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D.T1.4.2 – School Building Stock Audit Methodology - Final Version

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Executive Summary

The aim of the ENERGE Project is to develop an educational framework that helps post-primary schools in the NWE region to reduce their primary energy consumption by at least 15% without major renovation, and to sensitize all stakeholders, i.e. pupils, teachers, directors, concierges, public building-owners. This report was prepared in the context of Work Package (WP) T1 – *Pre-Intervention Analysis, Baselining and Stakeholder Engagement*. It corresponds with the outcome of Activity T1.4 – *School Building Stock Audit Methodology*.

D.T1.4.2 is a development on the Initial School Building Stock Audit Methodology (D.T1.4.1) which includes a literature review for the specific region and climate, and on an analysis of the measurements obtained from the project schools that are monitored. Since extrapolation towards the complete building stock is highly dependent on the literature data quality and of the number of analysed buildings (minimum of 30), the focus is on a methodology that should be applicable in all NWE-regions and even others.

The emphasis of this report is on an audit methodology. At the core of the audit, is the collection of detailed measurement of electric and thermal energy (where possible) and its repartition into the main consumers, in addition to the monitoring of comfort parameters. Subsequently, specific consumption characteristics are calculated with the aim of comparing these to literature data and to the other NWE-pilot-schools. Extrapolation to the building stock of secondary schools of this age is of course desired, but only possible when coupled together with good literature data.

1.0 Introduction

School buildings represent 16% of the floor area of non-residential buildings in the EU[1]. Therefore, schools are not negligible in the movement towards reducing energy consumption and greenhouse gas emissions. In addition, future EU-citizens are educated there, which could and should serve as multiplier in terms of long-term impacts. Public buildings that have a great outreach and excellent dissemination, should set an example according to the Energy Performance of Buildings Directive (2010/31/EU) (EPBD).

In order to reduce greenhouse gas emissions in buildings one must know and assess the actual situation to be able to plan optimisation measures. Therefore, an audit of the actual heat and electricity consumption in the pilot schools will be described as well as the results obtained in the pilot schools in Luxembourg. A cautious extrapolation to the building stock is possible if the pilots are representative for their category, based on good literature data for a specific region and the building category.

The building stock methodology is hence generally applicable and can be replicated to different regions. Once sufficient buildings are analysed, and/or good literature data for a certain region at a specific building period and category is available, the complete NWE-stock can be assessed.

Hence, we detail subsequently the audit methodology for a school's individual building(s) and then describe how the building-stock could be assessed to meet EU greenhouse gas emissions reduction targets in the building sector.

1.1 Work Package T1 Objectives

The goal of WPT1 - "Pre-Intervention Analysis, Baselining and Stakeholder Engagement" is to provide the foundation for work in other implementation work packages. This is done by gathering historical data from the demonstration sites, analysing the governance structures and financial models within each school and by documenting existing resources & teaching within school curricula related to energy & energy efficiency. The results of WPT1 will inform the development of pilot programmes within schools to enable teachers, students, school maintenance staff etc. to engage in energy efficiency, and the development of the ENERGE Platform and its accompanying business plan. Ultimately, the goal of WPT1 is to satisfy the decrease of annual primary energy consumption of public buildings in characterising the current status regarding emissions from the schools, school governance & educational strategies. The Project Outputs, Deliverables and Work Packages are fully described in the Final Application Form.

[1] Building stock characteristics (https://ec.europa.eu/energy/eu-buildings-factsheets-topics-tree/building-stock-characteristics_en)

1.2 Role of Deliverable D.T1.4.2

The role of deliverable D.T1.4.2 is to provide a methodology that enables assessment of school buildings to inform effective energy/carbon reduction investments and target school management/governance, sectoral agencies & local/regional/national government practices.

1.3 Relationship with other activities in project

Deliverable D.T1.4.2 exists within Activity 4 in WPT1. This deliverable is closely related to Activity 3 in WPLT, both D.T3.1 and D.T3.2 (ENERGE Methodology - Initial and Final Version), but it's also related to the WP T2 Deliverables D.T1.1.2 Metering and Sensor Strategy, D.T2.1.3 – Key Performance Indicators for School Energy Management.

