 518	1 807
Heating oil	GWh	1 145	1 058	904	818	784	496	500	367	363	581	604	906
Heat (other)	GWh	179	341	723	713	751	789	689	715	618	635	880	807
Total	GWh	2 772	3 045	3 344	3 059	2 977	3 101	2 966	2 889	2 752	2 793	3 001	3 520

Figure 28: Final energy demand by the commerce, trade and services sector between 2001 and 2012, broken down by energy carriers *(NEEAP3, 2014)*

Total heating consumption in the commerce, trade and services sector, corrected for climate, is stated as 3 520 GWh/a for 2012. It can be presumed that this value contains a smaller proportion of process heat for production, etc., meaning that the heat consumption relevant to the LTRS is likely to be somewhat lower. If this proportion is assumed to be 600 GWh/a, the share of building-related heating consumption that is relevant to the LTRS would be 2 920 GWh/a.

Electricity demand by the commerce, trade and services sector is specified as follows, broken down by use:

Electricity consumption in the commerce, trade and services sector, broken down by use													
Electricity use	**Unit**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
Lighting	GWh	756	601	651	608	675	686	821	805	759	774	885	1 017
Power	GWh	489	388	421	393	435	441	527	515	485	494	565	650
Process heat	GWh	129	102	110	103	113	112	133	129	121	122	140	162
Cooling/air conditioning	GWh	162	128	139	130	143	143	170	165	155	157	180	208
Information and communications technologies	GWh	377	300	326	304	339	347	417	411	388	396	452	519
Space heating	GWh	53	42	46	43	47	48	58	57	54	55	63	
Total	**GWh**	**1 967**	**1 560**	**1 693**	**1 580**	**1 752**	**1 777**	**2 126**	**2 082**	**1 962**	**1 998**	**2 286**	**2 628**

Figure 29: Electricity consumption by the commerce, trade and services sector between 2001 and 2012, broken down by use *(NEEAP3, 2014)* Note: Information and communications technologies: IT applications

Electricity consumption by the sector is stated as 2 628 GWh/a in 2012. If the electricity consumption for process heat that is not relevant to the LTRS (162 GWh/a) is subtracted and a non-building-related share of electricity consumption for power is also subtracted (based on the assumption that 500 GWh/a of total consumption for power (650 GWh/a) is generated through production processes), the share of building-related electricity consumption that is relevant to the LTRS can be estimated at 2 628 – 162 – 500 = 1 966 GWh/a.

Total building-related final energy consumption by the sector in 2012 would therefore be 2 920 + 1 966 = 4 886 GWh/a.

3.2.4. PWC Study

A study published by PWC in 2015 on the real estate market in Luxembourg contains (among other things) data on the office building and shopping centre market segments (PWC, 2015)

It does not provide any figures for the area accounted for by the office building segment, but future demand in 2015, 2016 and 2017 was estimated at an average of 92 000 m^2. Around one third of the total demand was expected to be met through speculative projects, and two thirds through non-speculative projects.

According to PWC, total office space will increase to just under 240% of its initial 1995 value by 2020. This places area-related growth slightly above GDP growth.

The study estimates the total space in shopping centres at 500 000 m^2. This figure is estimated to increase by 80 000 m^2 over the period up to 2017. According to PWC, this means that Luxembourg has one of the highest per-capita values for space in shopping centres.

3.2.5. Jones Lang Lasalle (JLL) study

The JLL study from 2016 states that rentable office space in Luxembourg stood at 3.9 million m^2 in the first quarter of 2016. The average figure for completed (including renovated) rentable office space over the period between 2013 and 2015 is given as around 97 000 m^2.

Letting Market	2013	2014	2015	Q1 2016
Take-up (cumulative) in '000 sq. m.	146	196 *	231	72
Stock in Mio. sq. m.	3.5	3.6	3.8	3.9
Completions (cumulative) in '000 sq. m.	71	104	116	26
Vacancy in '000 sq. m.	178	168	159	178
Vacancy Rate in %	5.1	4.7	4.2	4.6
Prime Rent in €/sq. m. /month	42	42	45	45
Capital Market				
Investment volume total in € Mio (**)	685	889	979	72
Prime Yield Band in % (typical 3/6/9)	5.75-6.50	5.50-6.50	5.00-6.25	5.00-6.25

Figure 30: Changes in rentable office space in Luxembourg *(JLL, 2016)*

JLL estimates demand at 100 000 m^2 in each of the years 2016 and 2017 and 44 000 m^2 in 2018. The non-speculative share has remained relatively constant at 36 000–62 000 m^2, but a significant drop in this figure is forecast for 2018.

	2016e	2017e	2018e
Future Supply, Speculative ('000 sq. m.)	65.7	41.1	4.4
Future Supply, Non Speculative ('000 sq. m.)	36.2	61.6	40.0
Total ('000 sq. m.)	**101.9**	**102.7**	**44.4**

Figure 31: Projected rentable office space in Luxembourg, 2016 to 2018 *(JLL, 2016)*

A study published in 2019 states that office real estate covers an area of 4 million m^2 (JLL, 2019).

3.2.6. Study by the University of Luxembourg on office and educational buildings

The study investigated non-residential buildings constructed between 1996 and 2010, i.e. buildings that were constructed after the entry into force of the first minimum requirements relating to U-values and before the entry into force of the 2011 Grand-Ducal Regulation (Maas, 2012). The investigations focused on 68 educational buildings (primary and secondary schools, including early years, preschool and childcare centres as well as gymnasiums) and 40 office buildings.

Figure 32 shows the average values for heating, hot water and electricity in educational buildings.

		Passivhaus	Low-energy building	Standard
Average final energy consumption for heating + hot water	kWh/m$^2_{GFA}$a	35	72	113
Average final energy consumption for electricity	kWh/m$^2_{GFA}$a	Educational buildings with catering facilities: 39		

		Educational buildings without catering facilities: 29

Figure 32: Average final energy demand for heating/hot water and electricity in the educational buildings under investigation *(Maas, 2012)*

The study reaches the conclusion that the average final energy consumption by educational buildings for heating and hot water is 93 kWh/m^2_{GFA}a. The evaluation reveals that construction age has a decisive impact: Buildings that were constructed after 2005 and designed in line with the funding requirements for Passivhaus and low-energy standards exhibit significantly lower final energy consumption values for heating and hot water: Classroom buildings that meet the Passivhaus standard achieve a value of 35 kWh/m^2_{GFA}a on average, which is significantly lower than those that meet the low-energy standard (72 kWh/m^2_{GFA}a) and the educational buildings standard (113 kWh/m^2_{GFA}a).

The average electricity demand for all educational buildings is 32 kWh/m^2_{GFA}a, while the average demand in buildings with catering facilities is 39 kWh/m^2_{GFA}a, compared to 29 kWh/m^2_{GFA}a for buildings without catering facilities.

The following table summarises the final energy consumption by the office buildings investigated.

		Punctuated façade	Strip-structured façade	Glazed double façade
Average final energy consumption for heating + hot water	kWh/m^2_{GFA}a	103	118	162
Average final energy consumption for electricity	kWh/m^2_{GFA}a	Financial sector: 217 Administration: 80		

Figure 33: Average final energy demand for heating/hot water and electricity in the office buildings under investigation *(Maas, 2012)*

The average final energy consumption for heating and hot water in all office buildings investigated is 131 kWh/m^2_{GFA}a. The lowest average value is observed for buildings with a punctuated façade (103 kWh/m^2_{GFA}a), and the highest for those with a double façade.

The average final energy consumption for electricity is 173 kWh/m^2_{GFA}a. The same figure for financial sector buildings is 217 kWh/m^2_{GFA}a on average, which is significantly higher than for administrative buildings (80 kWh/m^2_{GFA}a).

Final energy consumption for heating, hot water and electricity is therefore significantly higher for the office buildings under investigation than for educational buildings.

By way of contrast to other building types, the total final energy consumption for new office buildings tends to be higher than consumption in older buildings. This can be attributed to the fact that the level of technology is significantly higher on average (active cooling, typically with a high proportion of glazing, higher comfort requirements, higher consumption for IT applications).

3.2.7. Energy monitoring of public buildings

Figure 34 summarises the stock of government buildings, broken down by categories.

Owners	Users	Category	Number of buildings	Net useful floor area all construction years	Of which until construction	Of which from construction	Final energy for heating in GWh/a	Final energy for electricity in GWh/a	Average value for heat	Average value for electricity
			Number	m^2	m^2	m^2	GWh/a	GWh/a	$kWh/m^2_{NFA}a$	$kWh/m^2_{NFA}a$
Central		Administration	189	758 189	459 097	299 092	71 759 915	46 149 748	94.6	60.9
Central		Workshop/warehouse	68	188 239	91 733	96 506	11 797 894	3 824 380	62.7	20.3
Central		Other	1	21 513	0	21 513	180 300	401 100	8.4	18.6
Central		Various	104	314 306	250 112	64 194	29 656 989	11 443 979	94.4	36.4
Central		School	115	1 019 342	527 265	492 077	72 823 398	26 002 212	71.4	25.5
Central		Exhibition space	20	64 969	50 778	14 191	10 157 450	10 105 650	156.3	155.5
Central		Dwelling	55	117 294	96 994	20 300	17 043 403	1 994 405	145.3	17.0
Central		Accommodation	102	265 749	260 039	5 710	32 944 495	7 302 813	124.0	27.5
Central		Swimming pool	3	8 468	6 168	2 300	1 534 747	721 152	181.2	85.2
Central		Restaurant	27	44 819	20 511	24 308	4 108 144	2 024 919	91.7	45.2
Central		Sports venue	26	193 157	66 171	126 986	18 346 196	8 883 004	95.0	46.0
Total			710	2 996 046	1 828 869	1 167 177	270 352 930	118 853 362	90.2	39.7

Figure 34: Overview of the stock of central government buildings and their energy consumption for heating and electricity *(Trausch, 2020)*

As a total for all of the central government's buildings, the stock of public buildings has a useful floor area of almost 3 million m^2 across 710 buildings(Trausch, 2020). Almost two thirds of the stock had been built by 1995, and one third was built from 1996 onwards.

The average final energy consumption for heating by the total stock of public buildings is stated as 90 $kWh/m^2_{useful\ floor\ area}$, and consumption for electricity is stated as just under 40 $kWh/m^2_{useful\ floor\ area}a$.

The average final energy consumption for heating in schools is stated as 71.4 $kWh/m^2_{useful\ floor\ area}a$. This value is below that specified in the study by the University of Luxembourg (93 $kWh/m^2_{GFA}a$) (Maas, 2012). However, since the average for all schools also includes schools constructed more recently (from 2011 onwards), and since schools that have been constructed more recently in line with the Passivhaus standard consume significantly less energy for heating, an average consumption of 71.4 $kWh/m^2_{useful\ floor\ area}a$ is plausible. The use of different area-related measurements (useful floor area or gross floor area) means that the results may vary by around 20% to 30%, making it more difficult to compare them.

The next figure shows the values for buildings owned by municipalities.

Owners	Category	Number of buildings	Area	Final energy for heat	Final energy for electricity	Average value for heat	Average value for electricity
		Number	m^2	MWh	MWh	kWh/m^2a	kWh/m^2a
Municipality	Other air-conditioned buildings	743	461 191	62 588	18 707	135.7	40.6
Municipality	Event venues	275	225 741	33 162	13 024	146.9	57.7
Municipality	Nursing/retirement homes	5	9 945	2 631	1 114	264.5	112.0
Municipality	Colleges and universities	313	581 934	64 089	20 607	110.1	35.4
Municipality	Business premises	5	1 152	150	81	130.3	70.4
Municipality	Kindergartens and day care centres	180	216 557	22 366	9 743	103.3	45.0

Municipality	Boarding schools	1	1 386	256	116	184.6	83.9
Municipality	Swimming pools	17	58 949	17 914	12 576	303.9	213.3
Municipality	Restaurants	12	6 158	1 063	758	172.7	123.1
Municipality	Sports centres	170	241 843	35 533	16 075	146.9	66.5
Total		1 721	1 804 858	239 752	92 802	169.9	84.8

Figure 35: Overview of the stock of central government buildings and their energy consumption for heating and electricity *(myenergy, 2020)*

Evaluating the EnerCoach data (as at 2018) gives a total of 1 721 buildings covering a total area of around 1.8 million m^2 that are managed directly by the municipalities.

The average final energy consumption for heating of the total municipal buildings stock is stated as 170 kWh/m$^2_{\text{useful floor area}}$, and consumption for electricity is stated as almost 85 kWh/m$^2_{\text{useful floor area}}$a. These values are higher than those recorded for buildings managed by the central government; this may be attributable to the greater homogeneity (in terms of both construction year and use) of buildings at municipality level.

3.2.8. Summary of non-residential building stock

Based on the available (and fragmentary) data, the total useful floor area in non-residential buildings can be roughly estimated at around 11–14 million m^2, compared to 34 million m^2 of living space in 2020. This indicates that non-residential buildings – in terms of area – account for almost 24% to 29% of total living space and useful floor area. The statistically recorded average for non-residential buildings as a share of total area in all buildings newly constructed between 1985 and 2017 is 29%.

The EU Buildings Datamapper states that non-residential buildings in Luxembourg account for 33.5% of the total area in all buildings (datamapper, 2020). This suggests that the useful floor area in non-residential buildings is more likely to be in the region of at least 14 million m^2.

Private office buildings represent the largest individual category in terms of area, while the share of public buildings can be estimated at around 21–30% of the total area covered by non-residential buildings. Shopping centres/retail shops are another relevant category.

Since modern office buildings account for a large proportion of the total area covered by non-residential buildings, and since these buildings tend to exhibit a high level of energy consumption (high standards of comfort, active cooling in spite of glazed areas, extensive use of IT equipment, etc.), non-residential buildings account for a share of total final energy demand for all buildings that is disproportionate to the area they cover.

The share of total final energy consumption in all buildings accounted for by building-related final energy consumption in non-residential buildings can be estimated at around 43.5%.

Known variables include final energy demand for residential buildings (including domestic electricity) at 6 154 GWh/a and final energy demand under the ‘tertiary’ heading at 5 697 GWh/a (both figures taken from the 2018 consumption data according to STATEC).

However, the second of these values includes not only building-related consumption for heating, cooling, ventilation, hot water, auxiliary current and domestic electricity for lighting and IT, but also non-building-related consumption for power and production processes.

Since the consumption sectors ‘tertiary’ and ‘commerce, trade and services’ have not yet been clearly defined at either EU or national level, and since non-building-related energy consumption for power and process heat is not recorded and billed separately in many companies, the share of building-related final energy consumption accounted for by non-residential buildings can only be roughly estimated.

If the share of final energy consumption for process heat is estimated at 300 GWh/a and the consumption of power for production processes is estimated at 650 GWh/a, this results in final energy consumption for building-related energy uses in non-residential buildings of

5 697 – 300 – 650 = 4 747 GWh/a

Total building-related final energy consumption by residential and non-residential buildings would then be

6 154 + 4 747 = 10 901 GWh/a

Based on the aforementioned assumptions, the proportion of total building-related final energy consumption accounted for by non-residential buildings in Luxembourg would be

4 747 / 10 901 = 43.5%

Since it is impossible to determine the proportion of the total area in all buildings accounted for by non-residential buildings or the share of total building-related final energy consumption accounted for by these buildings, a number of plausibility checks were carried out on the values calculated for Luxembourg, as described below.

<u>Plausibility check 1:</u>

The proportion of total living space and useful floor area in Germany accounted for by non-residential buildings is specified as 27% (Dena, 2015) or 31.5% (datamapper, 2020), which places it on a par with the value of 24–29% (own estimate, see above) or 33.5% (EU Buildings Datamapper) calculated for Luxembourg.

The share of building-related final energy consumption accounted for by non-residential buildings in Germany is specified as 36% (Dena, 2019), which is significantly lower than the rough estimate of 43.5% for Luxembourg.

There are also gaps in the data available regarding areas and final energy consumption in non-residential buildings in Germany.

Plausibility check 2:

The proportion of total living space and useful floor area in the Austrian province of Vorarlberg accounted for by non-residential buildings is stated as around 39%, and the proportion of total final energy consumption in the region accounted for by non-residential buildings is stated as 34% (Engstler, 2019). Once again, there are gaps in the data available regarding areas and final energy consumption in non-residential buildings in Vorarlberg (and other Austrian provinces).

Plausibility check 3:

If building-related final energy demand by Luxembourg's non-residential buildings is assumed to be 4 747 GWh/a, with a total useful floor area of 11 million m^2 (lower estimate) this results in an average specific consumption by non-residential buildings of: 4 747 GWh/a / 11 million m^2 = 432 $kWh/m^2_{useful\ floor\ area}a$.

Based on a total useful floor area of 14 million m^2 (upper and more probable estimate), this results in an average specific consumption of 4 747 GWh/a / 14 million m^2 = 339 $kWh/m^2_{useful\ floor\ area}a$

Both values appear to be very high as an average for all non-residential buildings, as confirmed by a comparison with office buildings in Luxembourg (Chapter 3.2.6), public buildings in Luxembourg (Chapter 3.2.7), data for office buildings in Switzerland (Plausibility check 4) and data for office buildings in Germany and Switzerland (Plausibility check 5). One reason for high consumption by the commerce, trade and services sector in Luxembourg might be the fact that server centres (such as LuxConnect, EBRC, etc.) and bank-owned data centres are operated within the country. Consumption relating to uses of this kind is included in the total for the commerce, trade and services sector.

Plausibility check 4: Comparison with consumption benchmarks for office buildings in Switzerland.

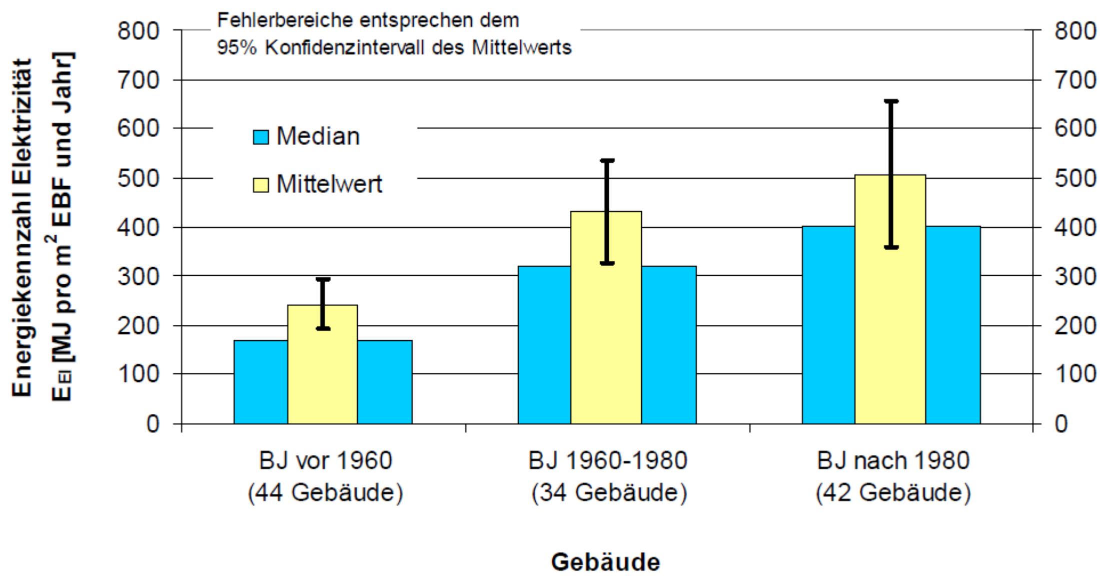
The following figure shows the results of consumption reports for office buildings in Switzerland, compared against the values pursuant to SIA 2024 (Aiulfi, 2010). The consumption data for the buildings (123 in total) were broken down into final energy for heating and final energy for electricity. Consumption of electricity in the buildings is also broken down according to the level of technology. A distinction was initially made between buildings with large servers (> 2 W/m^2_{GFA}) and those without large servers. Within these categories, a further distinction is made according to the level of mechanical ventilation or air conditioning.

	Final energy for heat	Final energy for electricity				
			No large servers		With large servers	
		Mostly not ventilated/air-conditioned	Partially ventilated and/or air-conditioned	Mostly ventilated and air-conditioned	Partially ventilated and/or air-conditioned	Mostly ventilated and air-conditioned
SIA 2024: average value	-	43	84	47	191	272
Survey: average value	94	51	67	126	181	152
Number of buildings	123	29	20	20	9	8

Figure 36: Average final energy consumption for heating and electricity in 123 office buildings in Switzerland, averages according to SIA 2024 – figures in $kWh/m^2_{useful\ floor\ area}a$ *(Aiulfi, 2010)*

Average consumption of energy for heating by the 123 office buildings is 94 $kWh/m^2_{useful\ floor\ area}a$. The lowest demand for electricity (51 $kWh/m^2_{useful\ floor\ area}a$) is seen in buildings that are mostly not ventilated/air-conditioned, and the demand in buildings that are partially ventilated and/or air-conditioned is significantly higher. Consumption in buildings with large servers is highest, at 152 or 181 $kWh/m^2_{useful\ floor\ area}a$.

Specific heat consumption in newer buildings is dropping, but the fact that the level of technology in these buildings is higher on average means that their consumption of electricity is rising significantly. This trend reflects the findings of the study on office buildings in Luxembourg (Maas, 2012).

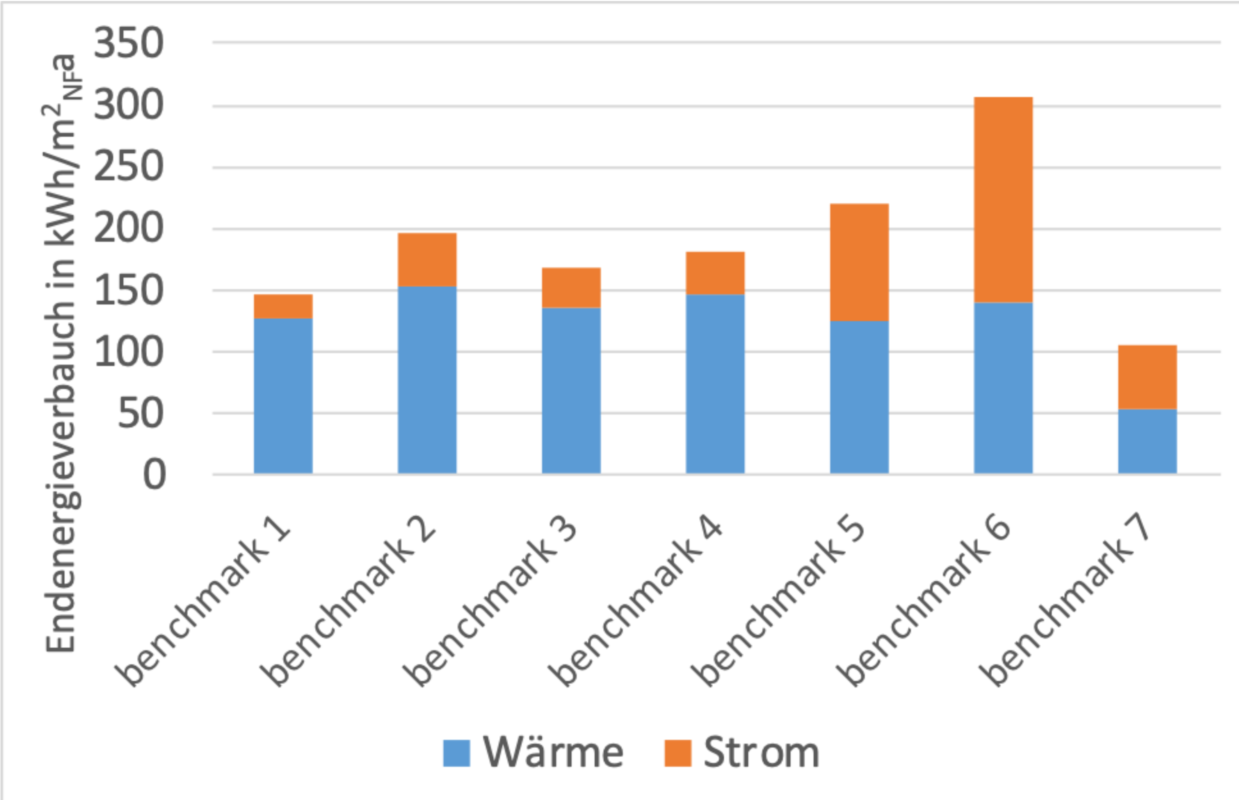


Fehlerbereiche entsprechen dem 95% Konfidenzintervall des Mittelewerts	Error margins correspond to the 95% confidence interval of the mean
Energiekennzahl Elektrizität E_{El} [MJ pro m^2 EBF und Jahr]	**Energy parameter for electricity EEI [MJ per m^2 ERA and year]**
Medien	Median
Mittelwert	Mean
BJ vor 1960 (44 Gebäude)	Construction year before 1960 (44 buildings)
BJ 1960-1980 (34 Gebäude)	Construction year 1960-1980 (34 buildings)
BJ nach 1980 (42 Gebäude)	Construction year after 1980 (42 buildings)
Gebäude	**Buildings**

Figure 37: Dependency of specific final energy consumption for electricity on building age class (NB: MJ/m$^2_{ERA}$ used as a unit) *(Aiulfi, 2010)*

Plausibility check 5: Comparison with other benchmarks for office buildings in Germany and Switzerland

The following figure shows benchmarks for the specific final energy consumption of office buildings in Germany and Switzerland. Benchmarks 1 to 6 represent large numbers of office buildings, while Benchmark 7 shows the consumption values for a single office building constructed in 1995 in line with the 'low-energy building' standard by way of a comparison.



Endenergieverbrauch in kWh/m²	Final energy consumption in kWh/m²
Wärme	Heating
Strom	Electricity

Figure 38: Benchmark values for specific final energy consumption in office buildings, in $kWh/m^2_{NFA}a$ *(Voss, 2006)*

The specific final energy consumption for heating by the buildings investigated in the benchmark studies (with the exception of the LEO 97 project that was built to a low-energy standard in the 1990s (Benchmark 7)) is within a range of around 120 to 150 $kWh/m^2_{NFA}a$. This is on a par with the value for office buildings in Luxembourg (see Chapter 3.2.6).

The specific final energy consumption for electricity is 20–167 kWh/m^2_{NFA} depending on the building's level of technology. The buildings investigated for the Benchmark 1 and Benchmark 2 studies were almost all public buildings, which were found to have a relatively low demand for electricity.

Evaluation of the data available for the non-residential building stock reveals that a detailed inventory of this stock is urgently required, as is the case in the other EU Member States.

Before this can happen, a comprehensible definition of the term 'non-residential building' is needed, differentiating these buildings from residential buildings and if possible applying throughout the EU. The non-residential buildings sector should also be broken down into comprehensible categories.

In order to determine the energy demand of non-residential buildings, the share of non-building-related energy consumption in the 'commerce, trade and services' sector needs to be estimated as accurately as possible.

A detailed inventory of the non-residential building stock is therefore a high-priority measure. A study of this kind is planned for 2021. Using this study as a basis, it will then be possible to move on to the next stage, which involves calculating the technical and economic saving potentials of non-residential buildings in different categories.

3.3. Identification of cost-effective approaches to renovation (Article 2a(1)(b));

Article 4(b) of the EED already required Member States to identify in their LTRSs cost-effective approaches to renovation relevant to building type and climatic zone. Article 2a(1)(b) of the EPBD provides that each LTRS 'shall encompass the identification of cost-effective approaches to renovation relevant to the building type and climatic zone, considering potential relevant trigger points, where applicable, in the life-cycle of the building'. Recital 12 of Directive (EU) 2018/844 clarifies that a 'trigger point' is 'an opportune moment in the life-cycle of a building, for example from a cost-effectiveness or disruption perspective, for carrying out energy efficiency renovations'. A trigger point could be: (a) a transaction (e.g. the sale, rental (5) or lease of a building, its refinancing, or a change in its use); (b) a renovation (e.g. an already planned wider non-energy-related renovation) (6); or (c) a disaster/incident (e.g. fire, earthquake, flood) (7). Certain buildings may not be subject to trigger points, hence the qualification 'where applicable'.

Linking energy-efficiency renovation with trigger points should ensure that energy-related measures are not neglected or omitted at a later stage in the life-cycle of the building. Focusing on energy efficiency at trigger points should limit the risk of missing opportunities to renovate and increase possible synergies with other action. Trigger points may lead to cost-effective renovation due to the economies of scale that can be achieved if energy-related renovation is carried out at the same time as other necessary work or planned renovation.

Energy-related building renovations will only become more established on the market if real energy consumption corresponds to the calculated demand values and the increase in costs is so low that the renovated buildings can be operated profitably (at least if any funding is taken into account).

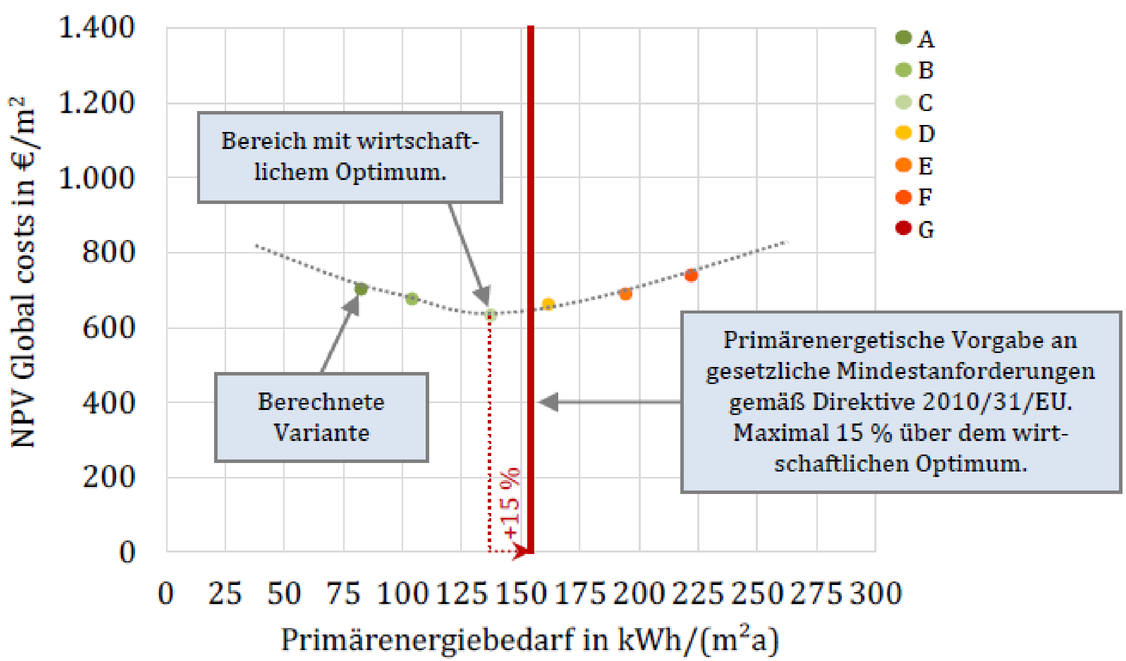
The profitability of the various concepts for energy renovations of residential and non-residential buildings were accordingly investigated as part of Luxembourg's cost-optimal analysis.

The Member States are obliged to carry out studies of this kind pursuant to Directive 2010/31 EU (EU, 2010), supplemented by Regulation (EU) No 244/2012 (EU, 2012), in order to calibrate the minimum requirements for the energy performance of buildings. The minimum requirements that are specified should be no more than 15% worse than the cost-optimal energy level calculated in the study. The studies therefore play an important role in setting a minimum level for the energy performance of new builds and renovations.

The outcomes of cost-optimal analyses do not indicate whether the cost-optimal energy level that has been calculated is compatible with the national, European or international climate action goals. The Member States can therefore impose national minimum requirements that are more stringent than the cost optimum.

Cost-optimal analyses involve identifying and comparing global costs for a number of typical example buildings, i.e. the net present values of total costs for investment, maintenance and upkeep and for energy for a large number of design variants with different energy performances and different concepts.

The same basis for the profitability calculations (net present value method, observation period of 30 years for residential buildings, 20 years for non-residential buildings, incorporation of residual values and replacement investments, interest rates) must be used by all the EU Member States. Other constraints (energy prices, energy price increases, etc.) and the costs of various energy efficiency measures are determined individually by the countries. The basic principle underlying the method is illustrated in Figure 39.



NPV Global costs in €/m²	NPV Global costs in €/m²
Bereich mit wirtschaftlichem Optimum	Range with economic optimum
Berechnete Variante	Calculated variant
Primärenergetische Vorgabe an gesetzliche Mindestanforderungen gemäß Direktive 2010/31/EU. Maximal 15 % über dem wirtschaflichen Optimum	Primary energy specified on the basis of statutory minimum requirements pursuant to Directive 2010/31/EU. Maximum 15% above economic optimum
Primärenergiebedarf in kWh/(m²a)	Primary energy demand in kWh/(m²a)

Figure 39: Graphical representation of the method for calculating the maximum value for the statutory minimum primary energy requirement *(KostOpti, 2019)*

For each sample building, alternative designs are investigated based on different energy levels (shown in the figure as efficiency classes A to G). The primary energy demand and the net present values of total costs for investments into energy-related building components, their maintenance and upkeep and energy costs are determined for each variant (global costs).

Costs that are irrelevant in terms of energy costs or costs of components that are identical at all energy levels do not need to be taken into account. The assessment is carried out on a 30-year basis for residential buildings. The economic optimum corresponds to the primary energy demand with the lowest global costs over 30 years. The assessment is carried out on a 20-year basis for non-residential buildings.

The minimum requirement specified by national law must not be more than 15% higher than the primary energy value that corresponds to the cost optimum.

The geometry data that are relevant in terms of energy and the characteristics of the buildings taken into account in the cost-optimal analysis are summarised in the following figure.

Table 16: Building geometries and characteristics used

Area	**Unit**	**G1** **G5**[40]	**G2** **G6**	**G3** **G7**	**G4** **G8**	**G9** **G13**	**G10** **G14**	**G11** **G15**	**G12** **G16**
Building type[41]	-	Non-residential	Non-residential	Non-residential	Non-residential	Residential	Residential	Residential	Residential
Type	-	Offices	Offices	Offices	School	Single-family dwellings	Single-family dwellings	Multi-family dwellings	Multi-family dwellings
Exterior facade	m^2	694	3 417	3 276	2 009	248	428	992	2 046
Window	m^2	251	1 517	1 050	420	41	75	289	660
Too unheated[42]	m^2	55	805	1 002	303	0	0	0	0
Floors	m^2	294	1 237	2 174	733	96	120	375	600
Roof	m^2	294	1 484	1 172	1 018	111	139	433	693
Building envelope	m^2	1 337	6 943	7 524	4 063	455	687	1 800	3 339
Energy reference area43	m^2	821	5 885	6 161	2 197	163	306	1 275	3 060
Gross volume	m^3	2 996	24 266	21 212	9 130	595	1 116	4 550	11 160
Compactness A/V	m^{-1}	0.45	0.29	0.36	0.45	0.77	0.62	0.39	0.30
Share of window area	%/Façade	36%	44%	32%	21%	17%	18%	29%	32%
Zone number	-	6	7	5	8	1	1	1	1
Heating	yes/no	yes	yes	yes	yes	yes	yes	yes	yes
Cooling	yes/no	yes	yes	yes	no	no	no	no	no
Lighting	yes/no	yes	yes	yes	yes	no	no	no	no
Domestic hot water	yes/no	yes	yes	no	yes	yes	yes	yes	yes
Ventilation[44]	yes/no/var.	yes	yes	yes	yes	var.	var.	var.	var.

Figure 40: Geometric and other characteristics of the building types used as a basis for the cost-optimal analysis *(KostOpti, 2019)*

The residential buildings (G9 to G12) include one large and one small single-family dwelling and multi-family dwelling in each case. Four non-residential buildings were also assessed. In addition to an 'artificially' created building (G1, G5) that was used for calibration purposes when drafting Luxembourg's Energy Saving Regulation, three blueprints of real buildings with differing designs were investigated. They are representative of the building geometries found in Luxembourg. Building 4 corresponds to a school building for the purpose of taking into account the lack of air conditioning.

The results of Luxembourg's cost-optimal analysis (KostOpti, 2019) are shown below, categorised separately for renovations of residential and non-residential buildings.

3.3.1. Residential buildings

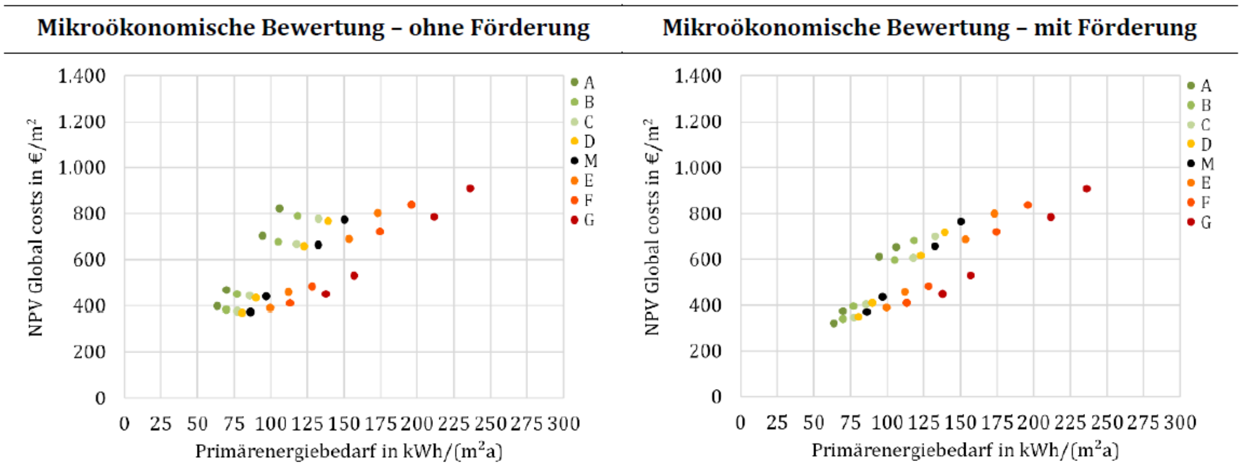
The cost-optimal analysis carried out in 2018 investigated the profitability of various building renovation energy standards using four residential buildings as examples, and compared them on the basis of global costs (net present values of their life-cycle costs for investment, maintenance and upkeep and for energy) (KostOpti, 2019).

Figure 41 shows the envelope performances assessed according to efficiency classes A to I. Since overall requirements for major renovations do not currently apply under the Energy Saving Regulation, the 'Min.' column in the table describes a performance that is just above the minimum requirements for modified individual components.

Class threshold	A	B	C	D	Min.[32]	E	F	G	H	I
U-value windows	0.78	0.92	1.12	1.36	1.50	1.90	2.30	2.70	3.20	5.00
U-value floors	0.15	0.22	0.28	0.34	0.40	0.50	0.60	0.90	1.00	1.08
U-value walls	0.12	0.17	0.23	0.27	0.32	0.45	0.60	0.90	1.10	1.70
U-value roof	0.10	0.13	0.17	0.21	0.25	0.30	0.40	0.65	1.23	1.95
Thermal bridges[33]	0.01	0.03	0.05	0.10[34]	0.10	0.10	0.05	0.05	0.05	0.05
Ventilation system in residential building[35]	85%	85%	-		-	-		-		-
Ventilation system in non-residential building[36]	75%	72%	68%	60%	60%	55%	50%	50%	50%	45%
Airtightness[37]	0.6	1.0	2.0	3.0	3.0	4.0	4.0	6.0	6.0	6.0

Figure 41: Technical parameters for the efficiency classes used in the cost-optimal analysis *(KostOpti, 2019)*

The figure below illustrates in graphical form the results of the cost-optimal analysis for the four residential building renovations that were investigated; the following figure summarises the results in the form of a table. The results shown are for the main scenario S1, which is based on an increase in energy prices of 2.8% per annum and interest on capital at 3.0% per annum.



Mikroökonomische Bewertung – ohne Förderung	Microeconomic assessment – without funding
Mikroökonomische Bewertung – mit Förderung	Microeconomic assessment – with funding
NPV Global costs in €/m²	NPV Global costs in €/m²
Primärenergiebedarf in kWh/(m²a)	Primary energy demand in kWh/(m²a)

Figure 42: Results of the cost-optimal analysis for renovation of the four residential buildings used as examples – microeconomic perspective – without and with funding *(KostOpti, 2019)*

Variant Identifier	Area A_n	Energy parameter Qprimary	Global costs microeconomic	Global costs microeconomic
-	m²	kWh/(m²a)	€/m² without funding.	€/m² with funding.
B_A_G 13_A2_E2,8%_D3%	163	106.3	820	652
B_B_G 13_A2_E.2.8%_D3%	163	118.5	788	682
B_C_G 13_A2_E2.8%_D3%	163	132.9	775	700
B_D_G13.A2_E2.8%_D3%	163	139.3	766	718
R.Min.G 13_A2_E2.8%_D3%	163	150.4	772	765
B.E.G13 _A2_E2.8%_D3%	163	173.1	800	800
B_F_G 13_A2_E.2.8%_D3%	163	196.1	837	837
B.G.G13 A2 E2.8%D3%	163	236.2	907	907
B_A_G 14_A2_E2.8%_D3%	306	94.5	702	611
B_B_G 14_A2_E2.8%_D3%	306	105.2	675	597
B_C_G14_A2_E2.8%_D3%	306	117.7	665	606
B_D_G14_A2_E2.8%_D3%	306	123.1	656	617
B_Min_G14_A2_E2.8%_D3%	306	132.7	662	657
B_E_G14_A2_E2.8%_D3%	306	153.6	687	687
B_F_G14_A 2_E2.8%_D3%	306	174.8	720	720
B_ G_ G14_ A2_ E F.2,8.8%_D3%	306	211.8	784	784
B _A_G15_A2_E2.,8%_D3%	1.275	69.9	467	374
B_.B_.G 15_A2_E2.,8%_D3%	1.275	77.0	449	396
B_C_G 15_A2_E2.8%_D3%	1.275	85.8	442	404
B_D_G15_A2_E2.,8%J)_D3%	1 275	90.0	434	410
B_Min_G15_A2_E2.8%_D3%	1 275	969	439	435
B_E_G15 _A2_F2.8%_D3%	1 275	112.3	458	458
B_F_G15_A2_H2.8%_D3%	1 275	128.2	482	482
B_G_ G GG15_ A2_E F.2.,8%_D3%	1 275	157.1	528	528
B_A_G 16_A2_E2.8%_D3%	3 060	63.7	396	320

B_B_G 16_A2_E2.8%_D3%	3 060	69.8	382	340
B_C_G16_A2_E2.8%_D3%	3 060	77.3	376	346
B_D_G 16_A2_E2.8%_D3%	3 060	80.5	369	349
B_Min_GC 16_A2_.E23.8%_D3%	3 060	865	373	370
B_E_GG 16_A2_F2^E2.8%_D3%	3 060	99.8	389	389
B_F_G16_A2_E2.8%_D3%	3 060	1135	410	410
B_G_.G.GG 1_ A2_ E2.,8%_D3%	3060	137.8	449	449

Figure 43: Results of the cost-optimal analysis for renovation of the four residential buildings used as examples *(KostOpti, 2019)*

As the figures show, the lowest global costs are achieved under the constraints of Scenario S1 (not including funding) with the thermal protection level of efficiency class D (the lowest value for global costs is highlighted in green in each case). The primary energy ratings, based on compliance with the current minimum requirements for building envelope components (‘Min’ variants), are 7.7% higher than those for the cost-optimal level (class D). The current minimum requirements for the building envelope components are therefore significantly less ambitious than the cost-optimal level. Since the Directive on the energy performance of buildings states that the cost-optimal primary energy rating can be exceeded by up to 15%, the current minimum requirements comply with the EU requirements, but are neither cost-optimal nor compatible with climate protection targets.

Taking into account the current funding schemes for energy renovations, the lowest global costs are achieved for three out of the four building types if the building envelope corresponds to the level of efficiency class A. In the case of the fourth type, the performance of the building envelope is cost-optimised with efficiency class B.

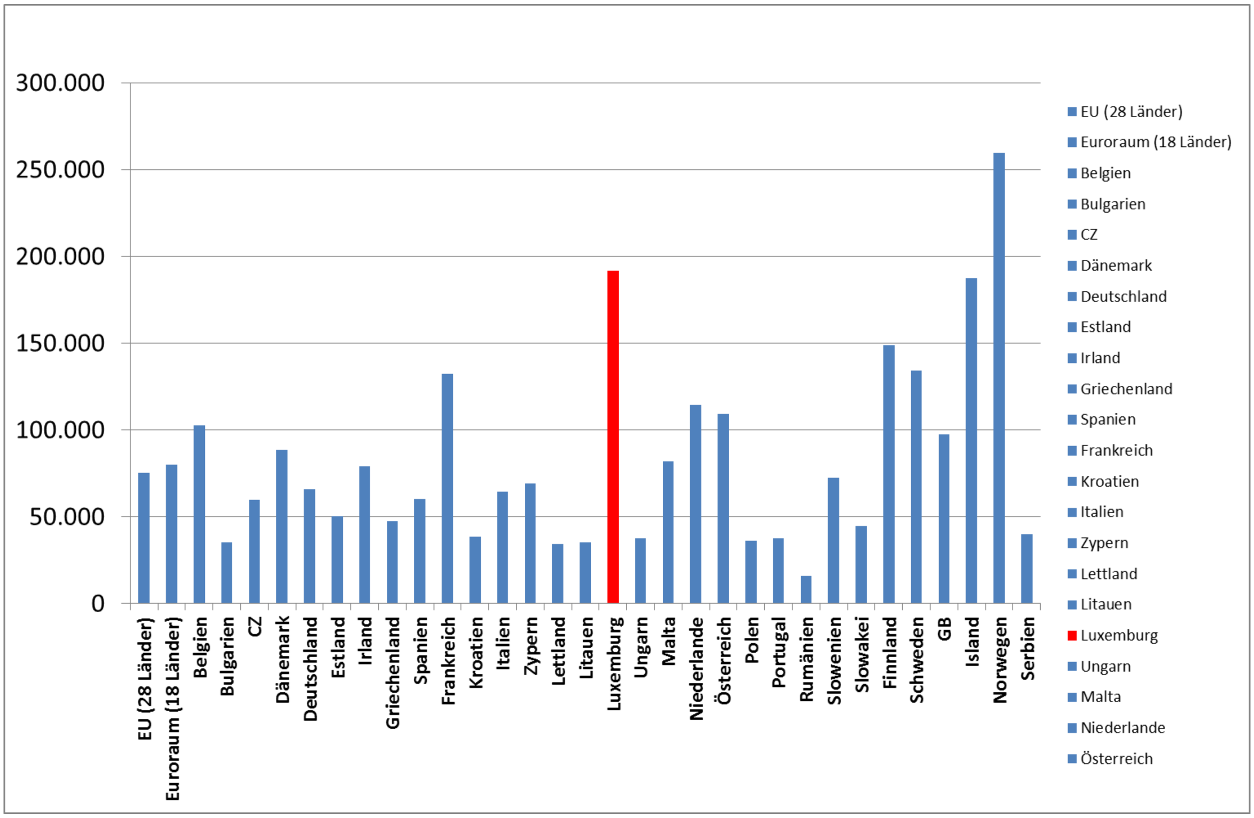
Conclusion of the cost-optimal analysis – renovation of residential buildings

As in other EU Member States, the cost-optimal analysis reveals that there is a great deal of room for political manoeuvre when stipulating the minimum requirements for energy renovations in buildings:

The global costs of efficiency classes A are therefore slightly higher than those of the cost-optimal efficiency class D, meaning that only moderate funding incentives would be required to turn the requirements of Classes A and B (which are compatible with climate protection targets) into the most economical efficiency level. If the current funding incentives are taken into account, the cost optimum is efficiency class A for three out of the four buildings investigated, and class B for the fourth.

When interpreting the results of the cost-optimal analysis, the following factors should be taken into account:

- The study takes as its basis the fact that energy prices are very low in Luxembourg compared to other European countries, particularly when purchasing power is taken into account. Gross domestic electricity prices in Luxembourg are almost 18% below the average for the EU 28 (EUROSTAT, 2020). If the very high average purchasing power in Luxembourg is taken into account, the following picture emerges:



EU (28 Länder)	EU (28 Member States)
Euroraum (18 Länder)	Eurozone (18 Member States)
Belgien	Belgium
Bulgarien	Bulgaria
CZ	Czech Republic
Dänemark	Denmark
Deutschland	Germany
Estland	Estonia
Irland	Ireland
Griechenland	Greece
Spanien	Spain
Frenkreich	France
Kroatien	Croatia
Italien	Italy
Zypern	Cyprus
Lettland	Latvia

Lituaen	Lithuania
Luxemburg	Luxembourg
Ungarn	Hungary
Malta	Malta
Niederlande	Netherlands
Österreich	Austria

Figure 44: Amount of electricity (in kWh/a) that an average household can afford based on its annual income *(EUROSTAT, 2016)*, *(EUROSTAT, 2015)*

The figure shows gross domestic electricity prices in the 28 EU Member States and other European countries in relation to average incomes (median equivalised total net income). The values displayed refer to the amount of domestic electricity that an average-income household would be able to afford each year. At almost 192 000 kWh/a, the value for Luxembourg is 2.54 times higher than the average value for the 28 EU Member States.

The average household in Luxembourg can afford 1.87 times more domestic electricity than the average household in Belgium, 1.45 times more than the average household in France, 2.91 times more than the average household in Germany, 1.75 times more than the average household in Austria and 2.17 times more than the average household in Denmark.

The same trend can also be observed for gas and oil prices; compared to the average purchasing power, they are much cheaper in Luxembourg than in the other EU Member States (see also the comments on energy poverty in Chapter 3.5.1d).

- The discounting rate of 3% selected for Scenario S1 (real interest rate, i.e. corrected for inflation) is a long way above Luxembourg’s current mortgage interest rate corrected for inflation. As revealed by the corresponding scenarios in the study, the cost-optimal curves are even flatter, i.e. the cost increases for Classes A and B compared to the current requirements are reduced yet further, if lower discounting rates are chosen.
- The outcomes outlined in this summary of the cost-optimal analysis relate to the microeconomic perspective, i.e. the business perspective of users. As shown by the corresponding scenarios in the study, if CO_2 levies are taken into account, then the cost optimums shift in the direction of classes that are better from an energy perspective. Levies of this kind have since been introduced in a number of different countries, for example in Switzerland (in place for over 10 years, as at 2018: CHF 96, around EUR 86/tonne), Sweden

(since 1991, as at 2019: EUR 120/tonne), Germany (from 2021, EUR 25/tonne increasing to EUR 55/tonne in 2025), Finland (currently EUR 62/tonne), Denmark (currently EUR 23/tonne). Other countries with CO_2 pricing schemes include France, the United Kingdom, Ireland, Slovenia, Poland, Estonia, Latvia and Norway. The graduated introduction of CO_2 pricing is also planned for Luxembourg from 2021 onwards.

Taking into account the above factors, the outcomes of the cost-optimal analysis are regarded as more conservative in nature.

Summary

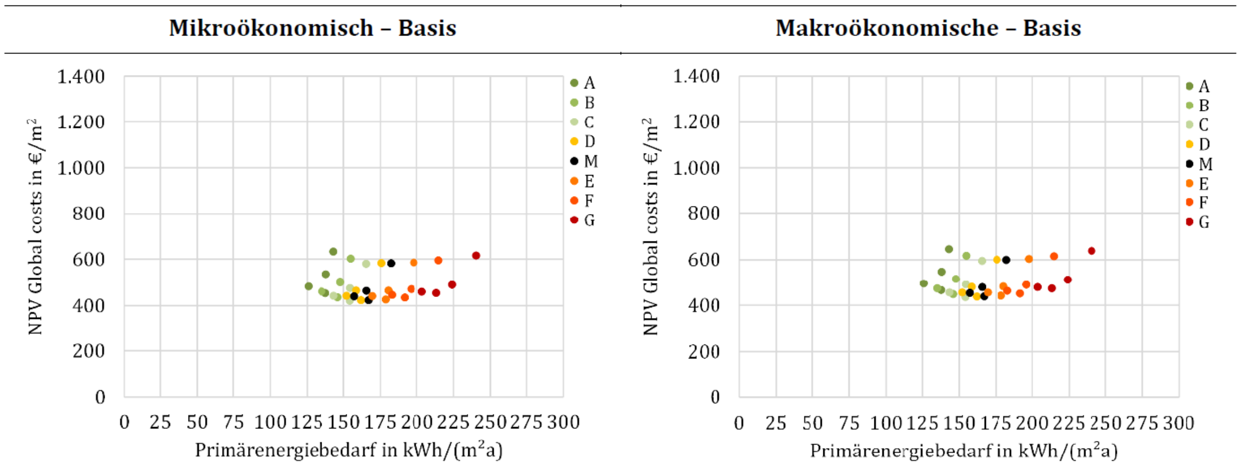
The outcomes of the cost-optimal analysis reveal that tightening up the minimum requirements for the efficiency of residential building renovations is a useful and economically justifiable step.

An important factor to take into account when tightening up the minimum requirements is that tradespeople and customers may regard more stringent requirements as an additional obstacle to renovation works ('the requirements are stricter than ever'). It is therefore expected that the Grand-Ducal Regulation that is currently being revised ('Amended Grand-Ducal Regulation of 30 November 2007 on the energy performance of residential buildings') will contain more stringent requirements when it enters into force on 1 January 2021 onwards, so that the market can adjust to these requirements and so that the level of acceptance is higher, but that these requirements will only apply after a transitional period of 2 years. The date from which these more stringent minimum requirements will apply will be specified in the Grand-Ducal Regulation and coordinated with the fade-out phase for the funding of fossil-fuel-based insulating materials under the PRIMe House/Lenoz (2.0) government funding scheme.

3.3.2. Non-residential buildings

By way of analogy to the procedure for residential buildings, the 2018 cost-optimal analysis was also carried out for four different types of non-residential buildings (KostOpti, 2019). The most important outcomes for the four residential building renovations that were investigated are summarised in graphical form in the figure below, and in the form of a table in the following figure.

The results shown are for the main scenario S1, which is based on an increase in energy prices of 2.8% per annum and interest on capital at 3.0% per annum.



Mikroökonomisch – Basis	Microeconomic – basis
Makroökonomisch – Basis	Macroeconomic – basis
NPV Global costs in €/m^2	NPV Global costs in €/m^2
Primärenergiebedarf in kWh/(m^{2}a)	Primary energy demand in kWh/(m^{2}a)

Figure 45: Results of the cost-optimal analysis for renovation of the four non-residential buildings – microeconomic and macroeconomic perspective – without funding *(KostOpti, 2019)*

Variant Identifier -	Area A_n m2	Energy parameter Qprimary kWh/(m^{2}a)	Global costs microeconomic €/m^2	Global costs macroeconomic €/M$^{2;}$
B_A_G G5_A 2_E2,.8%_D3%	821	143.2	633	646
B_B_G5_A2_E2.8%_D3%	821	155.0	602	616
B_C_G5_A2_E2.8%_D3%	821	165.5	579	594
B_C_G5_A2_E2.8%_D3%	821	175.7	583	599
B_Min_G5_A2_E2.8%_D3%	821	182.4(+10.2%)	582	599
	821	197.9	585	603
B_F_G5_A2_E2,8%_D3%	821	214.8	595	614
B_G_G5_A2_E2.8%_D3%	821	2405	616	638
B_A_G6_A2_E2.8%_D3%	5 885	126.1	483	495
B_G_G5_A2_E2.8%_D3%	5 885	135.1	461	474
B_C_G6_A2_F2.8%_D3%	5 885	143.4	442	455
B_D_G6_A2_R2E2.,8%_D3%</	5 885	152.1	442	+56
B_Min_G6_A2_E2.8%_D3%	5 885	157.3	440	454
B_E_G6_A2_E2.8%_D3%	5 885	169.6	441	456
B_F_G6 _A2_E2.8%_D3%	5 885	183.1	446	463
B_F_G6 _A2_E2.,8%_D3%	5 885	203.6	461	479
B_A_G7 _A2_E2.8%_D3%	6 161	137.7	454	466
B_B_G7_A2_E2.8%_D3%	6 161	146.0	435	448
B_C_G7_A2_E2.8%_D3%	6 161	154.3	421	+35
B_D_G7_A2_E.2.8%_D3%	6 161	162.0	423	437
B_Min_G 7_.A 2_E2.F.283%_D3%	6 161	167.1(83%)	423	438
B_E_G7_A2_E2.8%_D3%	6 161	1783	426	442
B_F_G7_A2_F2.8%_D3%	6 161	191.7	434	451
B G G7 A2 E2.8%D3%	6 161	213.3	454	474
B_A_G8_A2_E2.8%_D3%	2 197	138.1	534	547
B_B_G8_A2_E2.8%_D3%	2 197	147.8	501	515

B_C_G8_A2_E2.8%_D3%	2 197	154.6	476	490
B_D_G 8_A2_E2.8%_D3 %	2 197	158.6	466	480
B_Min_G8_A2_E2.8%_D3%	2 197	165.7	464	479
B_E_G8_A2_E2.8%_D3%	2 197	1803	465	482
B_F_G8_A2_E2.8%_D3%	2 197	196.1	471	489
B_G_G8_A2_E2.8%_D3%	2 197	224.1	491	512

Figure 46: Results of the cost-optimal analysis for renovation of the four non-residential buildings – microeconomic and macroeconomic perspective – without funding *(KostOpti, 2019)*

As shown by the figures, the cost optimum for building envelope performance in two of the four non-residential buildings investigated is achieved with the standard corresponding to efficiency class C, while in the two other buildings it is achieved with the standard that corresponds to the current minimum requirements for individual components (Min.).

The current minimum requirements for building envelope components result in average global costs that are 4.6% higher than those of the cost-optimal level. This figure falls below the 15% limit under the EU Directive on the energy performance of buildings, and is therefore permitted and reasonable.

The factors that should be taken into account when interpreting the outcomes of the cost-optimal analysis are similar to those that applied in respect of residential buildings.

- Energy prices are very low in Luxembourg. Taking into account purchasing power and economic power, energy prices in Luxembourg are cheaper than in any other EU Member State.
- The efficiency of higher envelope qualities and low-emission energy carriers will improve as a result of the planned introduction of CO_2 pricing in 2021; the revenues may be channelled into funding schemes, which will improve profitability yet further.
- The main scenario (S1) is based on extremely conservative assumptions, in particular as regards the interest rate of 3% (which corresponds to EU requirements). Actual interest rates are far lower in Luxembourg. The profitability of high renovation qualities is even higher if calculations are carried out on the basis of more realistic interest rates.
- The cost-optimal analysis reveals that the general principle whereby the global costs of efficiency class A are only slightly higher than those of the cost-optimal level, even on the basis of extremely favourable assumptions, also applies to renovations of non-residential buildings.

Summary

The outcomes of the cost-optimal analysis reveal that tightening up the minimum requirements for the efficiency of non-residential building renovations is a useful and economically justifiable step. This is all the more true in view of the plans to introduce a CO_2 pricing scheme in 2021, which will shift the cost optimums towards higher qualities. It is expected that additional incentives will be created (where applicable) through new funding opportunities that are only available for renovations in efficiency classes A and B.

3.4. Policies and actions to stimulate cost-effective deep redevelopment of buildings (Article 2a(1)(c));

Article 4(c) of the EED already required Member States to ensure that LTRSs encompass policies and actions to stimulate cost-effective deep renovation of buildings, including staged deep renovation. Article 2a(1)(c) of the EPBD provides that each LTRS 'shall encompass policies and actions to stimulate cost-effective deep renovation of buildings, including staged deep renovation, and to support targeted cost-effective measures and renovation for example by introducing an optional scheme for building renovation passports'. Deep renovations are those leading to refurbishment that reduces both the delivered and final energy consumption of a building by a significant percentage compared with pre-renovation levels, leading to very high energy performance. (8) According to the staff working document accompanying the Commission's 2013 report on Financial support for energy efficiency in buildings (9), 'deep renovation' can be considered as renovation that leads to significant (typically more than 60%) efficiency improvements. The EPBD refers to building renovation passports (BRPs) as an example of a measure whereby Member States can support targeted cost-effective renovation and staged deep renovation. The EPBD does not specify in detail what constitutes a BRP, but a number of common elements have been identified elsewhere (10), which may be used as examples: it is an electronic or paper document outlining a long-term (15–20 year) step-by-step renovation roadmap (with ideally as few steps as possible) for a specific building which may result from an on-site energy audit fulfilling specific quality criteria and outlining relevant measures and renovations that could improve its energy performance. (11)

As described in Chapter 3.3, higher qualities than demanded by the minimum requirements that currently apply are economical, even on the basis of conservative assumptions and without taking into account the availability of funding.

Although detailed analyses of renovation activities in Luxembourg still need to be carried out, it is safe to say that too few deep redevelopments are carried out on both residential and non-residential buildings, and that the energy quality of redevelopments is often too low, even though high-quality redevelopments are optimal in terms of costs.

As a basis for developing strategies and measures to encourage cost-effective deep renovations, efforts were undertaken in 2015 and 2016, as part of the work on the development of the building renovation strategy, to analyse challenges and obstacles; this was followed by the identification of initial strategies, guidelines and measures. In addition to a broad-based survey of house and apartment owners and tenants, several workshops were organised for the purpose of allowing key stakeholders in the construction sector to become involved in the consultation process.

The findings outlined in the document 'Development of the building renovation strategy – more ambitious strategy approaches and measures' (published in 2017), which ranged from outcomes through to proposed measures, have been expedited at policy level over the past 2 years, and in certain cases already implemented (Gebäuderenovierungsstrategie, 2017).

The outcomes were updated and expanded in connection with the production of the LTRS. The need to carry out deep redevelopments in several stages was also taken into account. In the absence of a more accurate definition, a deep redevelopment is assumed to be one that reduces the original energy consumption by at least 60%.

The outcomes of the updated analysis of obstacles and the strategies and measures that have been identified are listed below, broken down into residential/non-residential buildings.

3.4.1. Residential buildings

As revealed by the analysis of the building renovation strategy, the following reasons (among others) are decisive contributing factors to the low number of deep renovations of residential buildings (Gebäuderenovierungsstrategie, 2017):

1. lack of reserves for renovations;
2. absence of 'psychological stress' on the part of residents;
3. capacity constraints in the construction industry;
4. very low energy prices;
5. use of unsuitable methods for calculating profitability, particularly in the case of non-residential buildings;
6. unambitious minimum requirements for renovations of individual components and lack of requirements for deep renovations;
7. too few funding incentives for deep redevelopments;
8. lack of awareness of the efficiency potentials of the building owned and the State's long-term efficiency targets;

9. lack of positive examples;

10. lack of awareness of funding schemes/overly complex funding procedures.

Re 1. Lack of reserves for renovations

The lack of reserves for renovations is the main reason why very few deep redevelopments have been carried out to date even though very high energy qualities are more economical over a building's lifetime. This is true for all residential and non-residential market segments, albeit to differing extents. Reserves are required not only for energy renovations, but also and in particular for work on bathrooms, electrics, water pipes, cosmetic repairs, new floor coverings, adaptations for age-appropriate living, etc.).

The German association Haus & Grund recommends that homeowners should build up annual renovation reserves amounting to 1.5% of the cost of building their home (Haus_und_Grund, 2006).

The mandatory 'Maintenance and Improvement Contribution' that is paid by social housing tenants in Austria is an example of a system for the building up of renovation reserves that works very well. The contribution is paid as the third component of the rent (alongside the basic rent and service charges), and increases gradually according to the age of the building, up to a maximum of EUR $2/m^2_{\text{living space}}$ per month (EVB, 2018). The reserve must be earmarked for a specific purpose. As a result, social housing is the market segment with by far the highest renovation rate in Austria.

Re 2. Absence of psychological stress on the part of residents

The survey carried out as a basis for drafting the building renovation strategy proves that citizens are not suffering psychological stress as a result of the housing quality or energy costs of residential buildings in Luxembourg.

- Although damp-related mould damage occurs in a non-negligible number of residential buildings (as described in Chapter 3.8.1), it is a topic that is seldom discussed. It is only regarded as concerning from a health perspective in a small minority of cases.
- The fact that energy prices are very low means that energy costs are not a significant factor for the majority of the population.
- This hypothesis is backed up by the finding that many people are unfamiliar with energy costs or with how much energy they consume in their own house/apartment (even though they are familiar with the amount of fuel consumed by their cars, for example). When house and apartment owners and tenants were surveyed for the purpose of a representative survey in connection with the

drafting of the redevelopment strategy, 56% stated that they did not have an energy passport for their building/apartment or were not familiar with the efficiency class of their building. (ILRES, 2020)

- Even high levels of consumption within the home were regarded as normal, since respondents lacked points of reference for comparison (see also Section 10).

Re 3. Capacity constraints in the construction industry

In view of the significant increases in the output of new residential and non-residential builds, the Chamber of Tradespeople estimates the labour demand in the industry at around 5 000 people. (PAPERJAM, 2019). The number is based on a study by the Chamber of Craft Trades, which was in turn based on responses from around 12% of member companies. In total, around 9 400 tradespeople are needed. The figure in the construction sector is likely to increase if the demand for new-build dwellings continues to rise (as indicated in Chapter 2.4.2).

A rise in the rate and quality of redevelopment would increase the demand for labour yet further. The following figure illustrates the additional investments that would be created by increasing the current renovation rate of around 0.7 full renovation equivalents to an economically optimal renovation rate of 1.6% per annum, and the size of the corresponding labour force.

Building envelope renovation rate (full renovation equivalent)	Number of residential units to undergo deep renovations	Total living space to be renovated	Renovation investments (minimum performance)	Renovation investments (cost-optimal performance)	Workstations for minimum-performance renovation	Workstations for cost-optimal-performance renovation
%	Residential units/year	m^2 living space	EUR/a	EUR/a	EUR/a	EUR/a
0.4	1 000	129 000	47 730 000	69 660 000	430	627
0.6	1 500	193 500	71 595 000	104 490 000	644	940
0.7	1 750	225 750	83 527 500	121 905 000	752	1 097
0.8	2 000	258 000	95 460 000	139 320 000	859	1 254
1.0	2 500	322 500	119 325 000	174 150 000	1 074	1 567
1.2	3 000	387 000	143 190 000	208 980 000	1 289	1 881
1.4	3 500	451 500	167 055 000	243 810 000	1 503	2 194
1.6	4 000	516 000	190 920 000	278 640 000	1 718	2 508
1.8	4 500	580 500	214 785 000	313 470 000	1 933	2 821
2.0	5 000	645 000	238 650 000	348 300 000	2 148	3 135

Figure 47: Estimated additional demand for labour caused by a rise in the rate and quality of renovation *(Ploss, 2020)*

An increase in the building envelope redevelopment rate from a current figure of around 0.7% per year to 1.6% per year (based on the current total stock of around 250 000 residential units) would mean that around 4 000 residential units would undergo a complete building envelope renovation each year, instead of 1 750. This would correspond to an increase in investments of around 84 million (to EUR 279 million per annum) if the energy performance of the renovations were improved at the same time. A labour force of around 2 500 would be required (instead of the present figure of around 750), which is equivalent to an increase in demand of around 1 750.