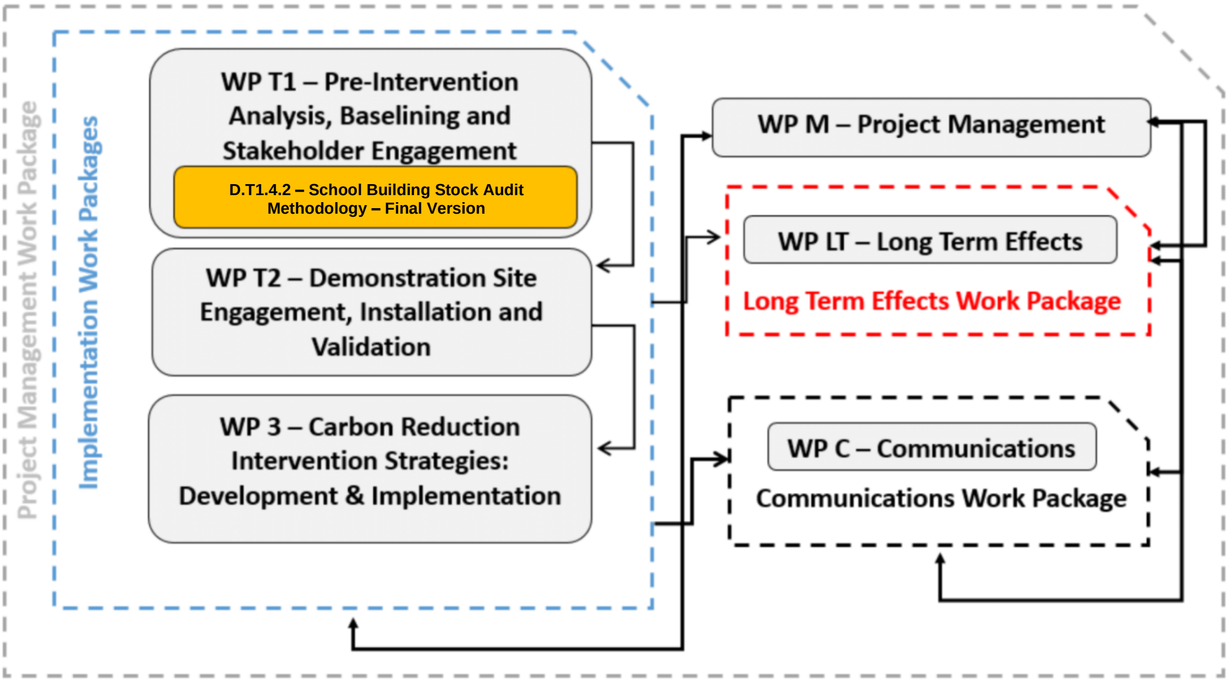

Figure 1.1: Relationship of D.T1.4.2 with other WPs and Deliverables

1.4 Approach to the Development of D.T1.4.2

The approach taken towards the development of D.T1.4.2 was initially to do a literature review and analyse the measurements obtained from the pilot schools, gathering information about energy audit and building stock methodologies in each NWE region. A second phase consisted on developing the school building stock methodology, by integrating the energy audit information obtained in the pilot schools along with the educational structures stock data of each country.

During the ENERGE Project the 3 pilot schools in Luxembourg were accessed in different levels, and the results from the energy audit were compared to the local benchmarks.

1.5 Document Outline

In line with the requirements of the Description of Activities described in the final accepted project application form, this report includes:

a) a consumption profile characterization through the energy audit procedure;

b) the definition of the school building stock audit methodology.

2.0 Energy Audit

In order to be able to develop any energy efficiency strategy, a full knowledge of the existing situation is needed. Consequently, the first step is to define a common procedure for the energy audit, suitable to all 6 countries composing the project, involving both historical data collection and ongoing measurements in pilot schools. Thereafter, it is necessary to gather benchmarking information about educational buildings in the different regions.

The energy audit itself consists of the analysis of the energy flows within a building. It consists of a method to determine the paths of used energy, from the different sources to the final consumers, understanding not only the detail of its distribution, but also the losses happening in the process. Such an assessment is essential when pursuing energy efficiency goals, as the first step to define a good improvement strategy is having a clear knowledge of the actual scenario.

Depending on the audit objectives, as well as on the budget, different approaches can be applied. There are four[2] basic levels of energy audit which are:

Type 0 – Benchmarking Audit

Involving a detailed preliminary analysis of energy usage and cost and identifying benchmarking indices.

Type 1 – Walk-through Audit

Among the least costly audit types, it consists of a tour to visually check each energy-consuming system, including the assessment of energy consumption to define patterns and trends, in addition to providing interesting low-cost savings opportunities through improvements in operational and maintenance practices.