A larger labour force would also be needed if the rate and quality of renovations in non-residential building were to be increased, and if the boiler replacement rate and the rate of installation of solar systems and ventilation systems were to be increased.

Based on these figures, priority should be given to measures that increase the attractiveness of jobs in the construction industry or that increase the effectiveness of renovation processes, for example through greater use of prefabricated components.

Re 4. Very low energy prices

As described in Chapter 3.5.1d in relation to energy poverty, energy prices in Luxembourg (compared to purchasing power) are currently the lowest in the EU. A high level of energy consumption is therefore affordable for the majority of the country's citizens without financial hardship. This means that energy costs, and thus energy consumption, are not regarded as priorities by the majority of the population.

Re 5. Use of unsuitable methods for calculating profitability, particularly in the case of non-residential buildings

Long-term capital investments such as real estate require strategies that guarantee their long-term profitability.

This is why the pay-back method that is frequently also used to calculate the profitability of residential buildings is systematically incorrect.

When this method is applied, measures that 'recover' the capital invested as quickly as possible through energy savings are prioritised. Measures selected in this way do not however result in the lowest overall costs across the entire lifespan of the building (or over an appropriate observation period of around 30–40 years for residential housing or around 20 years for heat generators).

Particularly at times when mortgage interest rates are low, optimisations based on the pay-back method result in poor financial decisions, and stand in the way of measures that would be sensible from a business and economic perspective.

In the real-estate sector, profitability calculations that are based on the net present value method over appropriate periods (30 to 50 years for residential housing) and that take into account residual values and replacement investments are most useful. This method is also prescribed for cost-optimal analyses by the Directive on the energy performance of buildings.

Re 6. Unambitious minimum requirements for renovations of individual components and lack of requirements for deep renovations

The minimum requirements for the energy performance of individual components have remained the same for a long time (since the introduction of energy passports for residential buildings in 2007 and non-residential buildings in 2010), and do not correspond to the cost-optimal level. As revealed by the scenario study carried out by the Vorarlberg Energy Institute, there is no way that full decarbonisation of the residential building sector can be achieved by 2050 on the basis of the current energy-related minimum requirements (Ploss, 2017).

Requirements relating to the heating demand and primary energy demand of deep redevelopments have so far been ineffective.

Re 7. Lack of funding incentives for deep redevelopments

Since the minimum level of requirements for renovations of individual components has not been tightened up for almost 15 years (as described in Section 6), and no requirements have yet been imposed for deep redevelopments in respect of heating demand and primary energy demand, the lowest levels of requirements under the PRIMe House funding scheme are not particularly ambitious. If the minimum requirements were tightened up, the two lowest levels of the funding scheme would be eliminated, and resources could be focused on the two highest levels of requirements.

In addition, substantial bonuses should be available as an incentive for deep renovations, i.e. the combination of as many individual building envelope measures as possible in conjunction with a switch to a heat generator operated using renewables; these bonuses might depend on the heating demand and primary energy demand that has been achieved, for example.

Re 8. Lack of awareness of the efficiency potentials of the building owned and the State's long-term efficiency targets

The majority of owners/tenants of residential houses/apartments are unaware of the efficiency potentials of their building, and are equally unaware of the State's long-term efficiency targets for the buildings sector. Renovation roadmaps (building renovation passports or BRPs) are a key means of providing information on both factors. These renovation roadmaps calculate and outline the savings achievable by means of deep redevelopments (in one or more stages). The efficiency target identified on the basis of the State's long-term targets for the buildings sector should therefore be 'translated' into an efficiency target for the building under investigation.

Storyline for the homeowner: 'Luxembourg wants to play its part in mitigating climate change. This means that the buildings sector must reduce its energy demand by x% by 2050, and all heating systems must be non-fossil-fuel-based by 2050 at the latest. In the case of your building, and taking into account the building type and profitability, this means that energy demand should be reduced by x% and the heating system should be switched to renewable energies at the next opportunity, for example when you next replace your boiler. The State will help you reach these targets with subsidies for efficiency measures, for switching to renewables and in some cases for the use of active solar installations.'

Re 9. Failure to communicate positive examples, or failure to target communications at the appropriate target group

As shown in Section 2, even energy consumption levels that are objectively high are often not regarded as a problem by building owners. This attitude can be attributed not only to low energy prices, but also to a lack of awareness of the fact that energy consumption levels and costs are much lower in buildings that have been renovated to a very high standard of energy performance.

Owners often only realise how poorly their own home performs after comparing it to these renovated buildings.

It would be useful to produce easy-to-understand documents describing the benefits of high-quality building redevelopments, based on examples from Luxembourg and abroad and tailored to different target groups. These documents should refer not only to energy savings and climate protection, but also and in particular to increases in thermal performance, improvements in terms of comfort, absence of any structural damage and security of supply (lack of reliance on energy imports from politically unstable countries).

Re 10. Lack of awareness of funding schemes/overly complex funding procedures

An evaluation of the TNS ILRES survey reveals that the main reason why respondents did not apply for State funding was that they were not aware of the funding programmes. Of those surveyed who had carried out renovation measures and not applied for funding, 35% said that they were not aware of the State funding programmes, and 47% said that they were not aware of the energy suppliers' programmes. A further 9% stated that they had not applied for subsidies because the application process was too complicated.

Guidelines, policies and actions for housing

Based on the main obstacles described above, the following guidelines, which serve as a basis for defining the implementing measures, were drafted as part of the strategy process for further development of the building renovation strategy:

1. Prioritisation of highly efficient renovations

2. Affordability of energy renovation measures

3. Alignment between the goals of energy policy and monument conservation

4. Consideration of factors relating to sustainable construction and the circular economy.

The guidelines describe the long-term focus of the building renovation strategy and are intended to serve as a framework for the implementation of measures by the responsible stakeholders or the stakeholders that need to be involved. Communication with the construction and real estate sector will be stepped up with a view to publicising the guidelines.

Re 1. Prioritisation of highly efficient renovations

According to the Energy Efficiency Directive (EED), the term 'deep renovation' is defined as follows: '… cost-effective deep renovation of buildings …, leading to refurbishment that reduces both the delivered and final energy consumption of a building by a significant percentage compared with pre-renovation levels, leading to very high energy performance.' According to Recommendation (EU) 2019/786, a deep renovation can be considered as a renovation that leads to significant (typically more than 60%) efficiency improvements (EU, 2019).

Based on the outcomes of the workshops and the TNS Ilres surveys, the target of 'deep renovations' was further clarified for Luxembourg in order to take account of 'lock-in effects'.

In future, steps aimed at increasing the efficiency of energy renovations compared to the rise in the number of residential buildings renovated with thin layers of insulation will be prioritised.

This guideline implements the EU's principle of 'efficiency first' for the buildings renovation sector, and is also enshrined in the NECP 2019.

The increase in efficiency is to be achieved by means of highly efficient insulation in the case of both individual measures and deep renovations. Energy renovations with thin layers of insulation are less advantageous in both economic and energy-related terms, since they are more expensive and deliver fewer savings in comparative terms.

Low-quality renovations do not fully exploit a building's savings potential, and furthermore block this potential for the duration of the replacement cycle (30–50 years). This lock-in effect is counterproductive, since in the long term it stands in the way of energy efficiency increases in the building stock.

Highly efficient renovations are also a cost-optimal solution for owners. Luxembourg's cost-optimal analysis reveals that the overall costs (i.e. the investment, maintenance and energy costs) of renovations for buildings in efficiency classes A to E are almost identical (see Chapter 3.3). Highly efficient renovations in classes A and B can be carried out profitably even with relatively low funding incentives. Economic analyses reveal that energy renovation measures are particular profitable if they are combined with renovation measures that are due to be carried out in any case (render repairs, replacement of windows, etc.).

When implementing this guideline, it will be necessary to evaluate the funding schemes and the planned new investment guides regularly so that they can be further developed on an ongoing basis.

Re 2. Affordability of energy renovation measures

The workshops carried out in connection with the further development of the building renovation strategy in 2016 and 2017 and the analysis of obstacles to highly efficient deep renovations that are summarised above reveal that owners regard renovation costs as the greatest obstacle to highly efficient renovations.

The aim of improving the affordability of energy renovations is twofold; it is intended on the one hand to increase the number of highly efficient renovations that are carried out, and on the other to curb the development of energy 'segregation' and the risk of debt, which might otherwise mean that low-income households cannot afford highly efficient energy renovations (see also Chapter 3.5.1d on the topic of energy poverty).

Luxembourg's Government has already taken the first steps towards improving the affordability of renovation measures. The Climate Bank that was set up in 2017 provides homeowners with funding to pre-finance energy renovation projects. Low-income households in particular are eligible for a zero-rate climate loan as an efficient means of funding energy renovation projects. However, the latest figures show that only very few enquiries have been received so far (only 20 during the period between January 2017 and January 2020). At the same time, the existing PRIMe House funding scheme will be topped up to promote highly efficient renovations; the details are to be worked out as part of the ongoing revision, which will be implemented in 2021. The LENOZ (Lëtzebuerger Nohaltegkéetszertifizéierung) system will also be combined with the PRIMe House funding scheme and further reinforced in order to ensure that account is taken of factors including sustainable construction, the circular economy and health-related aspects.

In addition to financial support provided by the government, improvements in the profitability of renovation measures also play a key role. Highly efficient renovations are cost-optimal and therefore profitable over the entire period of use. However, combining renovation works with maintenance tasks that need to be carried out in any case also plays a key role in increasing their profitability.

Reducing the cost of renovation measures improves their long-term profitability. Standard solutions could be developed (in cooperation with the construction sector) for the measures carried out most frequently, with a view to streamlining and bringing down the cost of renovation works. Streamlining and prefabrication measures would also help to counter any future skills shortage in the construction sector.

Monitoring measures should be put in place with a view to achieving continuous improvements in funding programmes and grants, thereby ensuring that the available resources can be utilised effectively.

Re 3. Alignment between the goals of energy policy and monument conservation

Particularly in a country like Luxembourg with a rapidly growing population and high new-build and demolition rates, preserving the country's architectural heritage represents a major challenge.

A need for better mutual alignment of the objectives of energy policy and monument conservation was however identified in connection with the further development of the building renovation strategy. On the one hand, Luxembourg's Government is required by the provisions of the EU Directive to implement the building renovation strategy on a country-wide basis and to work towards the targets outlined in this Directive. On the other hand, however, protecting the country's architectural heritage promotes the preservation of a cultural identity, the destruction of which might be regarded as problematic by citizens, which might pose a considerable challenge when implementing the building renovation strategy.

Priority areas where further consultation is needed were identified in connection with further development of the building renovation strategy, with a view to bringing these two goals closer together.

The aim of aligning both goals – by means of joint guidelines promoting energy renovations that comply with monument conservation law – is intended in particular to facilitate better coordination at government level. When renovations are carried out in architecturally valuable buildings that are protected as monuments, saving potentials will continue to be calculated on a project-specific basis and utilised in full where this is feasible from the perspective of aesthetics and profitability.

Re 4. Consideration of factors relating to sustainable construction and the circular economy

One of the criticisms levelled at energy renovations of buildings is that only the impact on operating energy demand has typically been assessed to date, and other factors such as energy expenditure on production and the environmental impacts of the types of insulating materials used have been ignored. When assessing (energy) renovation measures in the future, greater use should be made of the scientifically sound and highly relevant methods for holistic sustainability assessments that have been developed in recent years.

This should ensure that renovations are viewed from a more holistic and hence resource-friendly perspective, and designed to be more sustainable as a result. This should apply to both energy-efficient housing construction and renovation measures involving the building stock. Particular attention should be paid to the environmental and health impacts and to the recycling of construction materials. The State funding scheme PRIMe House is currently being revised in conjunction with the LENOZ ('Lëtzebuerger Nohaltegkéetszertifizéierung') certification scheme; these efforts represent a further step in this direction. In addition to other sustainability-related factors, the need to ensure that construction materials can be recovered after use has been specified as a prerequisite for the circular economy since 2017.

Parallel processes and developments are already in progress in Luxembourg, particularly in respect of the circular economy; examples include the Third Industrial Revolution (TIR) Study, the activities of the National Council for Sustainable Construction and the EcoInnovation Cluster. The guideline should make particular reference to the processes by means of which (energy) building renovations were identified as a key area of action. With a view to implementing the guideline, the conclusions and recommendations that emerge from these processes should be analysed with reference to the development of the building renovation strategy and included in this strategy as implementing measures.

Measures – residential buildings

The measures shown in the following table were identified in connection with the drafting of the LTRS, on the basis of the guidelines and the sectoral targets described in the NECP (NECP, 2020), the outcomes of the bottom-up study on changes in final energy demand by the residential building stock (Ploss, 2017) and the outcomes of the cost-optimal analysis (KostOpti, 2019). The measures are broken down into the following categories:

- regulatory provisions,
- tax law,
- support and funding,
- consultation,

- training,
- awareness raising and publicity work,
- research and model projects.

The targets should be interpreted against the backdrop of the following assumptions and constraints:

Assumptions and constraints		2020	2 030	2040	2050
Population (Q 10)	Individuals in primary and secondary place of residence	632 500	785 000	983 000	1 051 000
Residential units (Q 10)	Number	275 000	349 000	424 000	489 000
Residential units built before 1991 (reference variable for NECP (Q 10))	Number	150 000	150 000	150 000	150 000
Residential units until 2010 (comparative value for Vorarlberg Energy Institute's	Number	211 600	201 020	190 969	181 421
Total living space (Q 10)	m²	34 150 000	42 900 000	51 600 000	58 900 000
Average living space/residential unit (Q 10)	m²	124	123	122	120

Figure 48: Assumptions and constraints concerning the development of the residential building stock *(Ploss, 2017)*, *(NECP, 2020)*

Standardised descriptions of two measures are included in the annex as examples. Information on individual measures assigned to certain sub-segments can also be found in tables in the relevant chapters of this document.

List of measures for residential buildings
Primary targets for total residential building stock (including new builds): *Reduction in final energy demand according to the target scenario under Article 2.1a of the Paris Agreement, in line with Luxembourg's NECP, 2019* (NECP, 2020)*:* *from 6 438 GWh/a (2020) to 2 715 GWh/a (2050), with interim targets of 4 611 GWh/a (2030) and 3 551 GWh/a (2040)* *This corresponds to a reduction of 28% (2030), 45% (2040) or 58% (2050) compared to the value for 2020.* *Reduction in GHG emissions according to target scenario under Article 2.1a of the Paris Agreement, in line with Luxembourg's NECP, 2019:* *62% (2030) or 96% (2040), compared to the status quo* ***Sub-targets:*** *Building envelope redevelopment rate (according to the assumptions underlying the NECP* (NECP, 2020)*): 3% per annum of the total number of residential units built before 1991, corresponding to around 4 500 residential units per annum (full redevelopment equivalents)* *Building envelope renovation rate (based on the assumptions for the scenario study by the Vorarlberg Energy Institute)* (Ploss, 2017)*: around 1.6% of all residential units with a building envelope that has reached the average technical lifespan, corresponding to between 4 400 and 7 800 residential units*

per year (full redevelopment equivalents; number of residential units to be redeveloped is higher in spite of the fact that demolition is included because buildings constructed after 1990 are included) *Redevelopment quality: Efficiency class A/A to B/B, average renovation depth of around 72% according to the NECP* *Boiler replacement rate: around 5% per annum (in relation to the total area of residential buildings affected)*

Figure 49: Primary targets for total residential building stock and sub-targets *(Ploss, 2017)*, *(NECP, 2020)*

Regulatory provisions		Stage of implementation	Timeline for impact
No	Description		
R1	Introduction of more stringent minimum requirements for individual components from 2023 onwards (2021 Grand-Ducal Regulation on energy performance)	At the preparatory stage (2021)	2030
R2	Checks to monitor compliance with the requirements for renovation works (energy passport checks) (Overhaul of existing system of checks)	At the preparatory stage (2021)	2030
R3	Duty to notify renovation measures involving the envelope and heat supply (including individual measures) (energy passport obligation) (Programme for implementing the existing requirements)	Implemented	2030
R4	Building renovation passport – renovation roadmap *(Mandatory renovation roadmap with the aim of deliberately raising awareness about the need to carry out full renovations to an adequate depth ('deep renovations'))*	Idea	2030
R5	Obligation to build up financial reserves for freehold and rented apartments (based on the example of Austria's 'Maintenance and Improvement Contribution')	At the planning stage	2030
R6	Reduction in quorums for majority decisions in respect of energy renovation measures in co-owned multi-family dwellings	At the planning stage	2030
R7	Halt to the expansion of the gas network for residential developments (with the potential exception of density increases in existing networks) from 2020 onwards	Implemented	2030
R8	Introduction of an obligation to carry out renovations in the event that the support measures do not deliver adequate results	Idea	2050

Tax law		Stage of implementation	Timeline for impact
No	Description		
S1	Gradual introduction of CO_2 pricing from 2021 onwards (2021: EUR 20/tonne; 2022: EUR 25/tonne; 2023: EUR 30/tonne)	Implementation from January 2021	2030
S2	Harmonisation of the reduced VAT rate (3%) for energy renovations with the requirements of the PRIMe House scheme	At the planning stage	2030

Support and funding		Stage of implementation	Timeline for impact
No	Description		
F1	Revision of PRIMe House scheme: Funding of individual measures involving building envelope components (heavily scaled to promote high-performance renovations) (in combination with a tightening up of the minimum efficiency standards from 2023)	At the preparatory stage (2021)	2030
F2	Interest-free climate loan under the PRIMe House scheme for renovations by low-income households to be rolled out to all households	At the preparatory stage (2021)	2030
F3	Access to the PRIMe House funding scheme for certified tradespeople carrying out individual measures, and bonus payment for complete renovations only after a consultation with a certified energy consultant; significant increase in funding for consultation costs	At the preparatory stage (2021)	2030
F4	Funding for energy efficiency measures in buildings protected as historical monuments	At the planning stage	2030
F4	Funding in combination with a switch to renewable energy carriers	Implemented	2030

Awareness raising and publicity work		Stage of implementation	Timeline for impact
No	Description		
S1	Further development of the existing app ‘myrenovation’	Ongoing	2030

Research and model projects		Stage of implementation	Timeline for impact
No	Description		
Fo1	Model projects involving prefabrication of the components required for renovations with a view to shortening the length of renovations and combating labour shortages, in cooperation with other countries	At the planning stage	2030
Fo2	Model projects involving the redevelopment of residential developments with poor energy performance and heating systems based on fossil fuels Trial of funding schemes based on energy saving contracting Opening up of the PRIMe House funding scheme to include measures implemented by contractors More generous recognition of CO_2 savings achieved through renovations carried out by energy suppliers (measure currently being considered) In combination with stringent energy-related requirements under the PRIMe House funding scheme	At the planning stage	2030

Figure 50: Table of measures for residential buildings

3.4.2. Non-residential buildings

Although non-residential buildings account for around 24–29% (own estimates) or 33.5% (estimate by EU Statistics) of the area covered by the total building stock, and are likely to account for somewhere in the region of 40% of the total final energy demand by buildings (see Chapter 3.2.8), few in-depth analyses have been carried out on this section of the building stock to date. The development of strategies to increase the number of cost-efficient deep renovations is therefore still in its early stages in Luxembourg, as is the case in many other EU Member States.

It has been proposed that strategies and measures should be developed on the basis of the guidelines published for residential buildings:

These are as follows:

1. Prioritisation of highly efficient renovations

2. Affordability of energy renovation measures

3. Alignment between the goals of energy policy and monument conservation

4. Consideration of factors relating to sustainable construction and the circular economy.

The guidelines describe the long-term focus of the building renovation strategy and are intended to serve as a framework for the implementation of measures by the responsible stakeholders or the stakeholders that need to be involved. Communication with the construction and real estate sector will be stepped up with a view to publicising the guidelines.

The details of a strategy and implementing measures for the non-residential buildings sector will be worked out on the basis of the LTRS over the period 2020–2023. The first measures may be implemented from 2021 onwards, and additional implementing measures will enter into force in 2024 (and will be announced at as early a date as possible).

Important factors when developing the overall strategy include the following:

- 2021: announcement of renovation obligations for individual categories of the non-residential building stock, with entry into force from 2024 onwards and an appropriate deadline for implementation, e.g. by 2040. A similar strategy has been pursued by the Netherlands for a number of years.
- 2020: definition of a model project involving the cost-efficient renovation of office buildings in a manner compatible with climate protection targets; centralised scientific monitoring, specification of funding conditions and selection of projects; project term: 2021 to 2024.
- 2021: analysis of the current condition of the entire non-residential building stock (e.g. by the Institute for Housing and Environment, based on a methodology similar to that used for the German study).
- 2021: entry into force of the new Grand-Ducal Regulation for new non-residential buildings with much more stringent requirements (in particular as regards heat insulation).
- 2021: bottom-up scenario study on changes in final energy demand and CO_2 emissions by non-residential buildings, based on a methodology similar to that used for the study by the Vorarlberg Energy Institute for residential buildings (Vorarlberg Energy Institute/Institute for Housing and Environment).
- 2022: expanded cost-optimal analysis for different categories of non-residential buildings (calculation methods and approach in line with the requirements of the EPBD) (Goblet Lavandier).

- 2022: more ambitious renovation levels and potential renovation obligations for individual categories of non-residential buildings; specification of scope, timeframe and exemptions, development of accompanying funding schemes.
- 2024: entry into force of a Grand-Ducal Regulation on renovations of non-residential buildings, potentially including any renovation obligations with a deadline of 2040 (all office buildings subject to the renovation obligation must be renovated by 2040).

The following figure illustrates the timelines for the most important measures required when developing the renovation strategy for non-residential buildings.

	Schedule for implementation																				
Measure/step	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
Announcement of renovation obligations from 2024	■																				
Announcement of model project involving renovation of five office buildings	■																				
Execution of model project involving renovation of five office buildings		■	■	■	■																
Analysis of current non-residential building stock by way of analogy to Institute for		■																			
New Grand-Ducal Regulation for new builds in the non-residential sector		■																			
Announcement of funding scheme for renovation of non-residential buildings from		■																			
Funding scheme for renovation of non-residential buildings			■	■	■																
Mandatory renovation roadmap from 2023				■																	
Announcement of new Grand-Ducal Regulation on renovation for 2024		■																			
Scenario study for non-residential buildings			■																		
Expanded cost optimality study (for more categories of non-residential buildings)			■																		
Adjustment of requirements under Grand-Ducal Regulation on renovation and				■																	
Entry into force of Grand-Ducal Regulation on the renovation of non-residential					■																
Entry into force of renovation obligation for non-residential buildings with target					■																
Renovation of all non-residential buildings not covered by an exemption					■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■

Figure 51: Potential timeline including the most important measures for drafting the renovation strategy for non-residential buildings and the period of validity of measures

Measures – non-residential buildings

Based on the guidelines and the sectoral targets described in the NECP, the measures outlined in the following table were identified when drafting the LTRS.

As with residential buildings, the measures are broken down into the following categories:

- regulatory provisions,
- tax law,
- support and funding,
- consultation,
- training,
- awareness raising and publicity work,

- research and model projects.

When interpreting this figure, it should be noted that the proposed measures for the non-residential building sector should be regarded as initial proposals only owing to the lack of data, while the proposals for the residential sector are ready to be developed in much more detail.

Standardised descriptions of two measures are included in the annex as examples. Information on individual measures assigned to certain sub-segments can also be found in tables in the relevant chapters of this document.

List of measures for non-residential buildings (including public buildings)
Primary targets for total non-residential building stock (including new builds) *Reduction in final energy demand from 4 046 GWh/a (target for 2020) to 2 557 GWh/a (2050), with interim targets of 3 205 GWh/a (2030) and 2 883 GWh/a (2040) (NECP values for target scenario under the Paris Agreement)* (NECP, 2020) *As things currently stand, the 2020 target of 4 046 GWh/a will be missed by a large margin. The targets referred to in the NECP for 2030, 2040 and 2050 (based on the target scenario under Article 2.1a of the Paris Agreement) should therefore be regarded as extremely ambitious.* ***Sub-targets:*** *Building envelope redevelopment rate: 3% per annum of the useful floor area, as a total for all non-residential buildings (target according to the NECP) (full redevelopment equivalents). Based on a useful floor area of around 14 million m^2, this corresponds to an area to be renovated of around 420 000 m^2 per annum.* *Redevelopment quality: Efficiency class A/A to B/B* *Boiler replacement rate: around 5% per annum (in relation to the total area covered by the non-residential buildings affected)*

Figure 52: Primary targets for total non-residential building stock and sub-targets *(NECP, 2020)*

Regulatory provisions		Stage of implementation	Timeline for impact
No	Description		
R1-N	Introduction of more stringent minimum requirements for individual components from 2021 onwards (provisions of the 2021 Grand-Ducal Regulation on energy performance concerning the energy efficiency of non-residential buildings)	At the preparatory stage (2021)	2030
R2-N	Checks to monitor compliance with the requirements for renovation works (energy passport checks) (Overhaul of existing system of checks)	At the preparatory stage (2021)	2030

R3-N	Requirement to construct photovoltaic installations on all public buildings by 2030 (With the exception of buildings protected as historical monuments)	At the planning stage	2030
R4-N	Requirement to construct photovoltaic installations on the roofs of other non-residential buildings during redevelopments (with the exception of buildings protected as historical monuments and heavily shaded buildings) from 2024 onwards	At the planning stage	2030
R5-N	Coupling of 'Category B' electricity tariff ('compensation fund') with energy efficiency measures (currently no requirement, Category B if annual consumption > 25 MWh)	Idea	2030

Tax law		Stage of implementation	Timeline for impact
No			
S1-N	Gradual introduction of CO_2 pricing from 2021 onwards (2021: EUR 20/tonne; 2022: EUR 25/tonne; 2023: EUR 30/tonne	At the preparatory stage (2021)	2030
S2-N	Harmonisation of reduced VAT rate to 3% for high-performance energy renovations	At the planning stage	2030

Support/funding		Stage of implementation	Timeline
No	Description		
F1-N	Introduction of a de-risking tool in combination with energy performance contracting for energy efficiency measures	At the planning stage	2030
F2-N	Alignment of funding system for non-residential buildings with new regulations (new minimum requirements for heating insulation for individual components from 2021 onwards)	At the planning stage	2030

* Funding for non-residential buildings via the Ministry of the Economy (Act of 15 December 2017 on ENVIRONMENTAL PROTECTION AID SCHEMES (Ministry of the Economy), Article 7 – INVESTMENT AID FOR PROJECTS PROMOTING ENERGY EFFICIENCY MEASURES IN BUILDINGS)

Training	Stage of implementation	Timeline

No	Description		
W1-N	training on the energy-efficient optimisation of non-residential building redevelopments;	Idea	2030
W2-N	Further training on ways to reduce demand for cooling energy as a means of adapting to future climate change	Idea	2030

Research/model projects		Stage of implementation	Timeline for impact
No	Description		
FO1-N	Model projects involving highly efficient and cost-effective renovations of non-residential buildings	At the planning stage	2030
FO2-N	Model project involving the prefabrication of renovation components as a measure to counter labour shortages; cooperation with other countries	At the planning stage	2030

Figure 53: Table of measures for non-residential buildings, including public buildings

3.5. Overview of policies and actions to target the worst performing segments of the national building stock (Article 2a(1)(d));

In accordance with Article 2a(1)(d) of the EPBD, each LTRS must encompass 'an overview of policies and actions to target the worst-performing segments of the national building stock, split-incentive dilemmas, and market failures, and an outline of relevant national actions that contribute to the alleviation of energy poverty'. This is a new element that did not exist under Article 4 of the EED. Member States' LTRSs will now have to give an overview of policies and actions that target: (a) worst-performing segments of the national building stock; (b) split-incentive dilemmas (12); (c) market failures; and (d) the alleviation of energy poverty.

The overview should include at least a short description of each policy and action, its scope and duration, the allocated budget and the expected impact. Member States are to determine the worst-performing segments of their national building stock, for example by: (a) setting a specific threshold, such as an energy performance category (e.g. below 'D'); (b) using a primary energy consumption figure (expressed in kWh/m2 per year); or even (c) targeting buildings built before a specific date (e.g. before 1980). On 'split-incentive dilemmas', Member States are encouraged to consult the Joint Research Centre (JRC) 2014 report Overcoming the split-incentive barrier in the building sector' (13). The term 'market failures' refers to a range of problems that tend to delay the transformation of the building stock and the tapping of cost-effective energy savings potential. These may include, for example: (a) a lack of understanding of energy use and potential savings; (b) limited renovation and construction activity in a post-crisis context; (c) a lack of attractive financing products; (d) limited information on building stock; and (e) limited uptake of efficient and smart technologies. (14) The reference to 'energy poverty' in the amended EPBD is not new. The EED refers to 'energy poverty' (Article 7 and Recital 53 of the EED) and 'fuel poverty' (Recital 49 of the EED). Energy poverty is a result of a combination of low income, high energy expenditure and dwellings' poor energy performance – effective action to alleviate energy poverty should therefore include energy efficiency measures alongside social policy measures. While several Member States' LTRSs already address energy poverty, the EPBD now requires that

LTRSs outline 'relevant national actions that contribute to the alleviation of energy poverty'. (15) Article 2a(1)(d) of the EPBD, together with Recital 11 of Directive (EU) 2018/844, provides Member States with sufficient flexibility to implement the legislation in the light of national conditions, without interfering with their social policy competencies. (16)

3.5.1. Residential buildings

A) Worst-performing segments of the national building stock

The following four sub-segments of the residential building stock have been analysed as a basis for identifying measures for the worst-performing market segments:

1. buildings that can only be redeveloped to a limited extent (buildings under protection as historical monuments or listed groups of buildings);
2. buildings that are not under protection as historical monuments or listed groups of buildings and that have the highest average energy consumption;
3. under-occupied buildings;
4. social housing.

Re 1. buildings that can only be redeveloped to a limited extent (buildings under protection as historical monuments or listed groups of buildings);

The number of residential units that are protected as historical monuments or as groups of listed buildings has increased significantly in recent years as a result of the completion of a national inventory of architectural heritage, and is currently in the region of 13 588 buildings (SSMN, 2020). A leaflet published several years ago by Luxembourg's National Monuments and Sites Service describes various options for carrying out energy renovations in buildings protected as historical monuments on the basis of three examples, and covers the basics of monument conservation, energy efficiency and renewable energies (SSMN, 2015)

Examples from other countries reveal that reductions in final energy consumption$_{\text{heating + hot water}}$ of over 75% are possible even in buildings protected as historical monuments, and that values of around 50–60 kWh/m$^2_{\text{living space}}$a can be achieved (source: presentation by Schulze-Darup). Since the concept of energy efficiency in buildings protected as historical monuments is still in its infancy in Luxembourg, the scenario study by the Vorarlberg Energy Institute on changes in final energy demand and GHG emissions by Luxembourg's residential building stock assumes that average savings in this market segment are significantly lower.

The technical options available in connection with high-quality energy renovations of buildings protected as historical monuments will be investigated over the next few years on the basis of a number of example buildings. The findings gained from these model projects are to be publicised in formats suitable for laypeople and experts, and greater emphasis is to be placed on them during training courses. Special funding schemes are also to be developed for Luxembourg, based on the model of the special KfW funding schemes for buildings protected as historical monuments. The funding is to be linked to a consultation programme (either newly created or further developed on the basis of an existing programme).

The funding schemes operated by Luxembourg's National Monuments and Sites Service already include a separate scheme for the renovation of buildings protected as historical monuments, but these schemes do not include energy renovations. The PRIMe House funding scheme (energy measures) can be combined with the funding schemes operated by the National Monuments and Sites Service, and funding under both pillars is cumulative.

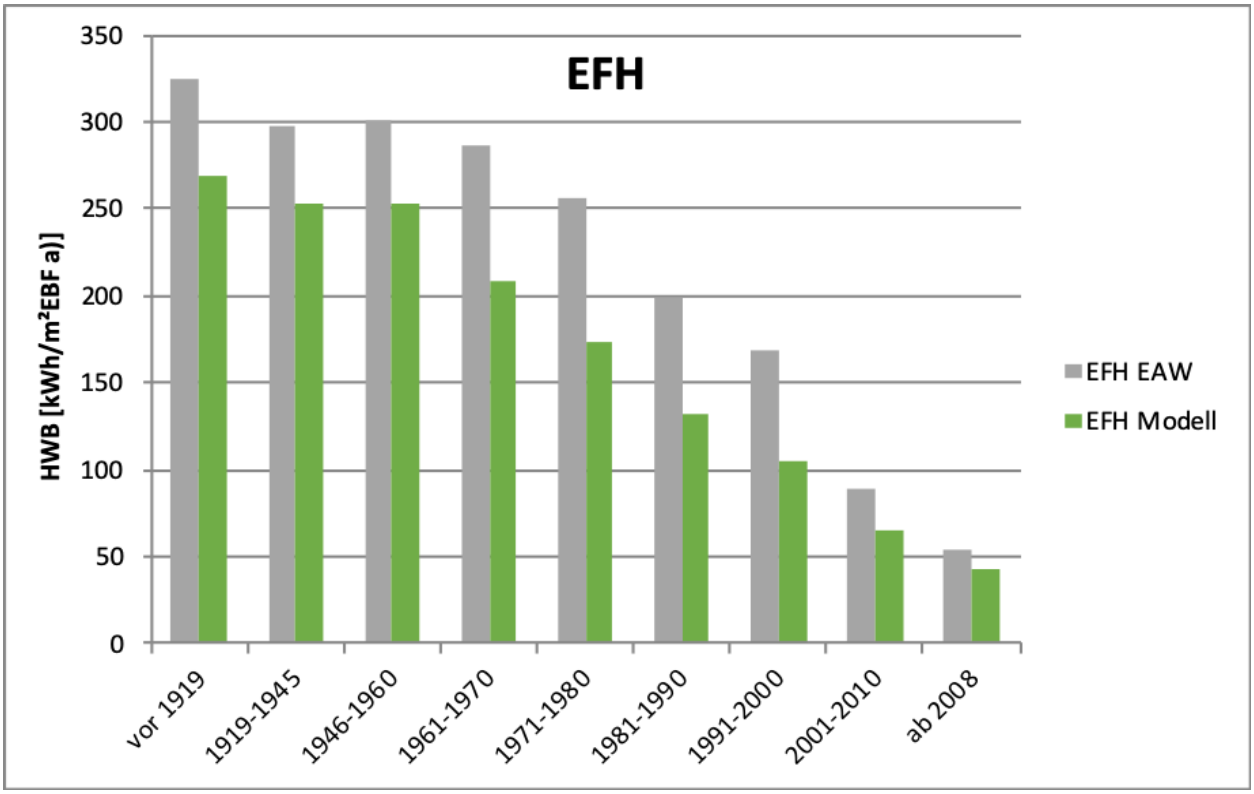
It is important to ensure that the communications and information targeted at architects, engineers, tradespeople and developers in this area are clear and send out a uniform message; this includes both parties focused more on energy consultations (myenergy) and those focused more on the monument conservation (National Monuments and Sites Service) → consultation programme 'Monument conservation and energy'.

No	*Description*	*Stage of implementation*	*Timeline for impact*
F4	*Funding for energy efficiency measures in buildings protected as historical monuments*	*At the planning stage*	*2030*

Figure 54: Table of measures relating to buildings protected as historical monuments

Re 2. Buildings that are not under protection as historical monuments or listed groups of buildings and that have the highest average energy consumption

The following figures show the values calculated for specific heating demand according to construction age in the Vorarlberg Energy Institute's scenario study on changes in final energy demand and GHG emissions by Luxembourg's residential building stock, broken down by single-family and multi-family dwelling.

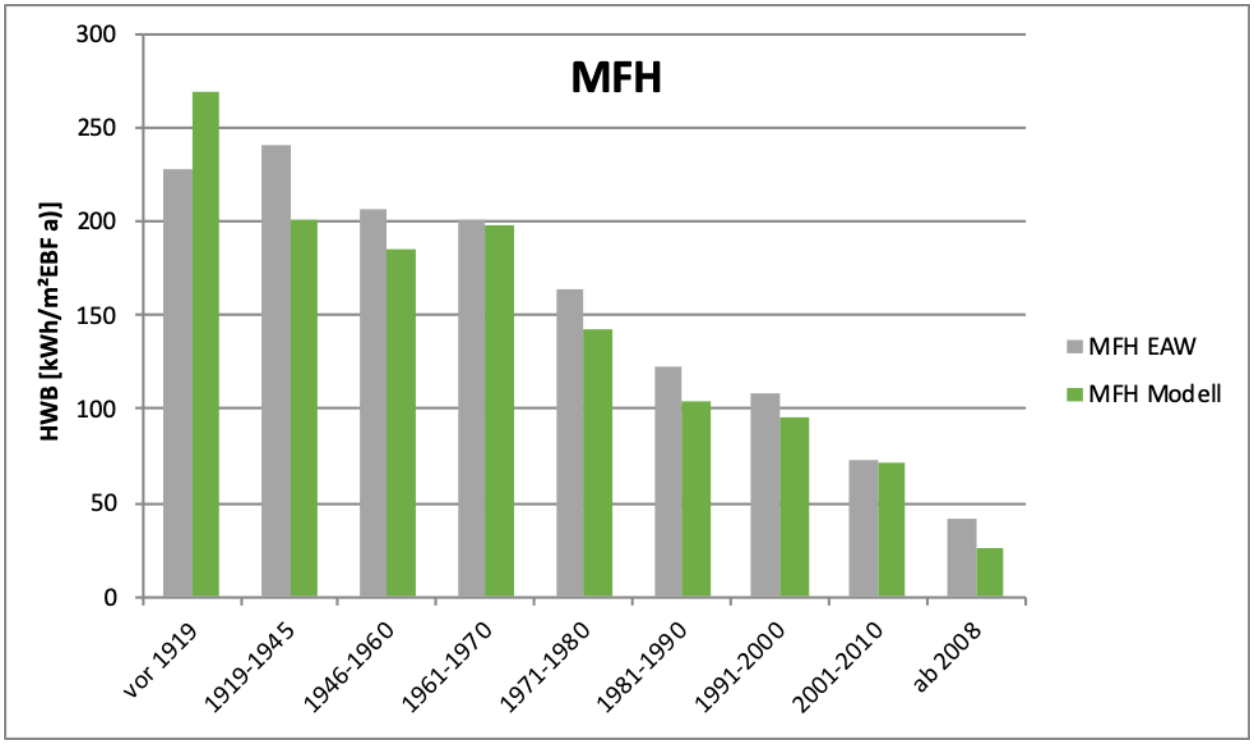


EFH	Single-family dwellings
HWB [kWh/m^2EBF a)]	Heating demand [kWh/m^2 ERA a)]
EFH EAW	Single-family dwelling EPC
EFH Modell	Single-family dwelling model

Figure 55: Specific heat demand of single-family dwellings according to building age classes *(Ploss, 2017)*

The figure shows two values for each construction age class; the value obtained on the basis of standardised constraints in the energy performance certificate/energy passport and the value obtained on the basis of the calculation model for the scenario study. The latter corresponds more closely to real consumption, since it takes account of the reduction in consumption in older buildings with worst-performing building envelopes (attributable to factors such as the restricted use of heating in certain areas or at certain times, reduced air exchange rates in winter, etc.). The standardised heating demand was corrected on the basis of a statistically derived model developed by the Institute for Housing and Environment (Born, 2003). The model also incorporates minor renovation measures such as replacement of the original single glazing with double glazing. The real energy saving potentials of buildings or of the entire building stock can only be calculated using the aforementioned realistic values for the current condition of the buildings in question.

The highest values were recorded for single-family dwellings constructed between 1919 and 1960, with average values of around 250 kWh/m$^2_{living\ space}$a.



MFH	Multi-family dwellings
HWB [kWh/m^{2}EBF a)]	Heating demand [kWh/m^2 ERA a)]
MFH EAW	Multi-family dwelling EPC
MFH Modell	Multi-family dwelling model

Figure 56: Specific heat demand of single-family dwellings according to building age classes *(Ploss, 2017)*

The highest values for multi-family dwellings were recorded for buildings constructed between 1919 and 1970, with average values of around 200 kWh/m$^2_{living\ space}$a. Average demand for building constructed between 1971 and 1980 was also high, at almost 150 kWh/m$^2_{ERA}$a. The funding schemes should therefore prioritise buildings in these age classes.

No	*Description*	*Stage of implementation*	*Timeline for impact*
R1	*Introduction of more stringent minimum requirements for individual components from 2023 onwards (2021 Grand-Ducal Regulation on energy performance)*	*At the preparatory stage (2021)*	*2030*
R8	*Introduction of an obligation to carry out renovations in the event that the support measures do not deliver adequate results*	*Idea*	*2050*
F1	*Revision of PRIMe House scheme: Funding of individual measures involving building envelope components (heavily scaled to promote high-performances)*	*At the preparatory stage (2021)*	*2030*

	(in combination with a tightening up of the minimum efficiency standards from 2023)		

Figure 57: List of measures for improvements in the performance of residential building envelopes

Re 3. Under-occupied buildings

Under-occupied buildings constitute another poorly performing market segment. Buildings or dwellings are referred to as under-occupied if they have at least two rooms more than required on the basis of the number of inhabitants (LISER, 2019).

Buildings of this kind may not exhibit unusually high energy demand in relation to the area they cover, but their per-capita energy demand is significantly increased because of the high person-specific living space.

Houses or apartments are regarded as slightly under-occupied if they have two or three rooms more than required, and as severely under-occupied if they have at least four rooms more than required.

Housing space demand is defined using the definition published by the EU in 2009, which is based on the relationship between the number of rooms and the number of residents, taking into account the following requirements:

- one room for the household,
- one room for each couple in the household,
- one room for each single person aged 18+,
- one room for two single people of the same sex between 12 and 17 years of age,
- one room for each single person of different sex between 12 and 17 years of age,
- one room for two people under 12 years of age.

The following figure shows the proportion of people living in under-occupied houses or apartments, broken down by the age of residents.

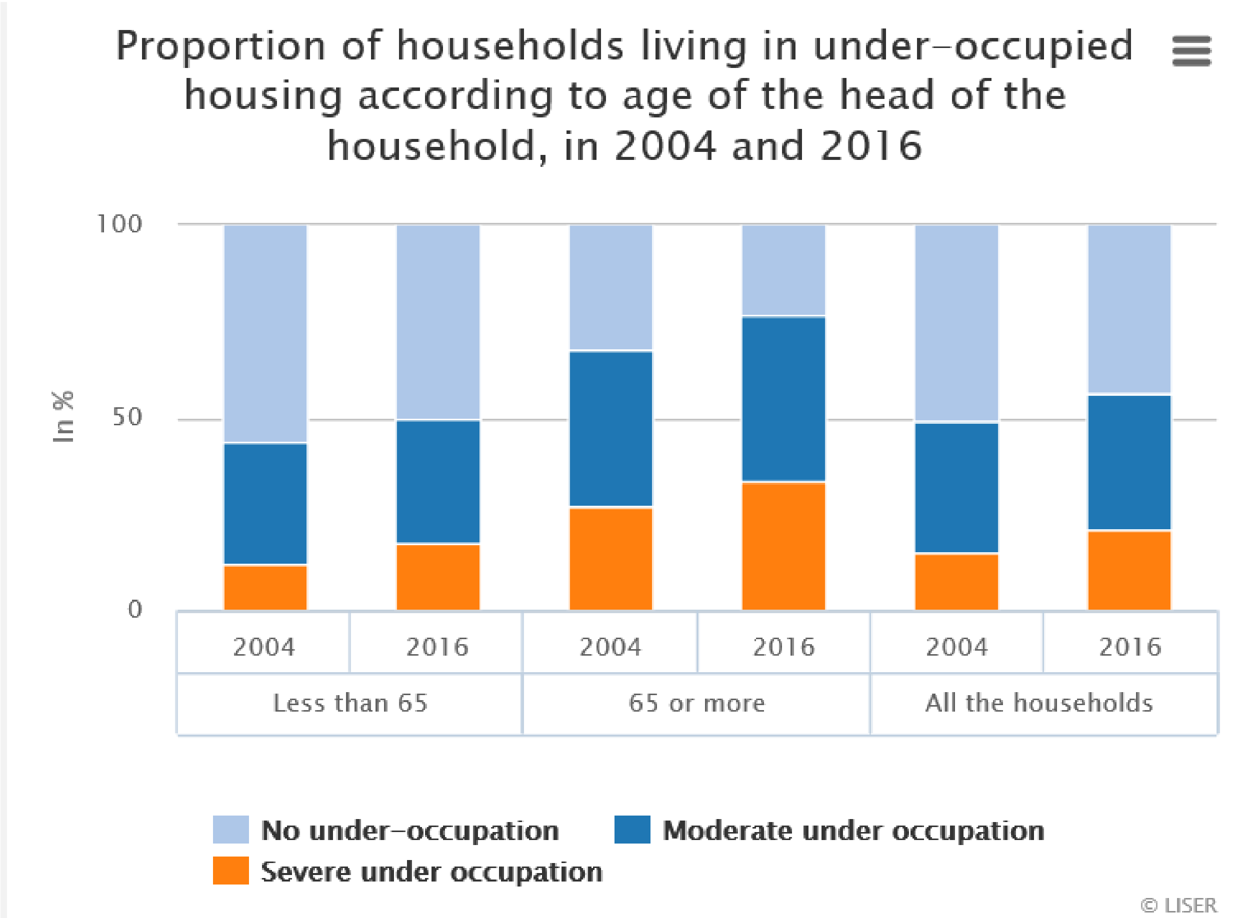


Figure 58: Proportion of households living in slightly or severely under-occupied buildings *(LISER, 2019)*

It can be seen that around 35% of households lived in slightly under-occupied houses or dwellings in 2016, and a further percentage (around 21%) lived in severely under-occupied units. The proportion of citizens aged over 65 living in under-occupied units is even higher, and stood at over 75% in 2016. A large proportion of the individuals in under-occupied residential units are living in family homes with empty bedrooms that were formerly occupied by children. The share of under-occupied residential units rose in all age classes between 2004 and 2016, however.

It is expected that the share of under-occupied units will continue to increase as a result of demographic changes and a rise in the proportion of older people.

Measures aimed at reducing the number of under-occupied residential units can help both to save energy and to improve the living situation of older people, since residential units of this kind are often not age-adapted. Yet this is an extremely sensitive topic, since individuals are often extremely reluctant to leave their homes, particularly if they built the home themselves.

Voluntary schemes offering advice about alternatives to individuals living in under-occupied buildings are a useful approach; a good example is the 'Redevelopment Pilot' scheme operated in the Austrian province of Vorarlberg. Under this scheme, individuals living in under-occupied buildings are provided with customised advice on the various alternatives available to them (splitting of the building into two residential units, addition of another storey and splitting, demolition and construction of several new residential units, some of which are age-adapted, sale of the residential unit and construction of a new build in a different location, sale of the residential unit and move to an existing smaller house or apartment, etc.). Checks should be carried out in connection with the development of implementing measures to determine whether a similar advice scheme could be introduced in Luxembourg.

Re 4. Social housing

As described in Chapter 3.1.5, the social housing units accounted for only a small share (3.6%) of the residential building stock in 2011 (last census). The output of new social housing has increased significantly in recent years, and the building envelopes of these buildings will only need to be renovated in around 40–50 years because of their construction age. In addition, the strict building envelope requirements for new builds mean that the energy performance of the buildings constructed over the past few years is very good, and they are therefore irrelevant to the LTRS in terms of their building envelope. They will only become relevant around 20 years after their construction with regard to a potential change in energy carrier.

Company / Number of dwellings	Housing Fund (since 1979)	SNHBM (since 2010)	AIS	Municipalities
Rental	1 937	280	…	…
Sale	1 737	872	…	…
State/institutions	484	72	…	…
Total	**4 158**	**1 224**	**…**	**…**

Figure 59: Key figures regarding social housing in Luxembourg

According to expert reports, an above-average proportion of the social housing constructed over the period up to 2011 has already been renovated, but precise figures on energy performance, the energy carrier mix and the proportion of buildings that has already been renovated are not currently available.

The two major public building developers (the Housing Fund and the National Low-Cost Housing Administration) were asked for their opinion on the matter.

For example, the Housing Fund is currently in the process of producing an inventory of its building stock with a view to compiling all of the available information in a single database. The buildings will be categorised in this database both by classes and by priority within the respective classes. The level of priority will be gauged on the basis of the anticipated post-renovation energy saving potential and the living conditions of residents. Other criteria include the construction age of the building, the current heating system and partial renovations that have already been implemented. Particular emphasis will be placed on buildings protected as historical monuments.

Based on this inventory and the priorities that have been defined, a multiannual plan will be produced that includes deadlines for renovation of the building stock. This plan will take into account not only the financial resources that are required and available and the availability of internal and external capacities required for implementation of the works, but also the situation of residents and the impacts of major works in an occupied building. If necessary, some of the occupants of the buildings in question may need to be relocated temporarily or permanently.

The implemented measures should also be appraised through regular monitoring of real energy consumption, and optimised if necessary.

In 2008, the National Low-Cost Housing Administration decided to renovate its entire building stock available for rental, since most of the buildings had been constructed in the 1940s and 1950s. A residence in Diekirch is currently being renovated, and another two older residences in Grevenmacher are to be renovated over the next 2 to 4 years. In addition, a number of older buildings have been demolished and replaced with energy-efficient new builds, which also led to an increase in the number of residential units. There are no further plans for renovations, since the building stock is otherwise very recent in date (or has already been renovated).

Based on the numbers reported by the two major housing companies, the stock of social residential units can be estimated at 5 500 as a minimum; the proportion of sold and rented residential units is approximately the same. Both companies have put in place ambitious renovation programmes, and the majority of the National Low-Cost Housing Administration's building stock has already been renovated. The Housing Fund systematically renovates all dwellings after the end of each rental agreement, i.e. all of the 100 or so dwellings that come up for reletting each year.

It is envisaged that a separate funding programme for energy renovations will be developed on the basis of a stocktaking exercise, as part of the work currently being carried out on the social housing strategy.

b) Split incentives

One of the obstacles standing in the way of energy-efficient and deep renovations in buildings that are not used by the owner is the owner/user dilemma (split incentives).

High quality energy renovations will only become widespread in this market segment if models can be developed that allow both owners and tenants to profit equally from the financial benefits of energy renovations.

An example from Austria that has proved its worth in practice (at least for the sub-segment in question), and which resulted in higher renovation rates and qualities, is described below.

Example of Austria's 'Maintenance and Improvement Contribution' for social housing

The 'Maintenance and Improvement Contribution' is the third component of the rent paid for social housing in Austria, alongside the basic rent and service charges. Tenants pay a monthly contribution that is used to build reserves for renovations. The maximum contribution increases with the age of the building. For buildings that are no more than 5 years old, the contribution is no more than 0.50 EUR/m^2 per month; it increases up to a maximum of EUR 2.00/m^2 per month for buildings that are 30 years old or more. These values were first determined in 2016, and have been regularly adjusted to the inflation index since April 2018.

The 'Maintenance and Improvement Contribution' is earmarked as a reserve for renovations, which ensures that money is saved over time to cover the renovation costs and these costs are not passed on to the tenants who happen to be living in the building at the time of the deep redevelopment.

The 'Maintenance and Improvement Contribution' is the reason why the highest renovation rates in Austria are achieved in the social housing segment.

Additional measures:

No	Description	Stage of implementation	Timeline for impact
R5	*Obligation to build up financial reserves (based on the example of Austria's 'Maintenance and Improvement Contribution')* *Legislative amendment 'co-owned multi-family dwellings – construction fund' is passing through the relevant legal channels (2021)*	*At the planning stage*	*2030*

Figure 60: Table of measures for split incentives

c) Cases of market failure

For the purpose of developing measures aimed at eliminating cases of market failure, the following four obstacles were analysed in connection with the work carried out in 2016/2017 to make the renovation strategy more comprehensive, and a statistically sound TNS Ilres survey carried out in this connection:

1. lack of awareness about energy consumption and potential savings;
2. capacity constraints in the construction industry;
3. lack of awareness about attractive promotional and funding products;
4. limited acceptance of efficient and smart technologies.

Re 1. Lack of awareness about energy consumption and potential savings

The majority of owners/tenants of residential houses/apartments are unaware of the efficiency potentials of their building, and are equally unaware of the State's long-term efficiency targets for the buildings sector. Renovation roadmaps can serve as an important tool for providing information on both of these factors. These renovation roadmaps must calculate and outline the savings achievable by means of deep renovations (involving one or more stages). The efficiency target identified on the basis of the State's long-term targets for the buildings sector should therefore be 'translated' into an efficiency target for the building under investigation.

Storyline for the homeowner: 'Luxembourg wants to play its part in mitigating climate change. This means that the buildings sector must reduce its energy demand by x% by 2050, and all heating systems must be non-fossil-fuel-based by 2050 at the latest. In the case of your building, and taking into account the building type and profitability, this means that energy demand should be reduced by x% and the heating system should be switched to renewable energies at the next opportunity, for example when you next replace your boiler. The State will help you reach these targets with subsidies for efficiency measures, for switching to renewables and in some cases for the use of active solar installations.'

Re 2. Capacity constraints in the construction industry

In view of the significant increases in the output of new residential and non-residential builds, the Chamber of Tradespeople estimates the labour demand in the industry at around 5 000 people (PAPERJAM, 2019). The number is based on a study by the Chamber of Craft Trades, which was in turn based on responses from around 12% of member companies. In total, around 9 400 tradespeople are needed. The figure in the construction sector is likely to increase if the demand for new-build dwellings continues to rise (as indicated in Chapter 2.4.2).

A rise in the rate and quality of renovation would increase the demand for labour yet further. The following figure illustrates the additional investments that would be created by increasing the current renovation rate of around 0.7 full renovation equivalents to an economically optimal renovation rate of 1.6% per annum, and the size of the corresponding labour force.

Building envelope renovation rate (full renovation equivalent)	Number of residential units to undergo deep renovations	Total living space to be renovated	Renovation investments (minimum performance)	Renovation investments (cost-optimal performance)	Workstations for minimum-performance renovation	Workstations for cost-optimal-performance renovation
%	Residential units/year	m^2 living space	EUR/a	EUR/a	EUR/a	EUR/a
0.4	1 000	129 000	47 730 000	69 660 000	430	627
0.6	1 500	193 500	71 595 000	104 490 000	644	940
0.7	1 750	225 750	83 527 500	121 905 000	752	1 097
0.8	2 000	258 000	95 460 000	139 320 000	859	1 254
1.0	2 500	322 500	119 325 000	174 150 000	1 074	1 567
1.2	3 000	387 000	143 190 000	208 980 000	1 289	1 881
1.4	3 500	451 500	167 055 000	243 810 000	1 503	2 194
1.6	4 000	516 000	190 920 000	278 640 000	1 718	2 508
1.8	4 500	580 500	214 785 000	313 470 000	1 933	2 821
2.0	5 000	645 000	238 650 000	348 300 000	2 148	3 135

Figure 61: Estimated additional demand for labour caused by a rise in the rate and quality of renovation *(Ploss, 2020)*

An increase in the building envelope renovation rate from the current figure of around 0.7% to 1.6% per year (based on the total current stock of around 250 000 residential units) would mean that around 4 000 residential units would undergo a complete building envelope renovation each year, instead of 1 750. This would correspond to an increase in investments of around 84 million (to EUR 279 million per annum) if the energy performance of the renovations were improved at the same time. A labour force of around 2 500 would be required (instead of the present figure of around 750), which is equivalent to an increase in demand of around 1 750.

A larger labour force would also be needed if the rate and quality of renovations in non-residential building were to be increased, and if the boiler replacement rate and the rate of installation of solar systems and ventilation systems were to be increased.

Based on these figures, priority should be given to measures that increase the attractiveness of jobs in the construction industry or that increase the effectiveness of renovation processes, for example through greater use of prefabricated components.

Re 3. Lack of awareness about attractive promotional and funding products

An evaluation of the TNS ILRES survey reveals that the main reason why respondents did not apply for State funding was that they were not aware of the funding programmes. Of those surveyed who had carried out renovation measures and not applied for funding, 35% said that they were not aware of the State funding programmes, and 47% said that they were not aware of the energy suppliers' programmes. A further 9% stated that they had not applied for subsidies because the application process was too complicated.

No	*Measure*	*Stage of implementation*	*Timeline for impact*
S1	*Further development of the existing app 'myrenovation'*	*Ongoing*	*2030*

Figure 62: Measures aimed at better publicising the funding options for the housing sector

Re 4. Limited acceptance of efficient and smart technologies

Certain types of insulation materials, such as EPS, have been the subject of criticism over recent years in certain EU Member States. According to a survey carried out by TNS Ilres, this factor does not so far play a particularly significant role in Luxembourg. The subsidies that have been available for some time for eco-friendly and semi-natural insulating materials are nevertheless popular; the bonus for choosing an eco-friendly material is granted in the case of around half of all insulation funding applications.

d) Energy poverty

The term ‘energy poverty’ has not yet been uniformly defined in Luxembourg or at EU level. The Ministry of Energy, in consultation with other ministries and institutions, is responsible for the area of energy poverty and will align its actions in this area with the requirements and definitions of the European Commission.

Three proposed definitions of the term are outlined below. A fourth proposal, which does not comprehensively define the term ‘energy poverty’ but which at least assesses some of its main causes, is also outlined.

In addition to these proposed definitions, the current status quo in Luxembourg is explained and compared to other European countries; finally, additional strategies and measures for reducing energy poverty (both existing and potential) are described. The impact on households at risk of energy poverty of the decision to introduce relatively low CO_2 pricing from 2021 onwards is also quantified and taken into account.

Proposed definitions:

1) A household is affected by energy poverty if the members of the household have to spend a certain proportion of their income on energy (electricity, heating, hot water). For example, a household in the United Kingdom is deemed to suffer from energy poverty if it has to spend more than 10% of its income on energy in order to guarantee a temperature of 21 °C in the main living room and 18 °C in the other rooms (Kopatz, 2010).
2) A household is affected by energy poverty if it cannot afford to heat its house or apartment, or if it has not been able to afford to pay its electricity, gas, water or heating bills over the past 12 months.
3) A third approach breaks the term ‘energy poverty’ down into ‘household energy poverty’ and ‘transport energy poverty’ and defines criteria for assessing both of these types of energy poverty.
4) A further approach involves quantifying one or more of the main causes of energy poverty referred to below:
    - financial problems on the part of the household affected;
    - poor energy performance of the building in which the household lives;
    - inefficient household devices in the building in which the household lives;
    - high or rising energy prices;
    - inefficient behaviours.

Financial problems on the part of the household affected and increasing energy prices are described as factors under (4).

5) Luxembourg's office of statistics (STATEC) is currently working on a definition of the term 'energy poverty', in collaboration with the Ministry of Energy. The assessment is to be carried out using the indicators 'energy effort rate (EER)' and 'low income, high expenditure (LIHE)', and is currently verified by means of an evaluation based on real data.

Re Definition 1: Energy costs as a share of total income

Data regarding spending on household energy as a share of total spending by households in different income brackets has been collected by the EU for a number of years across all the Member States (EU, 2019).

The following figure shows the outcomes of the most recent analysis for most Member States, with results for 2014 and 2015 in relation to the lowest-income decile.

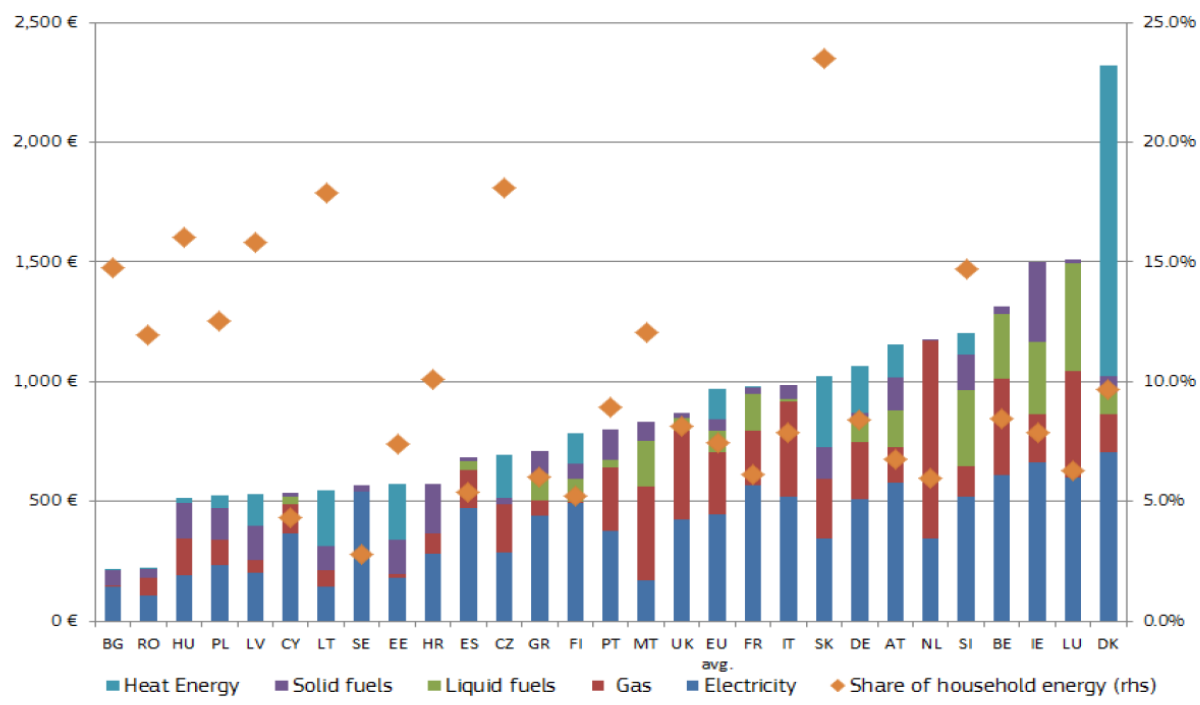


Figure 63: Energy spending by the lowest-income decile in the EU Member States *(EU, 2019)*

Spending on household energy (heating, hot water, domestic electricity) fluctuates greatly between the Member States. The percentage share accounted for by household energy costs varies between around 3% in Sweden and around 23% in Slovakia, in both cases with respect to the lowest-income decile. This figure stands at around 6% to 7% in Luxembourg, which places it close to the same level as the Netherlands and

France. The countries with lower percentage shares either have high average energy performances and relatively high incomes (Sweden, Finland) or warm climates with less demand for heating (Cyprus, Spain).

The percentage shares accounted for by household energy costs are generally lower in the third and fifth income deciles, and stand at almost 5% in Luxembourg.

Re Definition 2: A household cannot heat its home to an adequate temperature, or has been unable to pay energy bills over the past 12 months

Over the past few years, Eurostat has tracked the percentage of households that cannot adequately heat their homes. The following figure shows the values calculated for the period between 2010 and 2018 as a percentage of all households.

Inability to keep home adequately warm - EU-SILC survey
Last update: 17-12-2019
Table Customization show

TIME | GEO | Type of household: Total
Income situation in relation to the risk of poverty threshold: Total | Unit of measure: Percentage

GEO \ TIME	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
European Union (EU6-1958, E	:	:	9.8	10.8	10.7	10.2	9.4	8.7	7.8	7.3
European Union - 28 countrie	:	9.5	9.8	10.8	10.7	10.3	9.4	8.7	7.8	7.3
European Union - 27 countrie	9.3	9.5	9.8	10.8	10.8	10.3	9.4	8.7	7.8	7.3
Euro area (EA11-2000, EA12-	:	:	8.8 (e)	10.1 (e)	9.9 (e)	10.1 (e)	9.4 (e)	8.8 (e)	8.0 (e)	7.6
Euro area (19 countries)	7.7	8.0	9.2	10.4	10.1	10.2	9.4	8.8	8.0	7.6
Euro area (18 countries)	7.5	7.8	8.9	10.1	10.0	10.1	9.3	8.6	7.8	7.4
Belgium	5.1	5.6	7.1	6.6	5.8	5.4	5.2	4.8	5.7	5.2
Bulgaria	64.2	66.5	46.3	46.5	44.9	40.5 (b)	39.2	39.2 (b)	36.5	33.7
Czechia	5.2	5.2	6.4	6.7	6.2	6.1	5.0	3.8	3.1	2.7
Denmark	1.5	1.9	2.3	2.5	3.8	2.9	3.6	2.7	2.7	3.0
Germany (until 1990 former t	5.5	5.0	5.2	4.7	5.3	4.9	4.1	3.7	3.3	2.7
Estonia	1.7	3.1	3.0	4.2	2.9	1.7 (b)	2.0	2.7	2.9	2.3
Ireland	4.1	6.8	6.8	8.4	10.0	8.9	9.0	5.9	4.4	4.4 (p)
Greece	15.7	15.4	18.6	26.1	29.5	32.9	29.2	29.1	25.7	22.7
Spain	7.2 (b)	7.5	6.5	9.1	8.0	11.1	10.6	10.1	8.0	9.1
France	5.5	5.7	6.0	6.0	6.6	5.9	5.5	5.0	4.9	5.0
Croatia	:	8.3	9.8	10.2	9.9	9.7	9.9	9.3	7.4	7.7
Italy	10.8	11.6	17.8	21.3	18.8	18.0	17.0	16.1	15.2	14.1
Cyprus	21.7	27.3	26.6	30.7	30.5	27.5	28.3	24.3	22.9	21.9
Latvia	16.4	19.1	22.5	19.9	21.1	16.8	14.5	10.6	9.7	7.5
Lithuania	24.1	25.2	36.2	34.1	29.2	26.5	31.1	29.3	28.9	27.9
Luxembourg	0.3	0.5	0.9	0.6	1.6	0.6	0.9	1.7 (b)	1.9	2.1
Hungary	8.9	10.7	12.2	15.0	14.6	11.6	9.6	9.2	6.8	6.1

Figure 64: Share of households unable to heat their homes to an adequate temperature *(Eurostat, 2019)*

According to the Eurostat data, on average around 7.3% of households in the EU (EU 28) could not heat their homes to an adequate temperature; the figure for Luxembourg is 2.1%. Although this is the lowest percentage in any EU Member State, even in Luxembourg the share has increased significantly since 2010. Based on a total of around 250 000 households, 2.1% corresponds to around 5 000 households that are affected by energy poverty.

If the calculation is restricted to households at risk of poverty, i.e. with incomes lower than 60% of the national average, instead of all households in Luxembourg, the figure increases to 6.2% (compared to 1.7% in 2010).

Energy suppliers apply to cut off the supply of gas or electricity to around 1 000 households per year because of unpaid bills; this number has increased in recent years (l´essentiel, 2015). The electricity or gas supplier is obliged to inform the social welfare office in such cases. If the social welfare office does not award a grant to cover the costs, the system operator blocks the supply to the household in question in response to a written request by the supplier, with a notice period of 30 days.

Similar figures regarding the share of households that were unable to heat their homes to an adequate temperature can be found in the 'Member State Report' published by the EU Energy Poverty Observatory (EPOV); the share for Luxembourg is specified as 1.9% in 2017, whereas the EU average is 7.8%. The value of 1.9% for Luxembourg is broken down into household types as follows (eurostat, 2019):

- Owners: 1.4%
- Tenants (private landlords): 3.2%
- Tenants (social housing): 3.9%

The percentage share of households in arrears with energy suppliers over the past year is specified as 1.7% for Luxembourg, compared to an EU average of 7.0%.

Re Definition 3 – breakdown into indicators for household energy poverty and transport energy poverty.

As part of a study published in 2019 by the expert network 'OpenExp' (a network which includes the Wuppertal Institute and many other European research institutions), the European Energy Poverty Index (EEPI) was calculated for all EU Member States for the first time. The project was funded by the European Climate Foundation.

The study revealed that countries with stringent building regulations and a higher per capita GDP typically have lower levels of energy poverty, but that energy spending as a share of total household spending is increasing throughout Europe. The increase is particularly apparent among low-income households.

As can be seen from the following figure, the EEPI is made up of two sub-indicators:

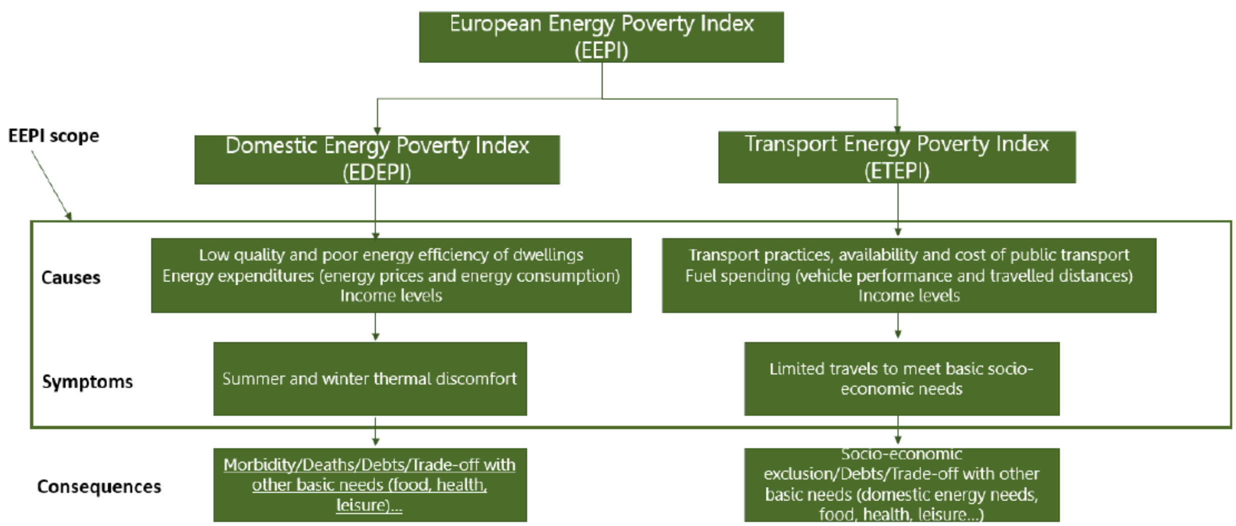


Figure 65: The sub-indicators making up the EEPI (one for household energy poverty and one for transport energy poverty) *(openExp, 2019)*

The EEPI is a means of assessing Member States' efforts to reduce the risks of both types of energy poverty.

Luxembourg holds second place in the overall EEPI ranking, behind Sweden. It stands in first place in respect of the transport energy poverty indicator (because public transport has been free in the country since March 2020), but in fifth place in respect of the household energy poverty index.

Re Definition 4. At-risk-of-poverty rate

Although Luxembourg has one of the smallest percentage shares of households at risk of energy poverty compared to other EU Member States, some of the indicators published by STATEC reveal that at least some of the causes of energy poverty are also on the rise in Luxembourg.

The following figure shows changes in the at-risk-of-poverty threshold and the at-risk-of-poverty rate.

Income and poverty	2003	2010	2016	2017
Available income in EUR/month				
Available average income per household	4 181	5 118	5 584	5 880
Available average income per equivalent adult	2 472	3 033	3 285	3 464
Available median income per household	3 532	4 350	4 666	4 957
Available median income per equivalent adult	2 148	2 694	2 818	3 006
Indicators relating to poverty and income distribution inequality				
At-risk-of-poverty threshold (in EUR)	1 289	1 617	1 691	1 804
At-risk-of-poverty rate (in %)	11.9	14.5	16.5	18.7

Figure 66: Changes in the at-risk-of-poverty rate in Luxembourg between 2003 and 2017 *(STATEC, 2019)*

The number of people at risk of poverty in Luxembourg rose from 11.9% to 18.7% between 1998 and 2017. Households are deemed to be at risk of poverty if their income is less than 60% of the national median income. In 2015, this figure stood at EUR 21 200/a for an individual.

At-risk-of-poverty rates different greatly between various population groups, with the highest risk being observed for single parents. The figure rose from 25.2% in 2003 to 40.7% in 2018 for this group. The at-risk-of-poverty rate is also high for families with three or more children, and increased from 16.7% in 2003 to 30.4% in 2018 (STATEC, 2019). The values for 2018 also vary between 11% and 23.3%, depending on level of education.

The definition of poverty on the basis of the at-risk-of-poverty rate is a relative approach, since it depends on the national median income.

An alternative approach involves defining poverty on the basis of 13 indicators that can be used to assess the financial capabilities of households or individuals, inter alia, in respect of their ability to socialise. (LISER, 2020)

The indicators are as follows:

indicators based on the inability of a household:

1. to cover unexpected expenses;
2. to pay for a week-long holiday each year;
3. to prevent arrears (on rent etc.);

4. to afford a meal containing chicken or fish every second day;
5. to keep the house/apartment adequately warm;
6. to have access to a car;
7. to replace furniture that has become unusable.

indicators based on the inability of an individual:

1. to replace worn-out clothing;
2. to own two pairs of properly fitting shoes;
3. to have a small amount of money they can spend as they wish;
4. to be able to take part in regular leisure activities;
5. to eat out with friends or family at least once per month;
6. to have access to the Internet.

If one of the members of a household meets at least 5 of these 13 indicators, they are regarded as materially and socially deprived. The following figure shows values for the EU Member States for comparative purposes.

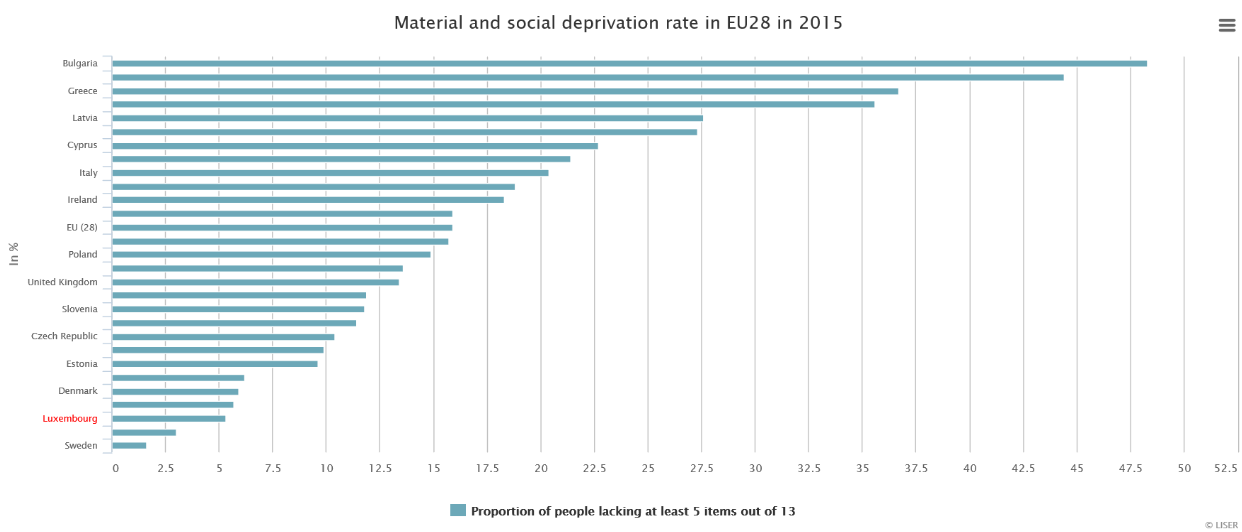


Figure 67: Percentage shares of financially and socially deprived individuals *(LISER, 2020)*

The figure reveals that Luxembourg has one of the lowest rates of financially and socially deprived individuals (5%).

Re Definition 4. Planned STATEC indicators ‘energy effort rate’ and ‘low income, high expenditure’

STATEC is currently developing a number of different energy poverty indicators.

These indicators are calculated separately by including or excluding fuel costs.

Energy effort rate (EER)

Energy effort rate is the first and oldest definition to be found in the literature. It describes the relationship between energy spending and total household income. Households are regarded as vulnerable if this relationship exceeds a particular threshold.

In the United Kingdom, this threshold has been set at 10% on the basis of studies published in 1988. More recent studies carried out in France resulted in the threshold being reduced to 8%. Defining this threshold is a critically important task, and it should not be defined in relation to other countries. We are currently analysing the possibility of defining a dynamic threshold that is twice as high as the median of the EERs calculated for all households.

We are also working on a version of EER that might be more informative for decision-makers, i.e. the EER calculated for the first three deciles of household income.

Low income, high expenditure (LIHE)

The second indicator we are working on is referred to as 'low income, high expenditure'.

This indicator was developed by France in an attempt to remedy a weakness inherent to the EER, i.e. that the latter specifies a threshold above which a household may be vulnerable without taking into account the level of household income. For example, households with very high incomes that do not need to worry about their energy spending (such as a household that heats its swimming pool to over 30 °C all year round) would be included in the figures based on the EER.

<u>The low income, high expenditure indicator is based on two selection criteria:</u>

Energy spending per unit of consumption must be higher than the median energy spending for all units of consumption.

The available income per unit of consumption must be less than 60% of the available median income for all units of consumption.

Once again, the setting of an arbitrary threshold of 60% on the basis of France's experiences might not be appropriate for Luxembourg, and we are currently testing other thresholds (e.g. 40%).

<u>Analysis of the typology of vulnerable households</u>

As well as calculating both of these indicators and their variants, it is important to be familiar with the characteristic features of the households selected on the basis of these criteria. An analysis of their typology is currently being produced.

Unsurprisingly, initial findings show that the selected households are predominantly made up of single unemployed persons.

<u>Analysis of the price sensitivity of indicators</u>

The sensitivity of the calculated indicators compared to the price of energy products also needs to be analysed in greater depth. Similar analyses carried out by other countries have revealed that the EER indicator is extremely sensitive to the price of energy products, but that this applies to a much lesser degree to the LIHE indicator.

<u>Initial results</u>

The following tables show annual changes in the EER and LIHE indicators (with variants), depending on whether fuel costs are to be included or excluded.

Spending on energy (without fuels/fuels excluded and with fuels/fuels included)

Energy spending (excluding fuels)

	2013	2014	2015	2016	2017
EER 8%	11.6%	10.6%	8.5%	6.4%	5.7%
EER 10%	6.9%	6.4%	4.6%	3.0%	3.3%
LIHE 40%	4.9%	5.2%	4.9%	4.8%	5.2%
LIHE 60%	10.4%	11.1%	10.8%	10.9%	10.3%

Energy spending (including fuels)

	2013	2014	2015	2016	2017
EER 8%	32.3%	29.4%	25.0%	21.0%	20.7%
EER 10%	19.9%	18.7%	15.0%	11.9%	12.0%
LIHE 40%	3.7%	3.8%	3.6%	3.9%	3.7%
LIHE 60%	9.5%	10.0%	10.1%	10.0%	8.9%

Figure 68: Changes over time in energy poverty levels according to STATEC indicators *(Thunus, 2020)*

Summary of current energy poverty levels in Luxembourg

As can be seen, Luxembourg is one of the EU Member States least affected by energy poverty and poverty in general.

The proportion of the population that is affected is nevertheless significant; according to EUROSTAT, around 5 000 households are unable to heat their homes to an adequate temperature, and an increasing share of households are obliged to rely on State benefits to pay their energy bills.

It is clear from the following graphs that problems relating to the affordability of energy costs are attributable not to energy prices, but to changes in the relationship between rent levels and available incomes.

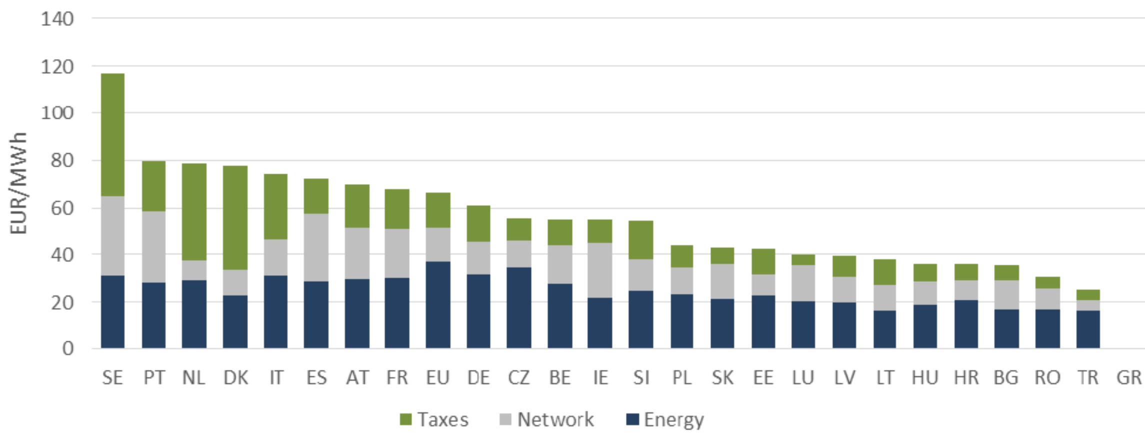


Figure 69: Gas prices for domestic customers in 2017 *(Commission, 2019)*

It is readily apparent from the graph that gas prices for domestic customers in Luxembourg are a long way below the EU average. Cheaper prices are only charged in countries that are much weaker economically speaking.

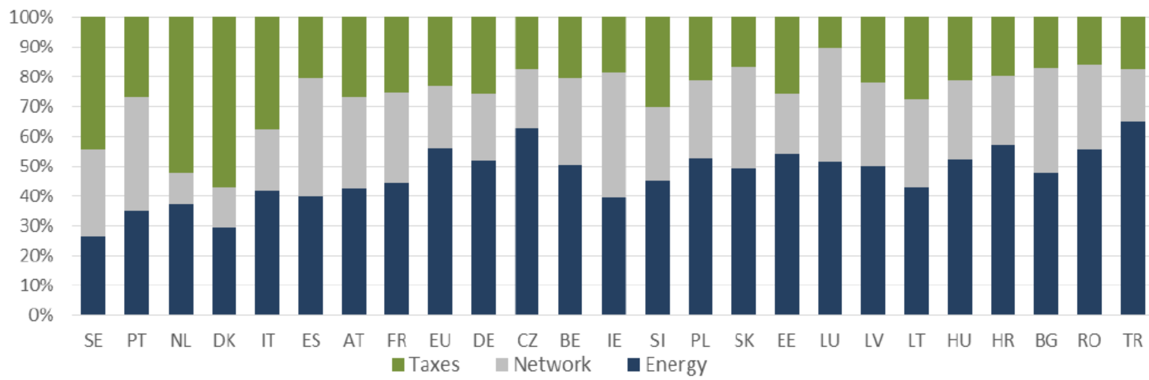


Figure 52 - Composition of household gas prices in 2017

Figure 70: Composition of gas prices for domestic customers in 2017 *(Commission, 2019)*

Luxembourg charges the least tax on gas for domestic customers anywhere in the EU.

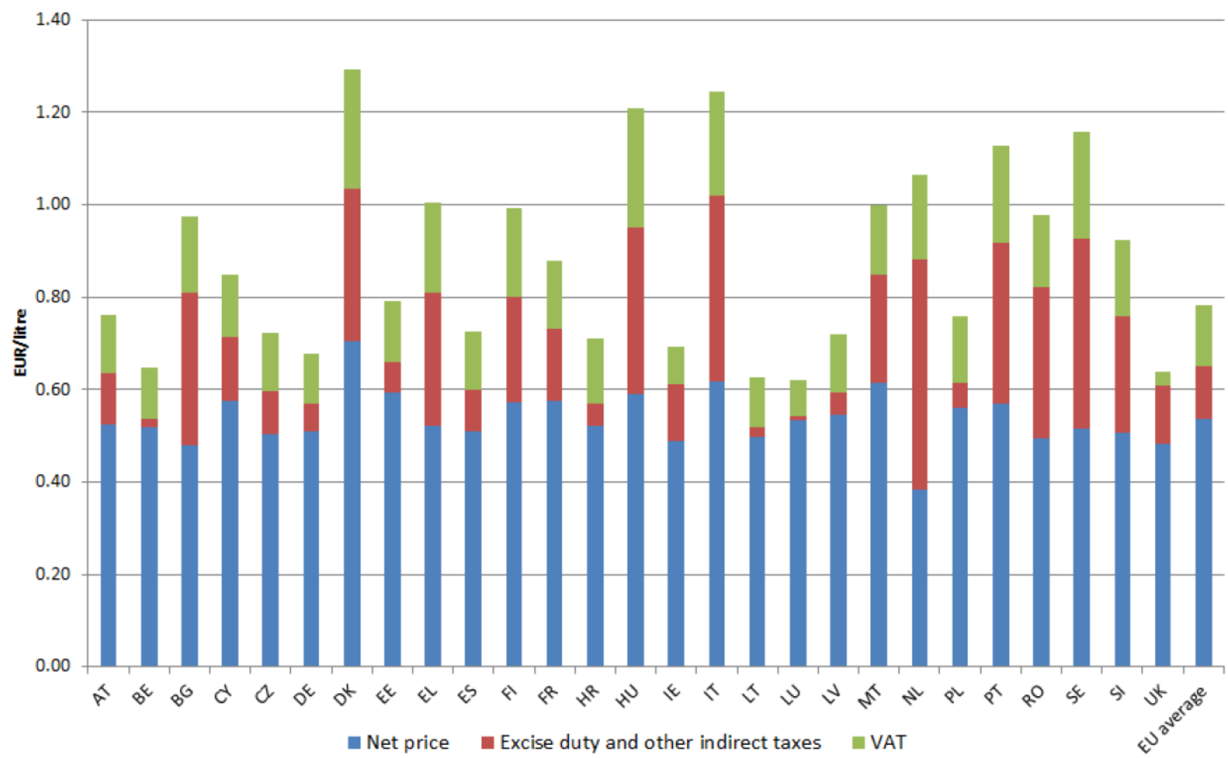
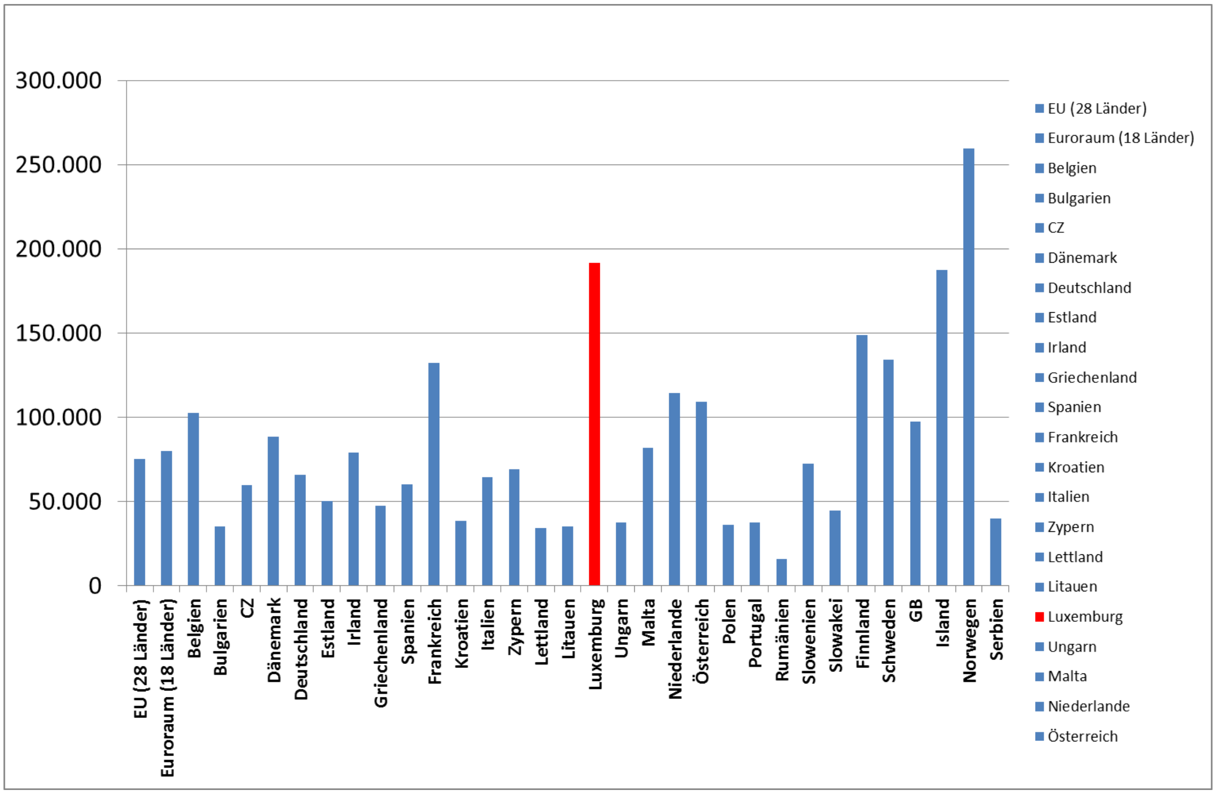


Figure 71: Composition of heating oil prices for domestic customers in 2017 *(Commission, 2019)*

Luxembourg has the lowest absolute heating oil prices for private customers anywhere in the EU. This is primarily due to the very low tax burden.

The following graph shows energy prices in the EU Member States and Iceland and Norway in relation to purchasing power. Domestic electricity prices are used by way of an example.



EU (28 Länder)	EU (28 Member States)
Euroraum (18 Länder)	Eurozone (18 Member States)
Belgien	Belgium
Bulgarien	Bulgaria
CZ	Czech Republic
Dänemark	Denmark
Deutschland	Germany
Estland	Estonia
Irland	Ireland
Griechenland	Greece
Spanien	Spain
Frenkreich	France
Kroatien	Croatia
Italien	Italy
Zypern	Cyprus
Lettland	Latvia
Lituaen	Lithuania
Luxemburg	Luxembourg
Ungarn	Hungary
Malta	Malta
Niederlande	Netherlands
Österreich	Austria

Figure 72: Amount of electricity (in kWh/a) that an average household can afford based on its annual income *(EUROSTAT, 2015) (EUROSTAT, 2016)*

The figure compares gross domestic electricity prices in the 28 EU Member States and other European countries against the average income (median equivalised total net income). The values displayed refer to the amount of domestic electricity that an average-income household would be able to afford each year. At almost 192 000 kWh/a, the value for Luxembourg is 2.54 times higher than the average value for the 28 EU Member States.

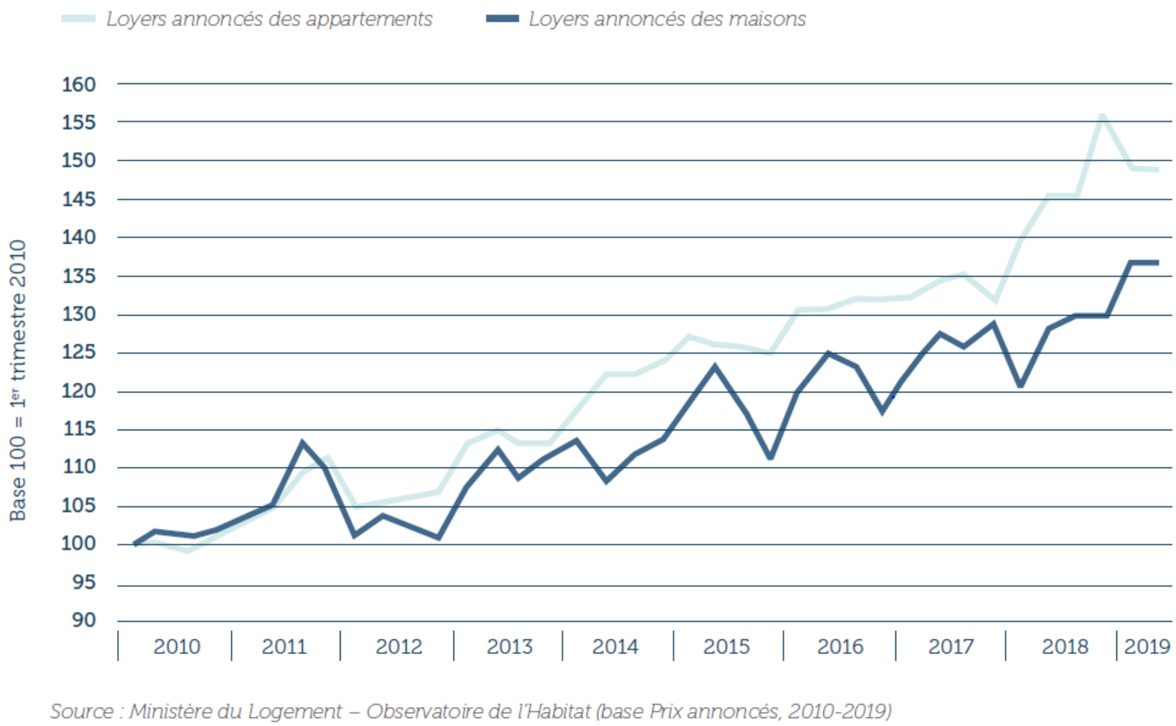
The average household in Luxembourg can afford 1.87 times more domestic electricity than the average household in Belgium, 1.45 times more than the average household in France, 2.91 times more than the average household in Germany, 1.75 times more than the average household in Austria and 2.17 times more than the average household in Denmark.

Gas prices display a similar trend, and are much cheaper than in other EU Member States compared to average purchasing power.

More recent investigations come to similar conclusions: 'In PPS (purchasing power standards, an artificial currency that compensates for general price differences between various countries), electricity prices for households in Finland (13.7 PPS per 100 kWh) and Luxembourg (13.8) were lowest, followed by the Netherlands (15.2), Malta (15.7), France (16.4), Sweden (16.5) and Lithuania (17.3), when viewed in comparison to the costs for other goods and services. The highest prices in PPS were recorded for Portugal (28.2), Germany (28.0), Spain (27.4), Belgium (26.6), Romania (26.3), Cyprus (24.5) and Poland (24.3).' (EUROSTAT, 2019)

The same is true in respect of gas for domestic customers: 'After correcting for purchasing power, the lowest gas prices were reported for households in Luxembourg (3.5 PPS per 100 kWh), ahead of the United Kingdom (4.7), Croatia and Estonia (5.6 each) and Belgium and Germany (5.7 each) when viewed in comparison to the costs for other goods and services. The highest prices were recorded for Sweden (10.1), Spain (9.7), Italy and Portugal (9.6 each).' (EUROSTAT, 2019)

As shown above, (energy) poverty in Luxembourg cannot be attributed to energy prices; instead, it is caused by changes in real estate prices or (in the case of households at risk of poverty) rental prices. The following figure shows changes in the rental price index for apartments and single-family dwellings.



Loyers annoncés des appartments	Reported rental price for apartments
Loyers annoncés des maisons	Reported rental price for houses
Base 100 = 1er trimester 2010	Base 100 = 1st quarter of 2010
Source : Ministère du Logement – Observatoire de l'Habitat (base Prix annoncés, 2010-2019)	Source : Ministry of Housing – Housing Observatory (based on reported prices, 2010-2019)

Figure 73: Changes in the rental price index for apartments and single-family dwellings since 2010 *(Observatoir, 2019)*

As can be seen from the figure, the rental price index for apartments rose to around 149 index points between 2010 and 2019. The index stood at 135 in 2017.

During the same period (between 2010 and 2017), the average median income rose by 14%, from EUR 4 359 to EUR 4 957 per household (STATEC, 2019).

Average available household income increased between 2010 and 2017 to 114.9% of the baseline value (STATEC, 2019), with average gross earnings rising to 110.4% in the industrial sector, 115.5% in the construction sector and 113.7% in the services sector (STATEC, 2019).

The rental price index therefore increased at a faster rate than the median income, which meant that average consumption expenditure by household on housing, water and energy rose from 33.8% to 36.5%.

Current measures to reduce (energy) poverty

Luxembourg has put in place a comprehensive policy framework aimed at combating poverty in general (minimum wage, social inclusion income, etc.). The country has also introduced a range of measures aimed at providing targeted assistance to individuals in energy poverty.

The Acts of 1 August 2007 on the organisation of the electricity market and the organisation of the natural gas market state that a domestic customer unable to pay electricity or gas bills is entitled to financial support from the competent social welfare office. In such cases, the supplier is entitled to arrange for a prepayment meter to be installed by the system operator at the home of the customer in question, upon request by the supplier(s).

The Act of 18 December 2009 on the organisation of social welfare states that the competent social welfare office, when applying the procedures specified in the aforesaid Acts on the organisation of the electricity and natural gas markets, must verify whether the domestic customer is able to pay the energy bills and is entitled to social welfare assistance. The social welfare office in question then notifies the suppliers involved and makes arrangements for payment of the customer's arrears.

In this connection, and with a view to gathering information on ways of assisting individuals in similarly vulnerable situations, My Energy GIE (hereinafter 'myenergy'), in cooperation with the Ministry of Sustainable Development and Infrastructure, the Ministry of Family Affairs, Integration and the Greater Region and the social welfare offices, has launched a support scheme for low-income households. The primary goal of this scheme is to identify more accurately the problems faced by households in connection with their energy situation, and to provide more effective support to these households in the form of basic information and advice (behavioural advice, investment proposals for energy savings and energy efficiency, etc.). A secondary goal is not only to provide the households in question with financial support, but also to combat energy poverty and change or reduce energy consumption in the long term. During the first phase, the social welfare offices will work together with the households in question to assess their situation, using a checklist created by myenergy. myenergy can use this checklist as a basis for reviewing the situation with the help of an energy consultant. In cases where a household is found to be using energy-hungry appliances (freezer, washing machine, dishwasher or fridge), it can apply for a government grant from the relevant social welfare office that covers 75% of the purchase price (including VAT) of a new appliance, up to a maximum of EUR 750 per appliance. The social welfare offices can develop a repayment plan with the household in question (for the part of the purchase price not covered by the grant) and carry out the purchase of a new electrical appliance together with the household.

Financial assistance for households for electricity, gas, heating oil, water, food and municipal levies, distributed via 30 social welfare offices	EUR 1 159 415 (28% of all payments by social welfare offices)	
Number of consultations provided by myenergy to households at risk of energy poverty (2016–2019)	30	
Number of subsidised electrical appliances (myenergy scheme 2017–2019)	46	EUR 23 754.52
Repayable advances (2019)	Ministry of Family Affairs: EUR 4 007 Ministry of the Environment, Climate and Sustainable Development: EUR 1 183	

Figure 74: **Statistical data on grants to cover energy and food bills, consultations for households at risk of energy poverty and electrical appliances purchased using grants *(Familienministerium, 2019)***

Impacts of planned CO_2 pricing on annual energy costs for households at risk of energy poverty

It is apparent that energy prices in Luxembourg are very low compared to other European countries, and that energy poverty cannot be attributed to them.

The following paragraphs consider whether this situation is likely to change as a result of introducing a CO_2 pricing scheme for fossil fuels, which is planned (on a graduated basis) for the period from 2021 onwards. The impact of CO_2 pricing at the levels stipulated for the years between 2021 and 2023 will be analysed on the basis of a household at risk of energy poverty. A three-person household (single parent, two children) will be used as an example.

It is assumed that the family lives in a 100-m^2 apartment constructed to a poor energy standard. A distinction is made between an apartment with an oil-fired heating system (final energy consumption$_{\text{heating + hot water}}$: 300 kWh/m$^2_{\text{living space}}$a) and an apartment with a gas-fired heating system (280 kWh/m$^2_{\text{living space}}$a); these energy consumption values are typical for the worst-performing market segment.

						CO_2 tax per tonne				Annual CO_2 tax per household			
		Specific CO_2 emissions	Final energy per Ref. variable	Ref. variable	CO2 emissions in kg	2020	2021	2022	2023	2020	2021	2022	2023
		in kg/kWh	in kWh/ (m^2 or	m^2 or km		in €	in €	in €	in €	in €	in €	in €	in €
Heating in buildings (heating+hot water)	Oil	0.288	300	100	8 640	0	20	25	30	0	173	216	259
	Gas	0.205	280	100	5 740	0	20	25	30	0	115	144	172
Mobility	Petrol	0.299			0	0	20	25	30	0	0	0	0
	Diesel	0.292			0	0	20	25	30	0	0	0	0

Figure 75: Impacts of the CO_2 pricing scheme (planned launch date: 2021) on the annual energy costs of a household at risk of energy poverty, own calculations *(Ploss, 2020)*

The costs of heating oil will rise as a result of CO_2 pricing from a baseline of EUR 20/tonne by around 0.6 ct/kWh or 6 ct/litre, and the costs of natural gas will rise by around 0.45 ct/kWh.

The annual costs of the sample household for final energy$_{\text{heating + hot water}}$ will increase as a result of the CO_2 pricing scheme from EUR 20/tonne in 2021 by EUR 173/year for the worst-performing buildings with oil-fired heating systems and by EUR 115/year for the worst-performing buildings with natural gas-fired heating systems. The additional costs for buildings with an identical building envelope energy performance but with oil-fired heating systems are higher because of the higher specific CO_2 emissions of oil as an energy carrier and the less efficient nature of oil-fired heating systems.

In 2022 and 2023, annual costs will increase to EUR 25/tonne and EUR 30/tonne respectively for the worst-performing buildings with oil-fired heating systems, resulting in an increase of EUR 216/year and EUR 259/year, owing to the slow progression of the CO_2 pricing scheme. The additional costs associated with gas-fired heating systems are EUR 144–172/year.

In a worst-case scenario (worst-performing building, oil-fired heating system, CO_2 pricing for 2023), the additional costs per month will be somewhere in the region of almost EUR 22/month.

Summary of impacts resulting from the introduction of CO_2 pricing

As shown by the calculations for the representative household, the introduction of CO_2 pricing at the level planned for the period between 2021 and 2023 will have only a minor impact, of up to EUR 22 per month. The higher expenses incurred in this connection by the comparatively small proportion of households in Luxembourg at risk of (energy) poverty can be balanced out by means of straightforward compensatory measures. One such compensatory measures is the introduction of free public transport in March 2020, and others are planned.

On 1 March 2020, Luxembourg become the first country in the world to introduce free public transport. The introduction of free public transport means savings of EUR 440/year, or EUR 37/month, which corresponds to the price of an annual ticket for one adult.

However, it should be noted that the costs incurred by households at risk of energy poverty that live in rural areas with poor public transport connections will rise as a result of the continuing need to use a car, since the CO_2 pricing scheme will also apply to fuels.

3.5.2. Non-residential buildings

Since the data concerning the non-residential building stock are significantly less accurate than those concerning the residential building stock (as explained in Chapter 3.2), the LTRS can only provide a rudimentary analysis of factors such as worst-performing segments, split incentives and cases of market failure.

One of the most important measures involves improving the data available as a basis for developing implementing measures.

A) Worst-performing segments of the national building stock

With a view to identifying measures for the worst-performing market segments, the following four sub-segments of the non-residential building stock were analysed, primarily on the basis of analyses of building types in other EU Member States with comparable climates and building standards:

1. older public buildings such as schools;
2. older office buildings;
3. new, high-technology office buildings;
4. retail buildings.

The next stage involves analysing the current status of Luxembourg's non-residential building stock (i.e. by way of contrast to the residential building stock, broken down into use types, areas and building-related energy demand/consumption by types). It is envisaged that a corresponding analysis of the current status will be commissioned in 2020 and completed in 2021. A final decision on the worst-performing market segments will only make sense on the basis of this study.

b) Split incentives

The owner/user dilemma (split incentives) is also an obstacle standing in the way of energy-efficient deep building renovations in non-residential buildings.

High quality energy renovations will only become widespread in this market segment (e.g. leased office premises) if models can be developed that allow both owners and tenants to profit equally from the financial benefits of energy renovations, or that involve third parties (energy performance contractors) funding and performing the energy saving measures.

No	*Description*	*Stage of implementation*	*Timeline for impact*
R3-N	*Requirement to construct photovoltaic installations on all public buildings by 2030 (with the exception of buildings protected as historical monuments and heavily shaded buildings)*	*At the planning stage*	*2030*
R4-N	*Preparatory measures for the construction of photovoltaic installations on the roofs of other non-residential buildings (with the exception of buildings protected as historical monuments and heavily shaded buildings) from 2024*	*Proposal*	*2030*
F1-N	*Alignment of the funding system for non-residential buildings with the new regulations (new minimum requirements from 2021)*	*At the planning stage*	*2030*

Figure 76: Measures in the non-residential building sector to reduce the split-incentive dilemma

c) Market failures

With a view to identifying measures aimed at eliminating cases of market failure, the following five obstacles were analysed for the non-residential building stock:

1. lack of awareness about energy consumption and potential savings as a result of low energy prices;
2. capacity constraints in the construction industry (and lack of interest on the part of the construction industry in renovation projects compared to new builds);
3. lack of awareness about promotional and funding products;
4. limited acceptance of efficient and smart technologies;
5. assessment periods that are too short, and methods for calculating profitability that are not fit for purpose.

Re 1. Lack of awareness about energy consumption and potential savings

The fact that energy costs are so low in Luxembourg means that building-related energy costs play a secondary role in most industries. In turn this means that many businesses are unaware of how much energy they consume and what it costs. Even if they are aware of the relevant figures, they are rarely able to assess them accurately, since sector-specific benchmark values for real consumption and electricity production through building-integrated photovoltaics are only available in rudimentary form, and have not been publicised effectively in the media.

Over the coming years, it will therefore be important to prepare and format consumption data for various categories of non-residential buildings, not only as a basis for developing funding schemes and controlling decarbonisation processes, but also as a basis for raising awareness among owners and tenants of non-residential buildings.

One of the first measures planned is a detailed survey of the area covered by non-residential buildings in all categories and their building-related energy consumption. As a next stage, energy-related databases are to be compiled and the energy-related data collected in a geographic information system.

Re 2. Capacity constraints in the construction industry

As explained in Chapter 3.4.1 using the example of building envelopes in the residential building stock, increasing the rate and quality of renovation will require a significant expansion of capacity in the construction sector. There is already a shortfall of several thousand workers in the construction sector, against a backdrop of rising demand for new builds/speculative new builds. This lack of capacity will therefore also represent a major obstacle to the necessary improvements in the rate and quality of renovations in the non-residential buildings sector, not least because new builds (which are easier to plan and implement) are likely to be more a more attractive prospect for the majority of businesses than the renovation market.

No	*Description*	*Stage of implementation*	*Timeline for impact*
FO2-N	*Model project involving the prefabrication of renovation components as a measure to counter labour shortages; cooperation with other countries*	*At the planning stage*	*2030*

Figure 77: Measures aimed at making skilled trades in the construction sector more attractive and increasing levels of efficiency in respect of production and assembly

Re 3. Lack of awareness about promotional and funding products

Promotional and funding products targeted at particular groups have been available in Luxembourg for many years. The TNS Ilres surveys carried out in connection with the further development of the renovation strategy reveal that the lack of awareness of funding programmes in the housing sector is regarded as one of the main obstacles. It can be assumed that the same applies to the non-residential buildings sector, although this hypothesis has not yet been confirmed (by means of surveys).

An overview of the various funding mechanisms that are currently in place or envisaged for energy efficiency improvement measures in Luxembourg is provided below, broken down by sectors and consumers.

PRIVATE INDIVIDUALS

- PRIMe House (State funding scheme for renovation measures in residential buildings) (funding scheme jointly operated by the Ministry of Housing, the Ministry of the Environment and the Ministry of Energy);
- funding programmes operated by most MUNICIPALITIES (on a municipality-specific basis).

CRAFT TRADES/SMEs

- Climate Package for SMEs (still at the development stage).

INDUSTRY and commerce, trade and services

- 'Accord volontaire FEDIL' (voluntary agreement with 50 major industrial enterprises);
- State funding scheme 'Public assistance to promote eco-technologies and sustainable development in enterprises' (Ministry of the Economy);
- funding for non-residential buildings (industry) via the Ministry of the Economy (Act of 15 December 2017 on ENVIRONMENTAL PROTECTION AID SCHEMES (Ministry of the Economy), Article 7 – INVESTMENT AID FOR PROJECTS PROMOTING ENERGY EFFICIENCY MEASURES IN BUILDINGS).

MUNICIPALITIES

- funding under the Environmental Protection Fund [fonds pour la protection de l'Environnement (fpe)];
- Climate Package for municipalities.

ALL CONSUMERS

- funding schemes operated under the aegis of the mandatory mechanism for electricity and gas suppliers (EEOs, 'Amended Grand-Ducal Regulation of 7 August 2015 on the mandatory mechanism for energy efficiency'; based on Article 7 of EU Directive 2012/27/EU);
- nova naturstroum fund (bonus scheme operated by an electricity supplier).

Luxembourg has launched an ambitious scheme aimed at publicising the importance of energy efficiency and the use of renewable energies throughout the country. To promote investments in this connection, it is expected that decision-makers in Luxembourg will be provided with a 'de-risking' instrument in the form of an investment platform, with a view to mobilising investments in energy efficiency projects (and in particular renovation measures), primarily in industry, in large functional buildings and in public buildings with a high energy potential.

An analysis of existing systems reveals that there are currently several financial support mechanisms aimed at the relevant stakeholders. In practice, the overall effectiveness of these mechanisms is hampered by a lack of coordination at national level between support, communication and control systems. If other tools were to be developed (e.g. in relation to energy performance contracting (EPC)), it would be necessary to ensure that these systems complemented existing systems if possible rather than competing with them.

Based on the targets set out in the integrated National Energy and Climate Plan (NECP), Luxembourg's Government intends to promote more energy-efficient investments by industry, SMEs and the construction sector (energy renovation measures). The Government is aware that in spite of the various combined 'carrot and stick' mechanisms that have been put in place, major obstacles still stand in the way of investments into energy efficiency, particular with regard to deep energy renovations of existing buildings. These obstacles may be associated with inadequate ROI, limited budgets and failure to prioritise the implementation of energy efficiency investments, as well as with a skills shortage within companies and inadequate capacities to implement these investments. Investments into energy efficiency are often categorised as falling outside a company's core business, which complicates the investment decision.

With a view to overcoming barriers on the investment market, a financial instrument (a 'de-risking' investment platform) is to be designed and implemented to mobilise energy efficiency investments by industry, SMEs and the buildings (renovation) sector, with the primary aim of making progress towards climate emissions, renewable energy and energy efficiency targets, and a secondary aim of reducing energy dependency and increasing energy productivity.

The aim of the 'de-risking' instrument is to eliminate the obstacles associated with energy improvements and renovations and the associated project funding.

In addition to problems relating to capital expenditure, the implementation of energy efficiency projects takes time and requires specific skills that companies (owners) may not necessarily have. Alternatively, the companies (owners) may prefer to concentrate on their core business. There is thus a need for targeted expert, technical and financial support with a view to streamlining and encouraging the implementation of projects in this context.

EPC (Energy Performance Contracting) models are very rare in Luxembourg at present; models of this kind can however be an optimal solution for larger renovation measures.

In autumn 2019, the Ministry of Energy (in cooperation with the European Investment Bank (EIB) and myenergy) launched a project involving the development of tools and methods for a future 'de-risking' platform. This project will be continued in 2020 in close cooperation with the Ministry of the Economy and the Ministry of Finance, with the involvement of banks and the market players concerned.

No	*Description*	*Stage of implementation*	*Timeline*
F1-N	*Introduction of a de-risking tool in combination with energy performance contracting for energy efficiency measures*	*At the planning stage*	*2030*

Figure 78: Measures to support investments in energy efficiency measures for non-residential buildings

The introduction of new minimum requirements from 2021 and the planned changes to the funding system should be used as an opportunity to launch an information campaign on promotional and funding instruments.

No	*Description*	*Stage of implementation*	*Timeline*
F2-N	*Alignment of the funding system for non-residential buildings with the new regulations (new minimum requirements from 2021)*	*At the planning stage*	*2030*

Figure 79: Information measures concerning promotional and funding instruments for non-residential buildings

Re 4. Limited acceptance of efficient and smart technologies

The acceptance of efficient and smart technologies tends to depend on economic viability to a greater extent in non-residential buildings than in residential buildings; if efficient and smart technologies are more economic than conventional solutions, they will gain popularity among developers.

Account must however also be taken of the level of acceptance among architects and engineers. New technologies are not always implemented directly and promoted to developers, since they may initially entail larger risks during implementation.

The range of training courses and project-specific consultancy available in the non-residential buildings sector should be expanded with a view to increasing acceptance.

No	*Description*	*Stage of implementation*	*Timeline for implementation*
W1-N	*Further training on methods for increasing the energy efficiency of renovation measures in non-residential buildings*	*Planned*	*2030*

W2-N	*Further training on ways to reduce demand for cooling energy as a means of adapting to future climate change*	*Planned*	*2030*

Figure 80: Measures aimed at increasing the acceptance of efficient and smart technologies

Re 5. Assessment periods that are too short, and methods for calculating profitability that are not fit for purpose

When investment decisions are taken in relation to non-residential buildings, the pay-back periods that are anticipated or prescribed are typically very short. The pay-back method results in optimisation measures that are systematically incorrect, since measures with very low pay-back periods are assigned a higher priority. Measures of this kind do not remotely utilise all of the existing saving potential, and are not economical over realistic calculation periods.

As part of the training provided on ways to optimise the profitability of energy renovations, the background context of meaningful calculation methods and the available calculation tools should therefore be explained.

No	*Description*	*Stage of implementation*	*Timeline for implementation*
W1-N	*Further training on methods for increasing the energy efficiency of renovation measures in non-residential buildings*	*Planned*	*2030*

Figure 81: Measures aimed at introducing appropriate methods for calculating profitability and life-cycle costs

In future, investment decisions relating to energy efficiency measures are to be based on a net present value method as described in the EU energy performance of buildings directive for the cost-optimal analyses by EU Member States. Calculations based on the net present value method can be prescribed in all cases where funding is granted by the State, with a requirement for meaningful calculation periods of 20–25 years and based on other standardised constraints. They should also be used to review any exemptions from renovation obligations for business-related reasons.

d) Energy poverty

The non-residential buildings sector differs from the residential buildings sector in that the topic of energy poverty is irrelevant.

3.6. Policies and actions to target all public buildings (Article 2a(1)(e));

In accordance with Article 2a(1)(e) of the EPBD, each LTRS must encompass 'policies and actions to target all public buildings'. The scope of LTRSs under Article 4 of the EED already included certain public buildings. However, Article 2a of the EPBD now requires LTRSs to include specific policies and actions that target all public buildings. This should include ongoing initiatives by Member States to fulfil their obligations under the EPBD and the EED. (17)

Both the EED and the EPBD require public authorities to lead by example by becoming early adopters of energy efficiency improvements; see, in particular, Articles 5 and 6 of the EED, which apply to 'public bodies' buildings'. However, Article 2a(1)(e) of the EPBD is broader in scope than Articles 5 and 6 of the EED, as it concerns all public buildings and not just 'public bodies' buildings' (18) that are owned and occupied by central government. Policies and actions under Article 2a(1)(e) should include, for example, buildings that are occupied (e.g. leased or rented) by local or regional authorities and buildings that are owned by central government and regional or local authorities, but not necessarily occupied by them. Unlike Article 5(2) of the EED (19), Article 2a of the EPBD does not exempt any categories of public building. In principle, it thus applies to buildings that may be exempt, in a certain Member State, from the renovation obligation pursuant to Article 5(2) of the EED. Many of the buildings listed in Article 5(2) of the EED can make a significant contribution to the achievement of national objectives. Financial mechanisms and incentives should promote public authorities' investments in an energy-efficient building stock, for example by means of public-private partnerships or optional energy performance contracts (20) through off-balance-sheet financing in line with Eurostat accounting rules and guidance (21).

In the 'Fourth National Energy Efficiency Action Plan for Luxembourg (2017)', which was drafted pursuant to Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on energy efficiency, Luxembourg identified energy efficiency measures in public institutions, some of which will be implemented and further developed by 2030. This means that energy efficiency improvements in public buildings may play a key role in the National Energy and Climate Plan. Luxembourg's Government is aware of its responsibilities in this regard, and intends to step up its efforts to play a pioneering and driving role in the future. Existing schemes and their outcomes will continue to be built upon, but new initiatives will also be launched or developed.

The Government is developing a strategy for sustainable and energy-efficient public buildings (both new builds and existing buildings) under the slogan 'Ultra-efficient public buildings'. The focus is not only on energy efficiency, but also on improving sustainability, the use of renewable energies, the introduction of circular economy principles and health-related aspects in public buildings, with the aim of turning buildings owned by the central government into the most efficient in all of the EU Member States. The introduction of an obligation to construct photovoltaic installations on buildings owned by the central government is relevant in this regard, and is reflected in a topping up of the existing photovoltaics scheme operated by the Public Buildings Administration. The intended target is to construct photovoltaic installations on all suitable public buildings by 2025.

In accordance with Article 5(7) EED, public bodies that are not owned by the central government should also be encouraged to play an exemplary role in terms of the energy efficiency of buildings. Particular emphasis should be placed on schools and their infrastructures, since young people are keen to experience and learn about climate protection at first hand. As part of the exchange of views with school pupils organised in spring 2019 ('ClimateXchange'), many different ideas were gathered for reducing the environmental footprint of schools. As well as the importance of promoting the use of renewable energies, making photovoltaics installations more popular and increasing the use of renewable heat, particularly in the form of medium-depth geothermal energy, sustainable mobility and transport concepts, should also be taken into account at the planning stage or during more extensive reconstruction measures, as well as factors that reduce water consumption.

In addition to school-based infrastructures, a decision has already been taken to transform the Herrenberg-based infrastructure into an 'energy autonomous zero CO_2' district. The houses will be renovated, solar energy systems will be installed on many roofs, and the heating network will also be switched over to renewable energies.

The capital city's airport is also to be transformed into Findel Green Airport as part of these efforts. In particular, this involves the implementation of energy-saving measures and the use of renewable energy, primarily to convert the existing terminal into an energy-plus building.

Another aspect of the state's pioneering role is the replacement of all light bulbs in public buildings and street lighting with LEDs by 2025 in order to improve efficiency and contribute to the fight against light pollution. In addition, the introduction of a state Top Runner programme should encourage the procurement of more efficient equipment by the state and the municipalities.

In 2019, the Public Buildings Administration was granted an additional budgetary envelope of EUR 87 million under the Maintenance and Renovation Fund. This was added to the balance of EUR 9.94 million for 2018, resulting in the earmarking of a total pot of EUR 96.94 million for guaranteeing the maintenance and renovation of State-owned buildings (Mobilitätsministerium, 2020). EUR 76.88 million was disbursed in 2019, with EUR 44.24 million spent on maintenance and EUR 31.76 million on renovation. In 2019, an addendum was added to the 'Strategy for energy renovation of buildings owned by the central government', which was presented for the first time in September 2014 to the Commission on Sustainable Development, stating that the strategy should be updated every 5 years. Analysis of the building stock reveals that 49% of buildings display substantial potential in terms of energy renovations. All other renovation projects (carried out because of the advanced age of the building or because the users have different space-related requirements) form part of the energy retrofitting strategy, and must be accompanied by energy retrofitting measures. Priority is given to educational buildings that exhibit the greatest potential for energy renovations. In summary, energy redevelopments have already been carried out (or are being carried out, or will be carried out) on a large portion of the buildings identified as holding potential for each functional category. However, the volume of buildings owned by the central government that need to be renovated is still considerable. According to Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on energy efficiency, Member States must renovate at least 3% of their built heritage per annum; this means that a significant increase in renovation works organised by the administrations of public buildings can be expected. The 3% rate is calculated on the total floor area of all buildings with a floor area over 250 m2.

The total useful floor area of the buildings in the stock of buildings to be renovated is around 66 205 m^2 at present. The area to be renovated by 2020 in accordance with the aforementioned Directive is likely to be around 15 670 m^2. The total area renovated between 2014 and 2019 was over 23 000 m^2, meaning that the requirements of the Directive were exceeded by around 7 300 m^2 , or 31%. In 2019, monitoring software that can visualise, compile and record consumption data (electricity, heating, water) was procured for the purpose of monitoring actual system consumption on an automated basis. Over the next few years, around 200 buildings exceeding a certain size, spread over more than 50 different locations, will be fitted with heat, electricity and water meters. By analysing the consumption data recorded, potential weak points may be identified in the operation or functioning of the technical systems involved. At the same time, by comparing consumption in similar buildings it will also be possible to carry out benchmarking exercises and identify priority buildings to be optimised or completely renovated. Building users will have access to the data that have been collected so that they can improve the operation of the technical systems. Continuous monitoring of consumption will subsequently make it possible to identify any excessive consumption in an optimised building and to guarantee long-term adherence to the relevant energy performance level.

Pursuant to Article 5 of the Energy Efficiency Directive, buildings owned and occupied by central government must be renovated at a rate of at least 3% per annum. The 3% rate shall be calculated on the total floor area of buildings with a total useful floor area over 250 m^2.

The Climate Package and the participating municipalities will also continue to play a role in terms of improving energy efficiency. Municipalities are already encouraged to assess their own buildings and infrastructures and to optimise them accordingly by means of the targets set for the reduction of greenhouse gases (see 2.1.3. Renovation concept for the corresponding measure). This measure will remain in place in its current form, but will become more quantifiable in future.

The Climate Package and the participating municipalities will also continue to play a role in terms of improving energy efficiency. Municipalities are already encouraged to assess their own buildings and infrastructures, to identify any weak points and to optimise them on the basis of a scheduled plan by means of the targets set for the reduction of greenhouse gases (see 2.1.4. Redevelopment concept for the corresponding measure). This measure will also remain in place in its current form in the updated version of the climate package (2.1.3 Renovation concept). The stock of existing buildings will be assessed using energy accounting software, made available to all municipalities within the framework of the climate package. The aim of the updated version is the ongoing expansion of analysis capabilities as a source of guidance for decision-makers involved in planning and prioritising energy renovations in the existing stock of buildings.

Alongside the aforementioned tools for promoting the renovation of buildings owned by municipalities, the climate package also provides for a planning instrument for 'promoting the construction or renovation of energy-efficient and sustainable private dwellings'.

It is also possible to access free consultations within the framework of the climate package, as a further source of guidance for municipalities on this specific topic. The municipalities can arrange appointments with a 'specialist consultant' in the field.

The measures for the public buildings sector are described in the table providing an overview of measures for all non-residential buildings; see Chapter 3.4.2. In many cases (e.g. decarbonising the heat supply), the same measures are carried out in multiple market segments, but implemented at an earlier date in the public buildings sector; a good example would be the ban on the installation of oil boilers. Differentiated renovation obligations are a further example of a measure that has been implemented more rapidly in the public buildings sector than in other market segments. The aim of this approach is to showcase the pioneering role played by the State and the municipalities.

3.7. Overview of national initiatives to promote smart technologies and well-connected buildings, as well as skills and education in the construction and energy efficiency sectors (Article 2a(1)(f));

One of the objectives of the EPBD's revision was to bring it up to date with technological developments such as smart building technologies and to facilitate the uptake of electric vehicles and other technologies, both through specific *installation requirements and by ensuring that building professionals can deliver the requisite skills and know-how. Article 2a(1)(f) of the EPBD provides that LTRSs 'shall encompass an overview of national initiatives to promote smart technologies and well-connected buildings and communities, as well as skills and education in the construction and energy efficiency sectors'. This is a new element which did not exist under Article 4 of the EED. Member States' LTRSs will now have to give an overview of national initiatives that promote: (a) smart technologies and well-connected buildings and communities; and (b) skills and education in the construction and energy efficiency sectors. The overview should include at least a short description of each policy and action, its scope and duration, the allocated budget and the expected impact.*

Smartness in buildings is an essential part of a decarbonised, renewable-intensive and more dynamic energy system geared towards achieving the 2030 EU targets on energy efficiency and renewable energy, and a decarbonised EU building stock by 2050. In accordance with Article 2a(f) of the EPBD, LTRSs must describe national initiatives on smart technologies and well-connected buildings and communities that may, for example, aim to: (a) achieve high energy efficiency by optimal operation of the building and facilitate the maintenance of technical building systems; (b) strengthen the role of demand-side flexibility in increasing the share of renewables in the energy system and making sure that the benefits are cascaded down to consumers; (c) ensure that the building users' needs are covered and that they can effectively interact with the building; and (d) contribute to the establishment of well-connected buildings (22), and smart communities also supporting citizen-centric and open standard-based solutions for smart cities. Member States may consider adopting measures that encourage the deployment of recharging points and ducting infrastructure for electric vehicles in the context of building renovation projects, even if the renovation is not considered to be a 'major renovation' within the meaning of Article 2(10) of the EPBD. The training of energy experts is essential in ensuring the transfer of knowledge on issues related to EPBD implementation. According to Article 17 of the EPBD, Member States must already ensure the independent energy performance certification of buildings and the inspection of heating and air-conditioning systems by qualified and/or accredited experts. LTRSs should present an overview of national initiatives that promote the skills needed by building professionals to apply new techniques and technologies in the field of NZEBs and energy renovation.

3.7.1. National initiatives on smart technologies and well-connected buildings and communities

The roll-out of smart electricity meters began on 1 July 2016 in order to promote renewable energies, paving the way for new economic developments such as electromobility and decentralised energy storage, meeting consumer demands and accommodating consumers' new habits. According to a Directive transposed into Luxembourg law[1], all electricity meters (95%) and gas meters (90%) across the country must be replaced, regardless of the system operator.

The installation of smart electricity meters throughout the country is likely to be completed by late 2020, marking the first step on the path to greater interconnectedness of the electricity infrastructure in the residential buildings sector. With a view to increasing the resilience of the electricity system, the technical

[1] Amended Law of 1 August 2007 on the organisation of the electricity market.

connection requirements for system operators have already been changed so that a connection to a smart meter is mandatory for certain consumers. This allows targeted load shedding if an incident occurs.

The regulatory framework for new buildings was also adapted in order to take account of the expansion of smart electricity meters, particularly when integrating photovoltaic installations and private charging stations. For example, since March 2019 it has been mandatory to lay empty conduits for electricity and data cables in residential and non-residential buildings to facilitate the later installation of charging stations or photovoltaic installations.

The current amendments to the Law on the electricity market will also assign a new and special role to the incorporation of own-consumption concepts (in conjunction with energy storage systems) and energy communities. As provided for by Directive (EU) 2018/2001, both concepts have already been incorporated into a legislative amendment so that accompanying measures and funding measures can be implemented promptly. Work is already in progress in this area. At the same time, however, Luxembourg still needs to determine how own consumption should be appraised from the perspective of State aid legislation (in general terms and particularly in the case of existing systems). Coordination and clarification are still required at EU level in this area.

As part of the overall photovoltaics concept (which involves attractive tariffs for small-scale installations, separate categories for cooperatives to encourage citizen participation, calls for tenders for medium-scale and large-scale installations from 200/500 kW), particular emphasis should be placed on own consumption in the category of 30–200 kW in order to create incentives for SMEs and office buildings.

3.7.2. National initiatives to promote skills and education in the construction and energy efficiency sectors

A further aim pursued by Luxembourg is to ensure that the volume of investment in the area of energy research and development increases on an ongoing basis, with a focus on the following key topics:

1. sustainable buildings and construction materials – energy efficiency and circular economy, decentralised renewable energies, ‘indoor pollution’;
2. eco-district made in Luxembourg – plus energy systems, car-free mobility, socially inclusive urban planning;
3. integration of renewable energies and electromobility into digital electricity systems, the energy Internet and sector coupling;

4. local and cross-border transformation processes in the areas of mobility and spatial planning;
5. societal transition processes and social innovation based on a shift towards ‘climate-positive lifestyles’.

In connection with the ongoing development of the training framework, it was proposed that an interactive tool should be created to manage the training provision in the sustainable construction sector. The tool will be implemented by OAI (‘Ordre des Architectes et Ingénieurs-conseils [Order of Architects and Consulting Engineers]’) in collaboration with CRTI-B (‘Centre de Ressources des Technologies et de l’Innovation pour le Bâtiment [Resource Centre for Technologies and Innovation in Construction]’), CNCD (‘Conseil national pour la Construction durable [National Council for Sustainable Construction]’), the House of Training and myenergy. The first aim of this tool is to allow professionals in the sector to manage their internal training plans more efficiently and estimate their training requirements more effectively. Its second aim is to help training course providers develop their offerings so that they may respond coherently and holistically to the sector’s needs.

‘Luxembourg Green Building Institute’ project: to promote research and development in Luxembourg in connection with the area(s) and the specific topics required to implement the targets under the NECP. Research and development for Luxembourg’s market; this project will be launched in 2020, based on close cooperation between the Ministry of Energy and the Ministry of Education.

In addition to the aforesaid investments in the field of R&D, investments are also required in a number of other fields in Luxembourg. These include solar and wind installations, charging stations for electric vehicles, energy efficiency measures for industrial enterprises and SMEs, the expansion of heating networks, the circular economy and (in particular) energy renovations of existing buildings. The Government is aware of this, and has put in place the relevant initiatives in respect of both basic and further training.

Luxembourg has however also set itself the goal of becoming a ‘start-up nation’ in the area of climate protection. Luxembourg’s pioneering role in key technologies (zero-energy buildings, electromobility, photovoltaics), its expansion of energy research and innovation, and in particular its wealth of skills relating to ‘green finance’ combine to make an environment conducive to providing support to companies already operating in Luxembourg in the field of climate protection, and to attracting new companies from Europe and all over the world.

3.8. Evidence-based estimate of expected energy savings and wider benefits, such as those related to health, safety and air quality (Article 2a(1)(g))

Article 4(e) of the EED already required that LTRSs give an evidence-based estimate of expected energy savings and wider benefits. Pursuant to Article 2a(1)(g) of the EPBD, each LTRS must encompass 'an evidence-based estimate of expected energy savings and wider benefits, such as those related to health, safety and air quality'. The amendment provides a non-exhaustive list of the type of wider benefits that LTRSs should evaluate. Certain measures to address energy performance can also contribute to a healthy indoor environment. Measures should for instance aim to: (a) prevent the illegal removal of harmful substances such as asbestos (23); (b) facilitate compliance with legislation on working conditions, health and safety, and emissions (24); and (c) promote higher levels of comfort and well-being for occupants, e.g. by ensuring complete and homogeneous insulation (25), coupled with the appropriate installation and adjustment of technical building systems (in particular, heating and air-conditioning, ventilation and building automation and control). Wider benefits may also include lower illness and health costs, greater labour productivity from better working and living conditions, more jobs in the building sector, and reduced emissions and whole life carbon (26).

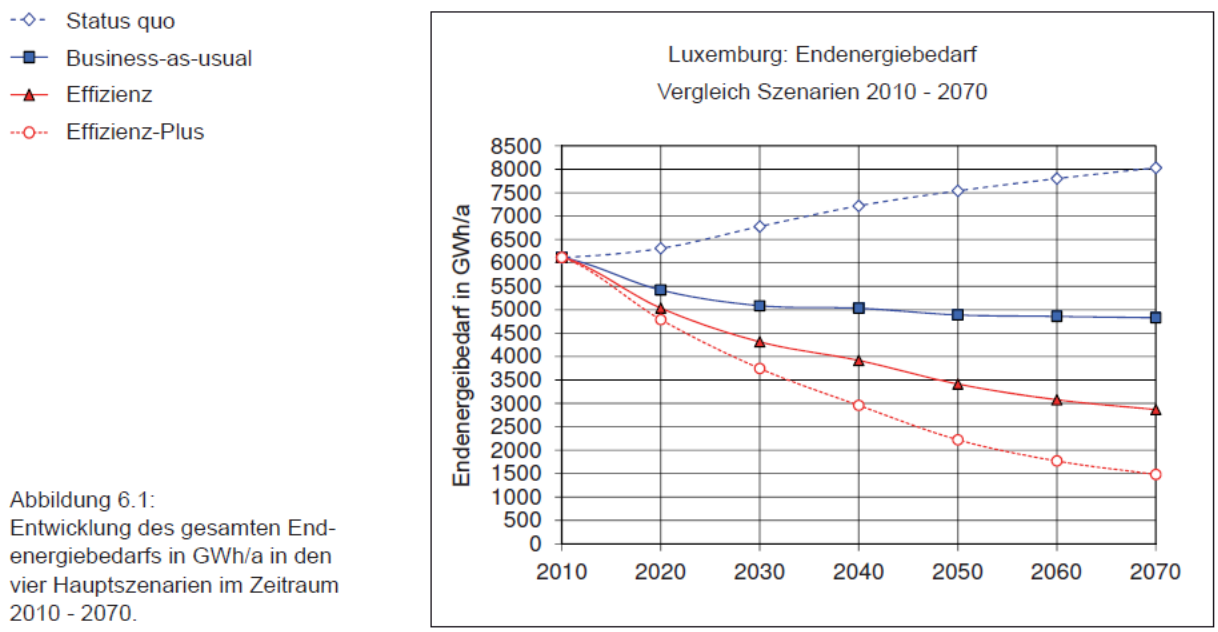
The evaluation of potential wider benefits associated with energy efficiency measures may enable a more holistic and integrated approach at national level, highlighting synergies that can be achieved with other policy areas and ideally involving other government departments, e.g. those responsible for health, environment, finance and infrastructure. In connection with these elements, it is generally recognised that efforts to reduce operational energy usage typically have embodied consequences, in terms of the carbon emissions linked to manufacturing of construction products and to construction. Therefore, reducing day-to-day energy use ideally should not be looked at in isolation, as there will inevitably be a carbon cost/benefit trade-off. Although something not explored in the EPBD, a whole life carbon approach would help in identifying the overall best combined opportunities for reducing lifetime carbon emissions, and help to avoid any unintended consequences. It would also help to find the most cost-effective solution. Ultimately, a low carbon building is one that optimises the use of resources and thereby limits carbon emissions during construction and use, over its lifetime. Renovations can be conducted in such a way that when the building reaches the end of its life or undergoes another major renovation, different construction products or materials can be separated from each other. This allows for reuse or recycling, which can substantially reduce the volume of demolition waste going to landfill. The possibilities for circularity in the future depend directly on how renovation is conducted, which materials are chosen and how they are assembled. The recycling of materials can have a positive impact on energy consumption, as manufacturing primary construction products normally requires more energy than using secondary ones. Benefits may also include measures to adapt buildings to climate change (27), in particular measures such as shading devices that protect buildings against overheating during heat waves. These have a direct impact on a building's energy consumption by reducing the need for active cooling (28). In addition, for new buildings and buildings undergoing major renovations, it is recommended that efforts are undertaken to avoid the creation of accessibility barriers for persons with disabilities and, where possible, existing accessibility barriers should be removed (29). Finally, in their evidence-based estimate of benefits relating to health, safety and air quality, Member States may include the effects of action that they take under Article 7(5) of the EPBD (30). In addition, they may include the effects of action under Article 2a(7) of the EPBD, which refers to fire safety and risks related to intense seismic activity.

3.8.1. Residential buildings

Estimate of expected energy savings

The expected energy savings for the residential building stock were estimated in two studies, both based on different approaches:

- Study 1: scenario study by the Vorarlberg Energy Institute (bottom-up),
- Study 2: estimate of savings by the Fraunhofer Institute for Resource Efficiency and Energy Strategies (IREES) for the purpose of the NECP (top-down).



Luxemburg: Endenergiebedarf	Luxembourg: Final energy demand
Vergleich Szenarien 2010-2070	Comparison of scenarios 2010-2070
Endenergiebedarf in GWh/a	Final energy demand in GWh/a
Status quo	Status quo
Business-as-usual	Business as usual
Effizienz	Efficiency
Effizienz-Plus	Efficiency plus
Abbildung 6.1: Entwicklung des gesamten Endenergiebedarfs in GWh/a in den vier Hauptszenarien im Zeitraum 2010-2070	Figure 6.1: Changes in total final energy demand in GWh/a over the period 2010-2070, based on the four main scenarios.

Figure 82: Changes in total final energy demand by the residential building stock in GWh/a, based on the four main scenarios *(Ploss, 2017)*

The bottom-up model developed by the Vorarlberg Energy Institute takes as its basis the condition of the residential building stock in 2010. Building on this basis, it then describes four different efficiency pathways with identical constraints such as population growth, increase in living space, renovation rate and demolition rate (renovation rate (full redevelopment equivalents): around 1.6% per annum in relation to total residential building stock in 2010; demolition rate for buildings protected as historical monuments: 0.1% per annum, for other buildings: 0.85% per annum). Differing political goals for new builds and redevelopments from 2010 onwards are then assigned to the different pathways, as follows:

Status Quo scenario: Energy levels for new builds and redevelopments 'frozen' at 2010 level – top limit value scenario

Business As Usual (BAU) scenario: slow increases in requirements for new builds and redevelopment, slightly increased rate of decarbonisation

Efficiency scenario: Increase in requirements to cost-optimal level (new builds: efficiency class A/A (as implemented in 2017, redevelopment at similar level (not yet implemented))

Efficiency Plus scenario: similar efficiency levels to the Efficiency scenario to start with, but multiple further improvements to the efficiency level as adjustments to technical upgrades and a shift in the cost optimum towards higher performances

Since the model was calibrated for the baseline year 2010, and the implementation of the measures and performances underpinning the scenarios was assumed to take place in the baseline year 2010, significant changes were projected for the decade between 2010 and 2020.

For 2030, the values ranged between 3 750 GWh/a for the Efficiency Plus scenario, 4 300 GWh/a for the Efficiency scenario, 5 100 GWh/a for the BAU scenario and 6 800 GWh/a for the Status Quo scenario.

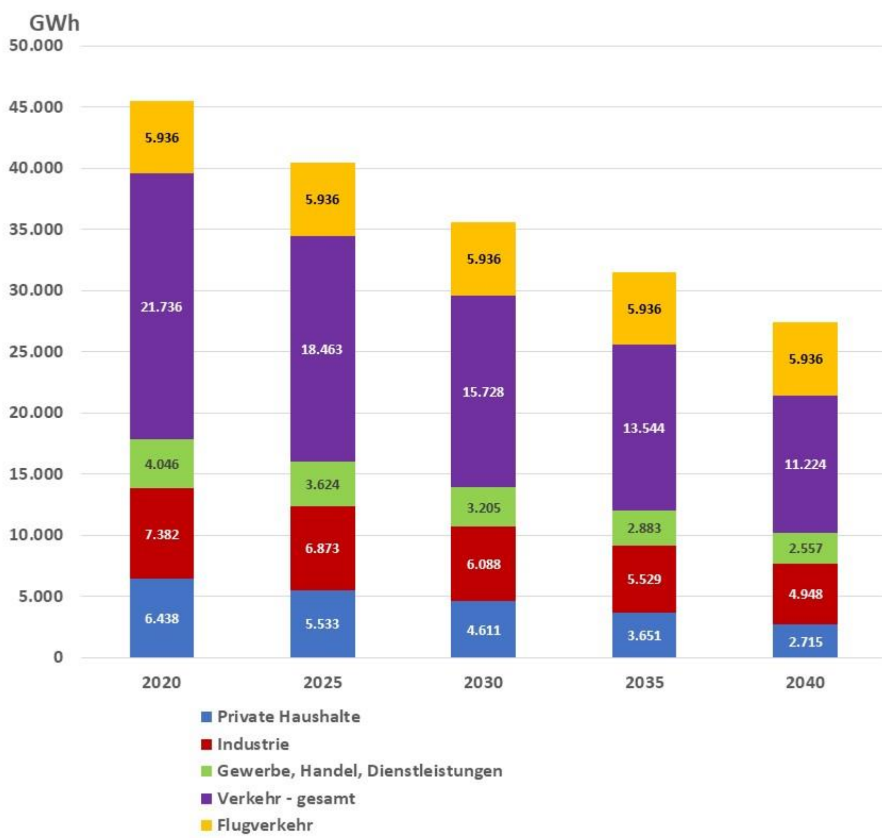
The energy performances under the Efficiency scenario taken as a basis for the model from 2010 onwards were achieved through a tightening up of the level of requirements for new builds in 2017.

As far as redevelopment is concerned, the energy performances achieved to date correspond to those of the BAU scenario. Implementation of a significantly more ambitious level for redevelopments is planned for 2021. Previous redevelopment rates correspond to around half of the rate assumed in the scenarios.

For 2040, the values ranged between 2 990 GWh/a for the Efficiency Plus scenario, 3 900 GWh/a for the Efficiency scenario, 5 000 GWh/a for the BAU scenario and 7 200 GWh/a for the Status Quo scenario. The final energy savings compared to the most recent consumption figures available (6 154 for 2018) are therefore 37% for the Efficiency scenario and around 51% for the Efficiency Plus scenario.

This results in the following values for 2050: 2 200 GWh/a (Efficiency scenario) and 3 400 GWh/a (Efficiency Plus scenario). The final energy savings compared to the most recent consumption figures available (6 154 for 2018) are therefore 55% for the Efficiency scenario and around 64% for the Efficiency Plus scenario.

The following figure illustrates the outcomes of the top-down analysis in the study by Fraunhofer IREES, which was used as a basis for the NECP (NECP, 2020). The study posits a significantly higher renovation rate than the study by the Vorarlberg Energy Institute, and the average renovation depth (72%) is also noticeably more demanding.



GWh	GWh
Private Haushalte	Private households
Industrie	Industry
Gewerbe, Handel, Dienstleistungen	Commerce, trade, services
Verkehr – gesamt	Transport – total
Flugverkehr	Aviation

Figure 83: Targets for final energy demand broken down by sector according to NECP for the period until 2040 *(NECP, 2020)*

A target of 4 611 GWh/a for total final energy demand by private households by 2030 is referred to in the target scenario under the NECP. This would correspond to a reduction of around 28% compared to the initial value of 6 438 GWh/a included in the 2020 NECP.

It would mean savings of 25% compared to real consumption in 2018, which stood at 6 154 GWh/a.

The NECP stipulates a target of 2 557 GWh/a for 2040, which corresponds to a reduction of around 60% compared to the baseline value of 6 438 GWh/a specified in the NECP for 2020. This represents savings of 58% compared to real consumption in 2018.

The target under the NECP is noticeably lower than the target under the Efficiency Plus scenario outlined in the Vorarlberg Energy Institute's scenario study.

The main reasons why the savings under the NECP target scenario for 2040 are higher than those for the Vorarlberg Energy Institute's study relate to the following assumptions:

- renovation rate (NECP: full renovations on 2.7% of the building stock per year, on top of the renovations under the baseline scenario (in relation to buildings constructed before 1991), Vorarlberg Energy Institute: full redevelopments on around 1.6% of the building stock, in relation to buildings constructed up to 2010);
- average reduction in heating demand after full renovation (NECP: 72%, Vorarlberg Energy Institute: lower, inter alia because account is taken of lower values for buildings protected as historical monuments).

Estimate of expected GHG reductions

Both of the aforementioned studies investigate changes in GHG emissions as well as changes in final energy demand.

Under the most ambitious scenario (Efficiency Plus) in the Vorarlberg Energy Institute's study, changes in the GHG emissions of the residential building stock are stated as -48% by 2030 and -84% by 2050 compared to the baseline year of 2010.

In the NECP, the changes are stated as -62% by 2030 and -96% by 2040 compared to the current status of the building stock.

Summary

In spite of the different methodological approaches and varying (in some cases widely varying) assumptions, both studies reveal that final energy demand in the residential buildings sector can be greatly reduced compared to real consumption in 2018, notwithstanding the major increases in living space:

- until 2040: 37% or 51% (Vorarlberg Energy Institute, Efficiency/Efficiency Plus scenarios; 58% (NECP, by 2040));
- until 2050: 55% or 64% (Vorarlberg Energy Institute, Efficiency and Efficiency Plus scenarios).

The same applies to GHG emissions; in spite of widely varying assumptions (inter alia in respect of the accounting rules for greenhouse gases), both studies show that enormous reductions are possible.

The studies make it clear that it is necessary exhaust current and future cost-optimised saving potentials in order to achieve these savings. Particularly in the field of building redevelopment, this requires very determined measures to reduce demand and accelerate decarbonisation.

The scenario studies for the future changes in final energy demand and GHG emissions by the residential building stock are to be updated regularly as a basis for monitoring (around every 4 or 5 years). It would be expedient to publish the first update in 2022 on the basis of the data from the 2021 survey.

With a view to estimating future reduction potentials and as a basis for monitoring success, existing databases such as the energy passport database, the chimney sweep database, etc. are to be compiled and evaluated regularly.

It is expected that the system for checking compliance with the energy passport obligation will also be amended when the energy passport database is upgraded.

In addition, it would be a good idea to collect the most important energy-related data on demand/consumption and generation in a country-wide geographic information system (GIS).

Creation of new jobs/demand for additional labour

In view of the significant increases in the output of new residential and non-residential builds, the Chamber of Tradespeople estimates the labour demand in the industry at around 5 000 people (PAPERJAM, 2019). The number is based on a study by the Chamber of Craft Trades, which was in turn based on responses from around 12% of member companies. In total, around 9 400 tradespeople are needed. The figure in the construction sector is likely to increase if the demand for new-build dwellings continues to rise (as indicated in Chapter 2.4.2).

An increase in the rate and quality of redevelopments would generate an increased demand for labour. The following figure illustrates the additional investments that would be created by increasing the current renovation rate of around 0.7 full renovation equivalents to an economically optimal renovation rate of 1.6% per annum, and the size of the corresponding labour force.

Building envelope renovation rate (full renovation equivalent)	Number of residential units to undergo deep renovations	Total living space to be renovated	Renovation investments (minimum performance)	Renovation investments (cost-optimal performance)	Workstations for minimum-performance renovation	Workstations for cost-optimal-performance renovation
%	Residential units/year	m² living space	EUR/a	EUR/a	EUR/a	EUR/a
0.4	1 000	129 000	47 730 000	69 660 000	430	627
0.6	1 500	193 500	71 595 000	104 490 000	644	940
0.7	1 750	225 750	83 527 500	121 905 000	752	1 097
0.8	2 000	258 000	95 460 000	139 320 000	859	1 254
1.0	2 500	322 500	119 325 000	174 150 000	1 074	1 567
1.2	3 000	387 000	143 190 000	208 980 000	1 289	1 881
1.4	3 500	451 500	167 055 000	243 810 000	1 503	2 194
1.6	4 000	516 000	190 920 000	278 640 000	1 718	2 508
1.8	4 500	580 500	214 785 000	313 470 000	1 933	2 821
2.0	5 000	645 000	238 650 000	348 300 000	2 148	3 135

Figure 84: Estimated additional demand for labour caused by a rise in the rate and quality of renovation *(Ploss, 2020)*

An increase in the building envelope redevelopment rate from a current figure of around 0.7% per year to 1.6% per year (based on the current total stock of around 250 000 residential units) would mean that around 4 000 residential units would undergo a complete building envelope renovation each year, instead of 1 750. This would correspond to an increase in investments of around 84 million (to EUR 279 million per annum) if the energy performance of the renovations were improved at the same time. A labour force of around 2 500 would be required (instead of the present figure of around 750), which is equivalent to an increase in demand of around 1 750.

A larger labour force would also be needed to increase the rate and quality of renovations in non-residential buildings and to increase the boiler replacement rate and the installation of solar systems and ventilation systems.

In view of these figures, priority should be given to measures that increase the attractiveness of jobs in the construction sector and that promote the effectiveness of renovation processes, for example greater use of pre-fabricated components.

Health – reduction in the frequency of mould-related damage

Highly efficient building renovations significantly reduce the risk of mould-related damage, which can be harmful to health. This benefit of energy renovations is explained below. The following secondary factors are investigated in this connection:

- frequency of damp and mould damage;
- health impacts of moisture-related and mould-related damage;
- causes of moisture-related mould damage;
- contribution of highly efficient building renovations to reducing the risk of mould.

Frequency of damp and mould damage

According to an EU study, around 17% of individuals are affected by damp-related damage in their homes. (Commission, 2019)

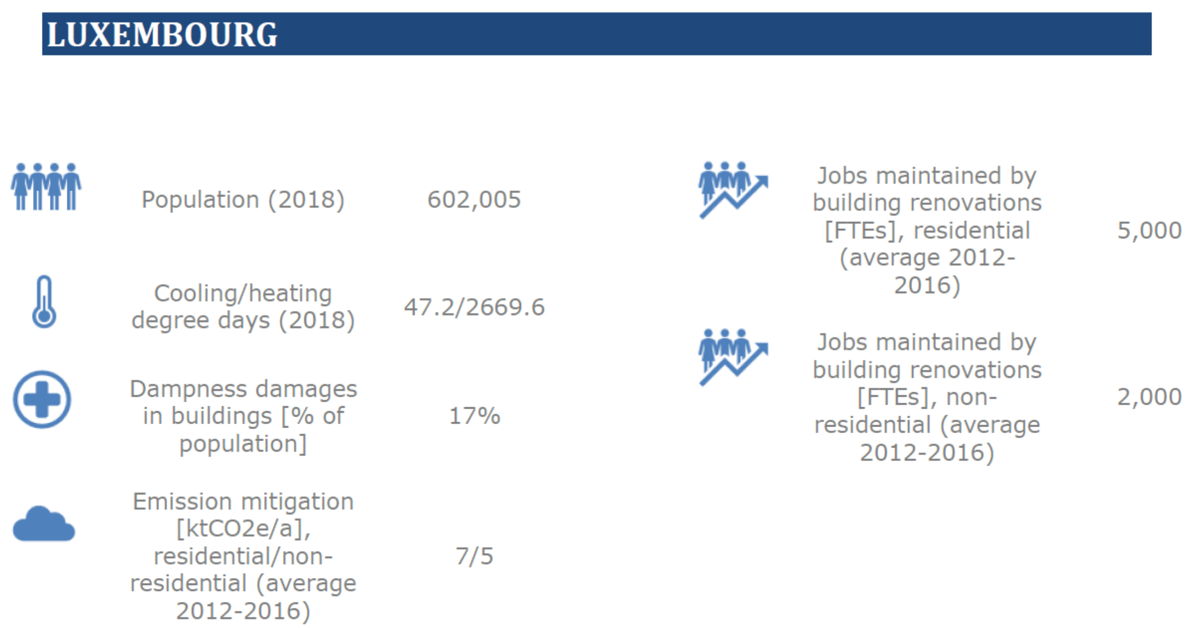


Figure 85: Estimate of the share of Luxembourg's population affected by damp-related damage to buildings *(Commission, 2019)*

Studies from Germany, Switzerland and Austria reveal that this value is not unique to Luxembourg, but is instead typical for countries with a similar climate and similar architectural traditions.

A German study that investigated 5 530 dwellings came to the conclusion that 21.9% of these dwellings exhibited damp-related damage, including 9.3% with mould-related damage (Brasche, 2003)

The Federal Office of Public Health of the Swiss Confederation cites similar figures: 'Moisture-related damage is not an isolated problem; every fourth or fifth dwelling in Switzerland and other European countries is affected' (Gesundheit, 2009). According to an Austrian study, between 10% and 18% of people suffer from health problems caused by dampness and mould in their homes (BIWALD, 2011). The highest values were recorded for dwellings in the lower rental price segment, which have often not yet been renovated

Health impacts of damp and mould damage

The health consequences of exposure to damp and mould are described as follows in a study by the World Health Organization (WHO):

'Various studies found that comprehensive removal of sources of dampness and mould reduced asthma exacerbation. Significant associations between dampness and illness were identified for both children and adults. One of the strongest reported studies (Pekkanen et al., 2007), a retrospective case-control study of incident asthma cases, showed that dampness or mould in the main living area of a house was related in a dose-response relationship to asthma development in infants and children. This well-designed study is the strongest available piece of evidence within a body of generally consistent findings that dampness-related exposure is not only associated with, but may cause, asthma in infants and children. The WHO experts therefore believe that a semi-causal relationship has been proven.'

Cause of damp-related and mould-related damage

Mould can grow if the interior surfaces of building envelope components remain at a temperature below 12.6 °C for several days. At these temperatures there is a risk that the room air humidity in the immediate vicinity of the cool surface will rise to over 80%, i.e. that the temperature of the surface will fall below the dew point.

It follows that there are two contributing factors that must be in place before mould can form:

- low surface temperatures in the vicinity of thermal bridges;
- low rate of air exchange that is insufficient to reduce the room air humidity to non-critical values.

Thermal bridge calculations reveal that surface temperatures of less than 9 °C occur in the vicinity of thermal bridges (such as corners where walls meet) in old and non-renovated buildings. There is a high risk that mould will grow in dwellings of this kind. The installation of insulating materials with an average energy performance (U-value after redevelopment of approximately 0.35 to 0.40 W/(m^2K) can increase the surface temperature in the vicinity of a thermal bridge in a corner where walls meet to around 16 °C. Provided that there is no furniture nearby, this typically eliminates the risk of damp and mould.

Placing a cupboard in a corner however reduces the exchange of heat with the room air, meaning that excessively low temperatures can occur in that corner and lead to the formation of mould. The only way to rule out mould-related damage even in the presence of a cupboard of this kind is to install insulating materials with U-values of around 0.15 W/(m^2K).

High-quality energy renovations that involve reducing thermal bridges are particularly important for densely occupied rental apartments, since a greater number of people give off greater amounts of moisture, and denser occupation often means that residents are forced to place furniture in the corners where exterior walls meet or where interior walls meet exterior walls. As explained above, this means that the surface temperatures in the vicinity of corners where walls meet are lower, and the placement of furniture in these areas also restricts ventilation and therefore the removal of moisture.

Contribution of highly efficient renovations to reducing the risk of mould

Highly efficient building renovations minimise the risk of mould both by reducing the number of thermal bridges and by installing needs-based comfort ventilation systems with heat recovery. Investigations carried out on new builds and renovated buildings have revealed that these systems not only reduce ventilation heat losses and help to remove contaminants, but also keep the moisture content of indoor air during the heating period (i.e. the period when the risk of mould is highest) within a range of between 25% and 50%. Comfort ventilation systems ensure that moist air is removed and replaced with fresh air from the exterior. This fresh air has a very low absolute humidity content in winter. Damp-related damage is unlikely at the aforementioned air humidity levels in buildings with comfort ventilation.

As a result, highly efficient building renovations allow all the rooms in the building to be used in full and for furniture to be positioned in any location. This is a particular advantage in densely occupied rented dwellings, since the ability to position furniture in any location increases the amount of space available.

Reduction in the energy consumed when manufacturing construction products and consideration of the circular economy

Reducing the energy consumed when manufacturing construction and insulating products and giving due consideration to the circular economy when selecting these products are factors that have gained in significance in Luxembourg over recent years. For example, the bonus payment available for building insulation products manufactured from near-natural materials is applied for and granted in around 50% of eligible cases.

3.8.2. Non-residential buildings

Estimate of anticipated final energy savings on the basis of evidence

Estimates of final energy savings in the non-residential buildings sector based on a bottom-up approach incorporating a building typology are not available owing to the lack of data. Instead, the anticipated final energy savings have been estimated in various studies (including those used as a basis for the Fourth NEEAP and the NECP) based on a top-down approach. The data underlying these studies included evaluations of audit outcomes.

The status quo value for 2018 and the targets for 2020 (under the Fourth NEEAP) and for 2030 and 2040 (under the NECP) are explained below.

Figure 86 shows real consumption for the period between 2016 and 2018 compared to the target for 2020 according to the Fourth NEEAP.

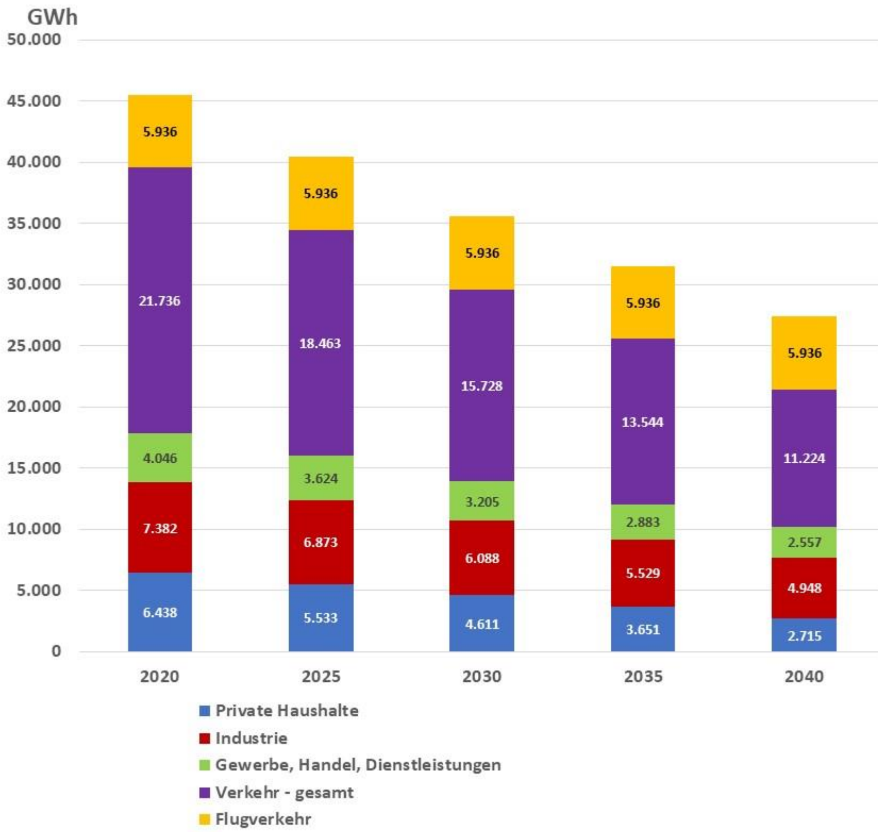
	Real energy consumption in GWh			**Projections for 2020 in GWh**				**Difference between actual figures for end of 2018/target for end of 2020**	
Year	2016	2017	2018	BaU projection for 2020	WM projection for 2020	Difference	Breakdown of savings	Difference between actual consumption in 2018 and WM projection for 2020	Savings to be generated per year in 2019 and 2020
Industry	8 202	7 587	7 693	7 861	7 027	834	32%	666	**333**
Transport	28 305	29 733	31 750	29 008	28 868	140	5%	2 882	1 441
Tertiary	4 826	5 429	5 697	4 782	4 068	714	28%	1 629	815
Households	6 426	6 587	6 154	7 311	6 405	906	35%	-251	-126
Agriculture	75	79	92	82	82	0	0%	10	5
TOTAL	**47 834**	**49 415**	**'51 386**	**49 044**	**46 450**	**2 594**	**100%**	**4 936**	**2 468**

Figure 86: Current final energy demand broken down by sector, and targets for 2020 under the Fourth NEEAP (notified by the Energy Agency)

According to STATEC, final energy demand by the 'tertiary' sector (commerce, trade and services) was 5 697 GWh/a in 2018. This value also includes consumption for non-building-related uses that are not relevant to the LTRS, i.e. power (production processes) and process heat.

Consumption has risen in this sector over recent years, and it is therefore highly unlikely that the target under the Fourth NEEAP (4 068 GWh/a by 2020) will be achieved.

The following figure shows the targets under the NECP for the consumption sectors over the period up to 2040.



GWh	GWh
Private Haushalte	Private households
Industrie	Industry
Gewerbe, Handel, Dienstleistungen	Commerce, trade, services
Verkehr – gesamt	Transport – total
Flugverkehr	Aviation

Figure 87: Targets for final energy demand broken down by sector according to the NECP over the period up to 2040 *(NECP, 2020)*, target scenario under the Paris Agreement

The NECP target scenario refers to a target of 3 205 GWh/a for total final energy demand by the commerce, trade and services (tertiary) sector by 2030. This would equate to a reduction of around 44% compared to the real consumption of 5 697 GWh/a in 2018.

The NECP refers to a value of 2 557 GWh/a for 2040, which would equate to a reduction of around 55%.

Creation of new jobs/demand for additional labour

Increasing the rate and quality of renovations and the boiler replacement rate, and expanding the use of building-integrated solar systems will also create new jobs in the non-residential buildings sector. In view of the fact that the data available are much less comprehensive than for the residential buildings sector, however, no attempts will be made to calculate the number of new jobs involved. It should nevertheless be noted that – as with the residential buildings sector – these new jobs on the one hand represent an opportunity for economic growth, but on the other hand signify a major challenge owing to the capacity constraints in Luxembourg's construction industry. The first task that must be accomplished is therefore to recruit and train the additional labour force required.

Health – reduction in damp-related structural damage and increased productivity at work thanks to good indoor air quality

The benefits of highly efficient and low-thermal-bridge building envelopes in terms of avoiding damp-related and mould-related damage have already been described in the chapter on housing.

This factor is likely to be less significant in the non-residential buildings sector than in the residential buildings sector, but a very good indoor air quality guaranteed by means of comfort ventilation with heat recovery is also very important in non-residential buildings; studies show that good indoor air quality not only increases levels of well-being, but can also boost productivity at work.

4. Measures, progress indicators and milestones (Article 2a(2))

In accordance with Article 2a(2) of the EPBD, 'In its long-term renovation strategy, each Member State shall set out a roadmap with measures and domestically established measurable progress indicators, with a view to the long-term 2050 goal of reducing greenhouse gas emissions in the Union by 80–95% compared to 1990, in order to ensure a highly energy-efficient and decarbonised national building stock and in order to facilitate the cost-effective transformation of existing buildings into nearly zero-energy buildings. The roadmap shall include indicative milestones for 2030, 2040 and 2050, and specify how they contribute to achieving the Union's energy efficiency targets in accordance with Directive 2012/27/EU.'

This is a new element which did not exist under Article 4 of the EED. The underlying objective is to achieve a highly energy-efficient and fully decarbonised building stock; this is essential to delivering on the EU's goal of reducing greenhouse gas emissions. A 'decarbonised' building stock is not defined in EU legislation, but it can be considered as one in which carbon emissions have been reduced to zero, by reducing energy needs and ensuring that remaining needs are met to the extent possible from zero-carbon sources. This approach allows for various routes to decarbonisation, taking into account the Member State's national energy mix, preferences, potential and characteristics. As the strategies are to set out a long-term vision to deliver on a 2050 decarbonisation goal, Member States should go beyond a simple inventory of existing measures (which provide the near-term elements) and provide a long-term view of the development of future policies and measures. The roadmap framework in the new Article 2a seeks to achieve this. According to Article 2a(2), roadmaps must include: (a) measurable progress indicators — these can be quantitative or qualitative variables to measure progress towards the long-term 2050 goal of reducing greenhouse gas emissions in the Union and ensuring a highly energy-efficient and decarbonised national building stock. They can be revised if necessary; and (b) indicative milestones — these can be quantitative or qualitative objectives. Member States must 'include indicative milestones for 2030, 2040 and 2050 and specify how they will contribute to achieving the Union's energy efficiency targets in accordance with Directive 2012/27/EU'. Member States can tailor their milestones and indicators to national specificities. The intention is not to introduce a sectoral target for the building sector, nor to establish legally binding targets. It is for Member States to define the specific milestones and to decide whether to make such objectives binding for the building sector (thus going beyond obligations in the EPBD). However, Member States should bear in mind that the setting of ambitious and clear milestones is key to reducing investor risks and uncertainties, and engaging stakeholders and business. The availability of consistent and reliable data is a major factor in determining measurable indicators. In accordance with Article 2a(2), the LTRS must specify how the milestones for 2030, 2040 and 2050 contribute to the indicative headline target defined by Member States in accordance with Article 3 of the EED, since buildings are a key pillar of energy efficiency policy. This information can help policymakers shape future energy efficiency policies and design appropriate measures.

4.1. Roadmap with measures and domestically established progress indicators

This chapter describes how the EU's long-term goal of a highly energy-efficient and decarbonised building stock and the cost-effective transformation of existing buildings into NZEBs can be achieved in Luxembourg. It is structured as a roadmap with primary targets, sub-targets, progress indicators and indicative milestones for 2030, 2040 and 2050. The roadmap is displayed as a table below, broken down into measures for residential buildings and non-residential buildings, and summarising primary targets, sub-targets, progress indicators and indicative milestones. The implementing measures provided for the purpose of achieving the primary targets and sub-targets and the milestones are summarised in tables in Chapter 3.4.1 for residential buildings and Chapter 3.4.2 for non-residential buildings. Two example measures are described in the annex on the basis of a standardised framework.

The aforementioned terms are explained below for the purpose of defining and differentiating them.

The term <u>primary target</u> refers to reductions in final energy demand and GHG emissions by the residential and non-residential building stock. The relevant targets were specified in Chapters 3.8.1 and 3.8.2 on the basis of the outcomes of the bottom-up and top-down scenarios. Achievement of the primary targets can be tracked using data from the national energy statistics.

The term <u>sub-target</u> refers to factors such as increasing the building envelope renovation rate and performance, increasing the boiler replacement rate, increasing the efficiency of installed heat supply systems, reducing the share of fossil fuels, increasing the share of solar thermal and photovoltaics and increasing the efficiency of domestic appliances and operating current for lighting, IT equipment, etc. in non-residential buildings. Sub-targets are selected in such a way that they can be verified on the basis of progress indicators such as useful heat demand, which are (or will be) available in data sources such as an energy passport database containing detailed evaluations, ideally backed up by consumption data, and other sources of statistical data.

The term <u>progress indicator</u> may refer to absolute figures (such as the number of buildings that undergo energy renovations each year or the area covered by these buildings), percentages (such as the amount of living space heated with fossil fuels as a percentage of total living space or total number of residential units) or average values (for example average heating demand or final energy demand of post-renovation buildings in a particular category). Progress indicators are selected in such a way that they are calculated on the basis of existing bottom-up building models, with the option of future tracking using data sources such as the energy passport database.

The term <u>indicative milestone</u> refers to figures assigned to the individual progress indicators, for example an average final energy demand of x $kWh/m^2_{NFA}a$ by a certain category of buildings, or a final energy demand of y GWh/a for a certain category of buildings. The indicative milestones can be estimated in advance on the basis of the existing bottom-up building models, with the option of future tracking using data sources such as the energy passport database.

The term <u>implementing measure</u> refers to measures that can be used to promote or accelerate the attainment of primary targets, sub-targets and indicative milestones. Implementing measures may take the form of regulatory provisions (establishment of strict limit values for redevelopment, bans on fossil fuels) and be targeted at the profitability and affordability of renovation measures (e.g. in the form of funding programmes or tax breaks for highly efficient renovations, individual insulation-related measures or the switch to renewable energy carriers). Implementing measures may however also be aimed at increasing the acceptance of highly efficient renovations (public outreach measures, campaigns, etc.), which demonstrate the profitability and technical feasibility of high-performance energy renovations in application-oriented research projects, or take the form of further training and consultation measures that build know-how among stakeholders in the construction sector.

4.1.1. Residential buildings

The following table summarises the primary targets, sub-targets, progress indicators and milestones for the years 2030, 2040 and 2050 for residential buildings. Certain entries relate to the entire residential building stock (current stock minus demolition plus new builds in the years to come), while others relate only to the current stock (construction years until 2010 according to the outcomes of the 2011 survey). In some cases the segments are broken down even further, for example into sub-segments such as:

- single-family dwellings, semi-detached houses and terraced houses;
- multi-family dwellings;
- buildings that can only be redeveloped to a limited extent (buildings protected as historical monuments, listed groups of buildings).

Most of the data originate from the bottom-up study by the Vorarlberg Energy Institute (Ploss, 2017), since this is the most detailed typological description of the residential building stock currently available.

The list should be viewed as a first draft that will be expanded in the future into a systematic collection of monitoring (consumption) data or values calculated for implementation scenarios.

In certain cases, the table contains only sub-targets, progress indicators and units, with no values provided. This is because consistent data are not yet available for the various progress indicators.

The specified indicative milestones are based on the following assumptions and constraints:

Assumptions and constraints		2020	2 030	2040	2050
Population (Q 10)	Individuals in primary and secondary place of residence	632 500	785 000	983 000	1 051 000
Residential units (Q 10)	Number	275 000	349 000	424 000	489 000
Residential units built before 1991 (reference variable for NECP (Q 10))	Number	150 000	150 000	150 000	150 000
Residential units until 2010 (comparative value for Vorarlberg Energy Institute's	Number	211 600	201 020	190 969	181 421
Total living space (Q 10)	m²	34 150 000	42 900 000	51 600 000	58 900 000
Average living space/residential unit (Q 10)	m²	124	123	122	120

Figure 88: Assumptions and constraints underlying the specified indicative milestones *(NECP, 2020)*, *(Ploss, 2017)*

Total residential building stock, i.e. current stock minus demolition plus increase						
Primary target	Progress indicator	Unit	Status quo	Indicative milestones		
			2020	2030	2040	2050
Reduction in final energy demand	Final energy demand (heating + hot water, including auxiliary power and domestic electricity)	GWh/a	6 438	4 611	2 715	
Reduction in GHG emissions	%			62	96	
Sub-targets	Progress indicator	Unit	Status quo	2030	2040	2050
Increase in building envelope renovation rate	Renovation rate (full renovation equivalents, in relation to total stock)	% per annum	0.7	1.6	2.0	2.0
Increase in the energy performance of the building envelope (building not protected as a historical monument)	Average heating demand	kWh/m^2a	125	82	61	43
	Average U-value for the renovation of individual exterior wall components	$W/(m^2K)$	0.17	0.15	0.14	0.13
	Average U-value for the renovation of individual roof/top floor ceiling components	$W/(m^2K)$	0.17	0.15	0.14	0.13
	Average U-value for the renovation of individual window components	$W/(m^2K)$	0.97	0.85	0.78	0.70
	Average U-value for the redevelopment of individual cellar ceiling components	$W/(m^2K)$	0.31	0.26	0.24	0.21
Reduction in heat losses from entire residential building stock	Heating demand (useful heat)	GWh/a	3 600	2 800	2 250	1 660
	Average specific heat demand of the stock of single-family dwellings	kWh/m^2a	125	100	75	50

	constructed over the period up to 2010					
	Average specific heating demand of the stock of multi-family dwellings that were built up until 2010	kWh/m²a	100	85	70	48
	Average specific heating demand of the stock of dwellings that can only be redeveloped to a limited extent and that were built up until 2010	kWh/m²a	190	170	130	110
Increase in boiler replacement rate	Share of residential units/total area with new boiler	%	2.5	4	5	5
Increase in efficiency of heat supply systems	Average efficiency of boilers (biomass)					
	Average annual performance factor of heat pumps					
Increase in share of renewable energy carriers	Share of renewable energies for heating	%	13.7	30.5	47.1	
	Living space for households with biomass boiler	m²				
	Living space for households with district heating (renewable)	m²				
	Living space for households with brine or groundwater pumps	m²				
	Living space for households with air source heat pumps	m²				
Increase in yield of solar systems integrated into the building	Gross area of solar thermal installations	m²				
	Installed output of photovoltaic	GW_{peak}				

	installations integrated into the building					

Figure 89: Primary targets, sub-targets, progress indicators with unit, indicative milestones

4.1.2. Non-residential buildings

The lack of data means that specifying indicative milestones for individual progress indicators would imply a level of accuracy that is not remotely possible.

Before the measures are identified, the condition of the current non-residential building stock must therefore first be analysed.

A bottom-up scenario study, broken down into categories of use, should then be carried out on this basis, following a similar procedure to that for the residential building stock. The aforesaid studies are scheduled to be carried out over the next 2 years and are included in the list of measures for non-residential buildings.

5. Chapter 4 Article 2a(3) EPBD

Article 2a(3) of the EPBD requires Member States to facilitate access to financial mechanisms to support the mobilisation of investments in the renovation needed to achieve the goals in Article 2a(1), i.e. a highly energy-efficient and decarbonised building stock by 2050 16.5.2019 L 127/50 Official Journal of the European Union DE (35) and the cost-effective transformation of existing buildings into NZEBs.

Article 2a(3) of the EPBD sets out possible mechanisms and builds on Article 20 of the EED, which requires Member States to facilitate the establishment of financing facilities, or the use of existing ones, for energy efficiency improvement measures.

Pursuant to Article 2a(3) of the EPBD, 'To support the mobilisation of investments into the renovation needed to achieve the goals referred to in paragraph 1, Member States shall facilitate access to appropriate mechanisms for:

(a) the aggregation of projects, including by investment platforms or groups, and by consortia of small and medium-sized enterprises, to enable investor access as well as packaged solutions for potential clients;

(b) the reduction of the perceived risk of energy efficiency operations for investors and the private sector;

(c) the use of public funding to leverage additional private-sector investment or to address specific market failures;

(d) guiding investments into an energy efficient public building stock, in line with Eurostat guidance; and

(e) accessible and transparent advisory tools, such as one-stop-shops for consumers and energy advisory services, on relevant energy efficiency renovations and financing instruments.'

This provision did not exist under Article 4 of the EED. To drive their LTRSs, Member States will need to provide access to a range of financial mechanisms to support the mobilisation of investments, in particular considering how to use *innovative financing to effectively enable small clients and small providers. The following is a non-exhaustive list of generic examples of types of financial mechanism.*

5.1. The aggregation of projects, including by investment platforms or groups (Article 2a(3)(a));

Luxembourg is currently developing a ‘de-risking instrument’ in the form of an investment platform in order to mobilise investments into energy efficiency projects, in particular renovation measures in large functional buildings and public buildings with a high energy potential (see Section 5.2). The bundling of projects should also be considered in this connection, in order to develop larger investment projects that are an economically attractive prospect for energy performance contractors with the associated project and funding costs for investors.

5.2. The reduction of the perceived risk of energy efficiency operations for investors and the private sector (Article 2a(3)(b));

To reduce the perceived risk of energy efficiency measures for investors and the private sector and to promote investments in this respect, it is expected that decision-makers in Luxembourg will be provided with a ‘de-risking’ instrument in the form of an investment platform. Its aim is to mobilise investments in energy efficiency projects, in particular renovation measures in large functional buildings or large parts of the residential building stock with a high energy potential.

To overcome barriers on the investment market, a financial instrument (a ‘de-risking’ investment platform) shall be designed and implemented to mobilise energy efficiency investments by industry, SMEs and the buildings (renovation) sector, with the primary aim of making progress in terms of climate emissions, renewable energy and energy efficiency targets, and a secondary aim of reducing energy dependency and increasing energy productivity.

The aim of the ‘de-risking’ instrument is to eliminate the obstacles associated with energy improvements and renovations and the associated project funding.

In addition to problems relating to capital expenditure, the implementation of energy efficiency projects takes time and requires specific skills that companies (owners) may not necessarily have. Alternatively, the companies (owners) may prefer to concentrate on their core business. There is thus a need for targeted expert, technical and financial support with a view to streamlining and encouraging the implementation of projects in this context.

EPC (Energy Performance Contracting) models are very rare in Luxembourg at present; models of this kind can however be an ideal solution for larger renovation measures (consisting of a number of smaller projects bundled together, where appropriate).

It is also expected that the 'de-risking' instrument will serve as the basis for building an economically attractive energy efficiency market in Luxembourg. For example, it should mean that energy service companies (ESCOs) are set up in Luxembourg or that existing companies of this kind based in nearby countries open an office in Luxembourg.

In autumn 2019, the Ministry of Energy (in cooperation with the European Investment Bank (EIB) and myenergy) launched a project involving the development of tools and methods for a future 'de-risking' platform. This project will be continued in 2020 in close cooperation with the Ministry of the Economy and the Ministry of Finance, with the involvement of banks and the market players concerned.

5.3. The use of public funding to leverage additional private-sector investment or to address specific market failures (Article 2a(3)(c));

PRIMe House, a national funding scheme that supports various measures, including renovation measures in the residential housing sector, is currently being revised. From 2021 onwards it should provide very attractive and easily accessible funding options paired with checks to ensure compliance with the energy requirements for 'deep renovations' (to avoid unwanted lock-in effects).

When developing the de-risking platform, any adjustments or additions to existing funding programmes that might facilitate access to grants by ESCOs will be investigated and identified.

5.4. Accessible and transparent advisory tools on relevant energy efficiency renovations and financing instruments (Article 2a(3)(e))

myenergy is the body responsible for promoting sustainable energy efficiency within the country. One of its tasks is to act as a partner and intermediary, supporting and encouraging Luxembourg's citizens in their efforts to achieve sustainable and efficiency energy use. myenergy's activities are focused on reducing energy consumption, promoting renewable energies and facilitating sustainable construction, living and mobility. The organisation views itself as a partner to all energy consumers and a source of support in their efforts to achieve a sustainable energy transition. These activities also promote the growth of the country's economy. Furthermore, myenergy acts as a neutral intermediary in the energy and construction sector, and supports professionals in these fields by proposing new solutions that enable efficient and sustainable energy use. It also monitors the behaviour of various consumer groups and stakeholders from the energy sector, and supports the competent political bodies by providing analyses and proposals in order to promote a sustainable energy transition.

myenergy offers free and independent basic consultations to private individuals. The service can be accessed both by calling a telephone hotline on 8002 11 90 and by attending a face-to-face consultation, either at a regional myenergy infopoint or at home. As at January 2019, myenergy operated a near-complete network of regional or municipal consultation points that covered virtually the entire country (split into 24 infopoints; infopoint.myenergy.lu/) in partnership with 100 municipalities. myenergy organises various activities through these partnerships, including campaign weeks and information events with talks. During the basic consultation, the customer is provided with targeted advice on useful services and products available on the market. Explanations are given regarding the advantages and disadvantages of potential measures; efforts are made to optimise the energy efficiency, sustainability and costs of a project; and information is provided on the use of renewable and sustainable energies, energy savings on a day-to-day basis, State and municipal funding programmes and the energy passport. As well as providing basic consultations, further key goals for myenergy include public information and awareness raising. It achieves these goals by attending national trade fairs, publishing information brochures and Internet platforms, appearing regularly on national media and developing its own events. myenergy also offers a free online calculator (‘myenergyhome’) so as to raise public awareness. Interested parties can use this calculator to carry out a simplified assessment of the energy efficiency of the building in which they live. This tool is currently used mainly for demonstrations at the various national trade fairs.

Since October 2019, myenergy has also offered the ‘myrenovation’ app, which allows users to calculate the State and municipal grants available for energy renovations based on a simulation. The app covers all stages, including grant applications and preliminary financing. This practical simulation tool also provides a great deal of valuable information on topics relating to renewable energies, sustainable energy renovations and electromobility.

On behalf of the Ministry of Sustainable Development and Infrastructure and the Ministry of Family Affairs, Integration and the Greater Region, since 15 September 2016 myenergy has offered customised basic consultations targeted specifically at low-income households, in cooperation with the social welfare offices. The social welfare offices identify the households in question, which are then given the opportunity to receive a basic consultation from myenergy. Based on a standardised checklist, the myenergy consultant analyses the household's specific situation, offers advice on potential improvements and user behaviour, and provides the household with a number of useful energy-saving tools (e.g. socket strip with switch, fridge thermometer). The energy consultant also identifies the electrical household appliances to be replaced, and the Ministry of Sustainable Development and Infrastructure and (where applicable) the social welfare office cover part of the replacement costs on the basis of the completed checklists.

6. Public consultation (Article 2a(5))

It was originally intended that a half-day workshop ('Renovation Day') would be held to finalise the draft LTRS, to be attended by the most important stakeholders. The unprecedented developments relating to COVID-19 made it impossible to carry out this public consultation on the draft version of the LTRS until mid-May at the earliest.

It was decided that it would be less beneficial to hold the public consultation after the loosening of restrictions in late May/early June, because the Government's 'top-up' coronavirus recovery programme would be presented at around this time. The LTRS would not receive the attention it merits if it were to be presented at the same time, and it is likely that market players would become confused.

Instead, workshops are planned for autumn 2020 if possible, or early 2021 at the latest (depending on whether the COVID-19 restrictions are tightened up again) for the purpose of presenting and discussing the LTRS, including the specific proposals contained therein. The new PRIMe House funding scheme will also be presented as a key element of the strategy during these workshops. In addition, the workshops will serve as an opportunity to discuss key measures from the LTRS with stakeholders and examine other potential measures in depth.

It is regrettable that it was necessary to postpone the public consultation as a result of the COVID-19 pandemic, not least because the concept had already been planned. At the same time, however, the fact that stakeholders have been very involved in previous processes means that the delay is less of a problem:

- several very well-attended workshops were held 3 years ago on the renovation strategy, and their outcomes were incorporated into the work on the LTRS;

- Workshops were held in connection with the drafting of the National Energy and Climate Plan 2019, and the topic of renovation was also discussed on these occasions.

7. Details of implementation, planned policies and actions (Article 2a(6))

Tables listing the implementing measures for residential and non-residential buildings can be found in Chapters 3.4.1 and 3.4.2. The measures are listed under the following headings:

- regulatory provisions,
- tax law,
- support and funding,
- consultation,
- training,
- awareness raising and publicity work,
- research and model projects.

Where applicable, the measures are broken down by market segments (residential building (single-family dwelling, rented multi-family dwelling, owned multi-family dwelling), non-residential building (public building, office building, etc.)) and buildings that can only be renovated to a limited extent (buildings protected as historical monuments and listed groups of buildings).

Where appropriate, the measures will also be broken down on the basis of other characteristics, such as construction age or current energy carrier.

Two example measures are described in the annex on the basis of a standardised framework.

8. Fire safety and risks related to seismic activity (Article 2a(7))

Member States have the option of covering the topics of fire safety and seismic activity in the LTRS. These topics are currently of secondary importance for Luxembourg, and are not therefore covered in this document.

Bibliography

Aiulfi, 2010. *Energieverbrauch von Bürogebäuden und Großverteilern ,* Bern: Bundesamt für Energie (BfE).

Berichtigung, 2018. *Berichtigung der Richtlinie EU 2018(844,* Brüssel: Amtsblatt der Europ. Union vom 19. Juni 2018.

BIWALD, 2011. *Schaffung von Public Value - Zentrale Aspekte und strategische Konsequenzen am Beispiel der gemeinnützigen Wohnungswirtschaft; Im Auftrag des Österreichischen Verbandes gemeinnütziger Bauvereinigungen – Revisionsverband und der Wohnbauförderungsabteilunge.* [Online]
Available at: https://www.kdz.eu/de/content/public-value-der-gemeinn%C3%BCtzigen-wohnungswirtschaft

Born, 2003. *Energieeinsparung durch Verbesserung des Wärmeschutzes und Modernisierung der Heizungsanlage für 31 Musterhäuser der Gebäudetypologie,* Darmstadt: Institut Wohnen und Umwelt.

Brasche, 2003. Vorkommen, Ursachen und gesundheitliche Aspekte von Feuchteschäden in Wohnungen - Ergebnisse einer repräsentativen Wohnungsstudie in Deutschland; Gesundheitsschutz. *Bundesgesundheitsblatt - Gesundheitsforschung.*

Capros, 2016. *EU Reference scenario 2016 - energy, transport and GHG emissions - trends to 2050,* Brüssel: EU Directorate Energy.

Cischinsky, 2018. *Datenerhebung Wohngebäudebestand 2016,* Darmstadt: Institut Wohnen und Umwelt.

Commission, 2019. *COMMISSION STAFF WORKING DOCUMENT, Accompanying the document, REPORT FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS Energy prices and costs in Europe.* [Online]
Available at: https://eur-lex.europa.eu/resource.html?uri=cellar:b3b8d285-13f5-11e9-81b4-01aa75ed71a1.0001.02/DOC_1&format=PDF

Commission, 2019. *Comprehensive study of building energy renovation activities and the uptake of nearly zero-energy buildings in the EU : Country reports: Luxemburg.* [Online]
Available at: https://ec.europa.eu/energy/sites/ener/files/documents/1.final_report.pdf

datamapper, 2020. *Breakdown of building floor area.* [Online]
Available at: https://ec.europa.eu/energy/eu-buildings-datamapper_en

Datamapper, 2020. *Energy consumption of residential for space heating per m2 (normal climate).* [Online]
Available at: https://ec.europa.eu/energy/eu-buildings-datamapper_en

Dena, 2015. *Der dena Gebäudereport 2015 - Statistiken und Analysen zur Energieeffizienz im Gebäudebestand,* Berlin: Deutsche Energieagentur (Dena).

Dena, 2019. *Dena Gebäudereport kompakt 2019,* Berlin: Deutsche Energieagentur (Dena).

DGET, 2008. *Trends to 2030 - update 2007,* Luxemburg: s.n.

energieagence, 2020. *Studie zu Ncihtwohngebäuden - unveröffentlicht,* Luxemburg: energieagence.

Engstler, 2019. *IMEAS-Sondierung: Energiebedarf Nichtwohngebäude Vorarlberg,* Dornbirn: Energieinstitut Vorarlberg.

EPBD, 2018. *RICHTLINIE (EU) 2018/844 DES EUROPÄISCHEN PARLAMENTS UND DES RATES vom 30. Mai 2018,* Brüssel: Europ. Parlament und Rat.

EU, 2010. *Richtlinie 2010/31 EU.* Brüssel: s.n.

EU, 2012. *EU - Verordnung 244/2012.* Brüssel: s.n.

EU, 2019. *Energy prices and costs in Europe - COM (2019) 1-final.* [Online]
Available at: https://op.europa.eu/en/publication-detail/-/publication/4e7efb2a-add9-11e3-86f9-01aa75ed71a1/language-en/format-PDF/source-119670846

EU, 2., 2019. *Empfehlung EU 2019/786 der Kommission vom 08. Mai 2019,* Brüssel: Kommission der EU.

EUROSTAT, 2015. *Eurostat: Preise Elektrizität für Haushaltabnehmer, ab 2007 - halbjährliche Daten.* [Online].

EUROSTAT, 2016. *Durchschnittliches und Medianeinkommen nach Alter und Geschlecht.* [Online]
Available at: http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=ilc_di03&lang=de

EUROSTAT, 2019. *eurostat Pressemitteilung 88/2019 vom 21. Mai 2019: Energiepreise für Haushalte in der EU.* [Online]
Available at: https://ec.europa.eu/eurostat/documents/2995521/9802437/8-21052019-AP-DE.pdf/e9cfc6b0-a280-4942-89d0-98811db8fb4e

Eurostat, 2019. *Inability to keep home adequately warm - EU-SILC survey.* [Online]
Available at: https://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=ilc_mdes01&lang=en

eurostat, 2019. *Member state Report Luxemburg.* [Online]
Available at: https://www.energypoverty.eu/sites/default/files/downloads/observatory-documents/19-06/member_state_report_-_luxembourg.pdf

EUROSTAT, 2020. *eurostat - Statistics Explained - Strompreisstatistik - Datenauszug Nov 2019.* [Online]
Available at: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Electricity_price_statistics/de#Strompreise_f.C3.BCr_Haushaltskunden

EVB, 2018. *Was ist neu beim EVB?.* [Online]
Available at: https://mietervereinigung.at/News/841/27043/Was-ist-neu-beim-EVB

Familienministerium, 2019. *Quelle : Ministère de la Famille, de l'Intégration et à la Grande Région, Rapport d'activité 2019, février 2019,* s.l.: s.n.

Gebäuderenovierungsstrategie, 2017. *Weiterentwicklung der Gebäuderenovierungsstrategie,* Luxemburg: Wirtschaftsministerium Luxemburg.

Gesundheit, B. f., 2009. *Vorsicht Schimmel - Eine Wegleitung zu Feuchtigkeitsproblemen und Schimmel in Wohnraumen.* [Online]
Available at:
https://www.bundespublikationen.admin.ch/cshop_mimes_bbl/2C/2C59E545D7371EE493C483AB1AFBAF80.pdf

Haus_und_Grund, 2006. *1,5% der Herstellungskosten als Instandhaltungs¬rücklage ... jährlich!.* [Online]
Available at: http://www.baulinks.de/webplugin/2006/1758.php4

ILRES, T., 2015. *La rénovation énergétique de l'habitat au Luxembourg – Volet ménages Enquête par sondage réalisée par TNS Ilres en octobre-décembre 2015,* s.l.: s.n.

ILRES, T., 2020. *perception et comportemements énergetiques - Baromètre 2020,* Luxemburg: TNS ILRES.

JLL, 2016. *Office market report Luxemburg 1st Quarter 2016.* [Online].

JLL, 2019. *Luxemburg property market.* [Online]
Available at: https://www.jll.lu/en/trends-and-insights/research/Luxembourg-Property-Market-Overview-Q3-2019

Klobasa, 2016. *Bewertung des Potenzials für den EInsatz der hocheffizienten KWK und der effizienten Fernwärme- und Fernkälteversorgung,* Luxemburg: Wirtschaftsministerium Luxemburg.

Kommission, 2018. *Ein sauberer Planet für alle - eine Europäische, langfristige Vision für eine wohlhabende, moderne, wettbewerbsfähige und klimaneutrale Wirtschaft,* Brüssel: s.n.

Kopatz, 2010. *Energiearmut: Stand der Forschung, nationale Programme und regionale Modellprojekte in Deutschland, Österreich und Großbritannien. ..* nbn-resolving.de Hrsg. s.l.:Wuppertal Paper Nr. 184 (Oktober 2010).

KostOpti, 2019. *Berechnung kostenoptimaler Niveaus von Mindestanforderungen an die Gesamtenergieeffizienz für neue und bestehende Wohn- und Nichtwohngebäude,* Luxemburg: Ministerium für Energie und Raumentwicklung Luxemburg.

l´essentiel, 2015. *Immer öfter wird der Strom abgedreht.* [Online].

LISER, 2019. *Under-occupation of housing increases with age.* [Online]
Available at: https://www.liser.lu/ise/index.cfm

LISER, 2020. *LISER proposed a new indicator which has been endorsed at the EU level: Material and social deprivation rate.* [Online]
Available at: https://www.liser.lu/ise/display_indic.cfm?id=480#)

Maas, 2012. *Wie viel ENergie verbrauchen neue Unterrichts- und Bürogebäude in Luxemburg?,* Luxemburg: Cahier scientiefiques.

Mobilitätsministerium, 2020. *rapport d´ activité - Département des travaux publics ,* s.l.: s.n.

Monitoring, kein Datum *Fünfter jährlicher Monitoringbericht Luxemburgs 2017,* Luxemburg: s.n.

myenergy, 2020. *Zusammenstellung der Flächen und Energieverbräuche gemeindeeigener Gebäude,* Luxemburg: myenergy.

NECP, 2019. *INTEGRIERTER NATIONALER ENERGIE- UND KLIMAPLAN LUXEMBURGS FÜR DEN ZEITRAUM 2021-2030,* Luxemburg: Energieministerium Luxemburg.

NEEAP3, 2014. *Dritter Nationaler Energieeffizienzfahrplan - interne excel-Tabelle, Blatt HH-Basisdaten,* Luxemburg: Wirtschaftsministerium Luxemburg.

NEEAP4, 2017. *Vierter Nationaler Energieeffizienzaktionsplan Luxemburg,* Luxemburg: Wirtschaftsministerium Luxemburg.

Observatoir, 2019. *Prix de vente et loyers des logements au Grande-Fuché de Luxembourg - Edtion 2019,* Luxemburg: Wohnbauministerium Luxemburg.

openExp, 2019. *European Energy Poverty Index (EEPI) - assessing member states' progress in alleviating the domestic and transport energy poverty nexus.* [Online]
Available at: https://www.openexp.eu/european-energy-poverty-index-eepi

PAPERJAM, 2019. *L'artisanat cherche 9.400 salariés.* [Online]
Available at: https://paperjam.lu/article/artisanat-en-quete-plus-9-000-

Peltier, 2019. *working papers no. 106 ,* Luxemburg: STATEC.

Ploss, 2017. *Energieperspaktiven Luxemburg 2010 bis 2070 - Szenarien zum künftigen Energiebedarf des Wohngebäudeparks Luxemburg.* Dornbirn: Energieinstitut Vorarlberg.

Ploss, 2020. *Abschätzung des zusätzlichen Arbeitskräftebedarfs bei Steigerung der Renovierungsrate und -qualität.* [Online].

Ploss, 2020. *Auswirkungen CO2-Steuer auf Jahresenergiekosten eines Energiearmut-gefährdeten Haushalts,* s.l.: s.n.

Ploss & M., 2015. *Arbeitsdokument im Rahmen der Erstellung einer netionalen Renovierungsstrategie,* Nonnenhorn: s.n.

PWC, 2015. *Der Immobilienmarkt in Luxemburg 2020.* [Online]
Available at: https://www.pwc.lu/en/real-estate/docs/pwc-re2020-2015-de.pdf

Schön, 2016. *Wissenschaftliche Beratung zu Fragen der Energiestrategie Lu-xemburgs mit besonderem Fokus auf Erneuerbare Energien,* Karlsruhe: IREES GmbH + Fh ISI.

SSMN, 2015. *Patrimoine bâti, efficience énergétique, énergies renouvelables.* [Online]
Available at: https://ssmn.public.lu/dam-assets/fr/publications/patrimoine-efficience-nerg-tique.pdf

SSMN, 2020. *Rapport d´avtivités 2019,* Luxemburg: Service des sites et monuments nationaux.

STATEC, 2013. *Recensement de la population 2011 - Premiers résultats No. 9 - Feb 2013: Le logement - surface et équipement du logement,* Luxemburg: s.n.

STATEC, 2018. *Statistiques des bâtiments achevés.* [Online].

STATEC, 2019. *Entwicklung der Armutsgefährdungsquote.* [Online]
Available at:
https://statistiques.public.lu/stat/TableViewer/tableView.aspx?ReportId=12957&IF_Language=eng&MainTheme=3&FldrName=1&RFPath=29

STATEC, 2019. *Le portail des statistiques.* [Online]
Available at:
https://statistiques.public.lu/stat/TableViewer/tableViewHTML.aspx?ReportId=12773&IF_Language=fra&MainTheme=1&FldrName=4&RFPath=51#WDS_row_summary_0_1

STATEC, 2019. *Luxemburg in Zahlen 2018,* Luxemburg: s.n.

stock, b., 2020. *EU building stock observation - EU building stock observation.* [Online]
Available at: https://ec.europa.eu/energy/sites/ener/files/documents/lux.pdf

Thunus, 2020. *Definition von Energiearmutsindikatoren durch STATEC.* [Online].

Trausch, 2020. *Zusammenstellung Flächen und Energieverbräuche öffentlicher Gebäude,* Luxemburg: myenergy.

Voss, 2006. *Bürogebäude mit Zukunft.* s.l.:TÜV Verlag.

Annex

Standardised descriptions of two measures as examples; all measures that are identified, analysed and assessed in the LTRS are documented using this standardised description, as well as measures that are rejected after being analysed and that are not implemented.

F 1	**Revision of the PRIMe House funding scheme**
Type of measure	State funding scheme
Market segment	Residential construction (renovation)
Effect	Reduction in final energy demand and GHG emissions for heating and hot water
Description	The PRIMe House funding scheme is the central funding instrument for the energy renovation of residential buildings. The following changes are to be made as part of the planned revision: (1) More ambitious minimum requirements based on the guideline ‘Prioritisation of highly efficient renovations’ (changes to the minimum requirements in place since 2008 (introduction of energy passports) (from 2023 onwards, but announced and publicised from the start of 2021 as part of the new PRIMe House scheme so that the market can adjust; minimum requirements aligned with the requirements under the Grand-Ducal Regulation on the energy efficiency of residential buildings (LuxEeB-H)) (after the changes to the minimum requirements, funding ‘below’ the minimum requirement will no longer be available) (see measure R 1). (2) Heavier scaling of funding for premium-performance deep renovations (prioritisation of ‘deep renovations’) (full renovations in stages will continue to be possible). (3) Reduction in consultation costs for individual measures and introduction of the option for (certified tradespeople) to provide consultations and requests for individual measures (new option, see measure F 3). (4) Consideration of further aspects relating to sustainable construction and the circular economy, as well as consideration of health-related aspects for the first time (health of residents, construction materials that are free from hazardous materials (safe list, Service for Indoor Environmental Analysis)) (aligned with Lenoz certification (direct link between PRIMe House and Lenoz in future). (5) Revision of the funding arrangements for technical installations (heating systems) based on a profitability analysis, with a focus on the promotion of fossil-fuel-free installations. (6) Replacement scheme: Bonus for replacing oil-fired boilers with a heating system based on fossil-fuel-free energy carriers (electricity (heat pump), wood (pellets), etc.) (‘mazut replacement scheme’) (where applicable including the replacement of gas-fired heating systems and direct electric heating systems).

Entry into force	New PRIMe House scheme from April 2021 (after expiry of the top-up programme 'gréngen Neistart' on the basis of the current PRIMe House scheme, which runs until 31 March 2021) (more stringent minimum requirements only after transitional period, from 2023 onwards)
Legislative basis	Revision of the Grand-Ducal Regulation on the Climate Bank and sustainable construction (of 23 December 2016)
Status	Currently being drafted
Exceptions	None, since it is a voluntary funding scheme
Funding/financial implications	Funding via the Climate and Energy Fund; in some cases also funded via revenues from CO_2 pricing (in some cases cross-subsidies from fuel tourism)
Accompanying/reinforcing measures	F 2 Expansion and streamlining of interest-free climate loans F 3 Access to the PRIMe House funding scheme for certified tradespeople + bonus payment for complete renovations only after a consultation with a certified energy consultant; significant increase in funding for consultation costs S 2 Harmonisation of reduced VAT rate to 3% for energy renovations R 1 Stricter minimum statutory requirements for individual components ...
Costs/profitability for owner/user	The increase in costs associated with a very good building envelope compared to building envelopes of average performance is low, and should be compensated for in large part with the funding available. As revealed by the cost-optimal analysis, the increased costs for classes A and B compared to the cost-optimal efficiency class D are so low that they can be compensated for with only moderate levels of funding.
State costs/revenues	No revenues; costs cannot be estimated accurately owing to lack of data (statistical data from past years for the PRIMe House scheme taken as a basis, factoring in increased demand for the new scheme because it is more attractive).
Potential reduction in final energy demand/GHG emissions	Moderate, since the number of people applying for funding has been relatively low to date.
Quantitative effectiveness	High
Timescale for effectiveness	Fast, since introduction is planned from 2021 onwards
Technical feasibility	All the necessary technologies and concepts are already available on the market (skilled trade businesses must however adapt to the new scheme, and will become more involved in the funding programme thanks to the option for tradespeople to carry out the consultations/submit requests for individual measures)
Political feasibility	Good, since decisions have already been made on the guiding principles (e.g. prioritisation of highly efficient renovations under the building renovation strategy, consideration of the circular economy and health, etc.)

Legislative jurisdiction	Ministry of the Environment, Climate and Sustainable Development (in cooperation with the Ministry of Energy and Spatial Planning and the Ministry of Housing)
Quantifiability for monitoring purposes	Only indirectly (through the evaluation of funding applications), since the measure interacts with many other measures (deliberate overlap, since this further increases the attractiveness and level of awareness)

<table>
<tr><td>R 1</td><td>Introduction of more stringent minimum requirements for the renovation of individual building envelope components (2021 Grand-Ducal Regulation on energy performance)</td></tr>
<tr><td>Type of measure</td><td>Requirement under regulatory provisions</td></tr>
<tr><td>Market segment</td><td>Residential buildings</td></tr>
<tr><td>Effect</td><td>Reduction in useful heat demand and GHG emissions for heating</td></tr>
<tr><td>Description</td><td>Tightening up of minimum energy requirements for renovations of individual building envelope components
<table>
<tr><td>Component</td><td>Unit</td><td>Current requirement</td><td>Proposal from 2023</td></tr>
<tr><td>U-value for exterior wall</td><td>W/(m²K)</td><td>0.32</td><td>0.28</td></tr>
<tr><td>U-value for roof/top floor ceiling</td><td>W/(m²K)</td><td>0.25</td><td>0.22</td></tr>
<tr><td>U-value for windows</td><td>W/(m²K)</td><td>1.50</td><td>1.20</td></tr>
<tr><td>U-value for cellar roof</td><td>W/(m²K)</td><td>0.30</td><td>0.27</td></tr>
</table>
The measure does not impose an obligation to carry out energy renovations, but instead sets out minimum requirements that must be met by energy renovations.
The cost-optimal analysis revealed that the current requirements fell short of the cost optimum. The proposed values are within the range of the cost optimum if the planned CO_2 pricing is taken into consideration.
More ambitious minimum requirements will mean that the least ambitious efficiency class under the PRIMe House funding scheme can be removed, and the funding can be targeted at more stringent requirements.</td></tr>
<tr><td>Entry into force</td><td>Grand-Ducal Regulation 2021 with effect from 2023</td></tr>
<tr><td>Legislative basis</td><td>Amendments to Grand-Ducal Regulation</td></tr>
<tr><td>Status</td><td>At the preparatory stage</td></tr>
<tr><td>Exceptions</td><td>If the building is protected as a historical monument or if it is not technically or financially feasible</td></tr>
</table>

Funding	No State funding measures if the minimum requirements are met, financial gain for property developers through reduction in energy costs
Accompanying/reinforcing measures	R 3: Duty to notify renovation measures involving the building envelope and heat supply (including individual measures) R 8: Introduction of an obligation to carry out renovations in the event that the support measures do not deliver adequate results F 1 Funding of PRIMe House scheme S 2: Harmonisation of the reduced VAT rate (3%) for energy renovations with the requirements of the PRIMe House scheme
Costs/profitability for owner/user	High qualities are compatible with profitability, as shown inter alia by the cost-optimal analysis.
State costs	No costs, since it is a mandatory requirement
Potential reduction in final energy demand/GHG emissions	high, since it is mandatory for all renovations apart from exceptions such as buildings protected as historical monuments; therefore it is applicable to all renovations in approximately 250 000 residential units (as at around 2017).
Quantitative effectiveness	High, since it is mandatory when renovating the component
Timescale for effectiveness	Short, since introduction in 2021 is possible, with entry into force from 2023 onwards after transitional period (where applicable)
Technical feasibility	High, thanks to the option of using tried-and-tested solutions
Political feasibility	High, due to alignment with outcomes of the cost-optimal analysis
Legislative jurisdiction	Ministry of Energy (2021 Grand-Ducal Regulation on energy performance) and Ministry of the Environment (Grand-Ducal Regulation on the PRIMe House scheme)
Quantifiability for monitoring purposes	Good, if R6 is introduced in parallel (duty to notify renovation measures involving the building envelope)