Type 2 – Standard Audit

A detailed quantification of energy uses and losses is carried out, through a deeper analysis of the operational characteristics, systems and equipment, in addition to punctual

[2] Thumann, A., Niehus, T. and Younger, W. (2013). Handbook of energy audits. Lilburn, GA: Fairmont Press.

characteristic on-site measurement and testing. Improvements may be achieved by analysis of real operating time versus the real users' presence and minimizing excess-time, the assessing the efficiency of HVAC technology and optimizing their set-points.

Type 3 – Detailed Audit

A more complex audit involves detailed evaluation of the energy flow-patterns, by measurements and by means of computer simulation, taking into account not only the buildings technical information, but also considering external influences like climate and specific user data. Once the model is established and reflecting the real measured values, i.e. it is validated, then it is possible to simulate different improvement scenarios before proposing energy efficiency intervention measures and check their impact and cost. Furthermore, it is possible to compare specific efficiencies versus standard ones. Considering that Type 3 goes beyond the requirements defined on ISO 50002:2014 on Energy audits: Requirements with guidance for use, it is important to underline that it is not a mandatory step, here in the ENERGE context.

2.1 References

Considering the ENERGE project and the involvement of partners in different countries, the designation of common baselines is essential for the development of the study. Therefore, a clear definition of the reference area and the primary energy conversion factor of combustibles for heat and electricity supply has been discussed and defined, to make it possible to compare the results from different NWE-countries on the same basis.

2.1.1 Reference Area

After analysis, the gross internal area (GIA) was defined as the reference area for ENERGE independent of the country, although it is well-known that some countries use the gross floor area (GFA) while others use net floor area (NFA) in national energy certificates.

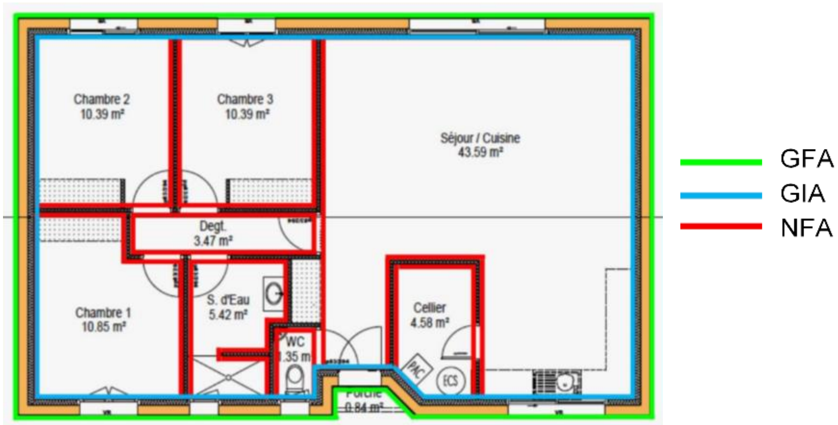

Figure 2.1: Example of GFA, GIA, and NFA in a 2D model[3]

[3] Da Cruz Antunes, Joël. Energy saving potential of secondary schools with low investment NWE ENERGE – Project. Masters thesis - University of Luxembourg - UL (2019)

As shown in Figure 2.1, the GIA corresponds to the total inside area enclosed by the external walls of a building, including the internal area of all walls and considering all floors in the building. The GFA corresponds to the sum of all conditioned/heated floor areas from all levels of a building calculated by the external dimensions of the building, including the area used up by walls, doors etc. The NFA is the sum of the usable floor areas of a building, excluding the wall surfaces.

2.1.2 Primary energy conversion factor

A clear and unique definition of the reference area and conversion factor of combustibles for heat and electricity supply is necessary within ENERGE. To make it possible to compare the results from all ENERGE-regions we propose to use a primary energy factor of 1.1 for all type heat energy (i.e. heat from natural gas, fuel-oil, wood-pellets) and 2 for electricity, to calculate the primary energy based on final energy, here based on the lower calorific value. Final energy is the energy that crosses the building's borders, e.g. electricity or fuels or heat and that is paid by the clients. Normally these primary energy factors are defined on national basis. They account for all production and distribution losses before the final energy arrives at the building. But within ENERGE, we apply the same factors for all countries for reasons of comparability.

2.2 Data collection

Considering the context of this project, the energy audit procedure proposed is composed by the following steps:

2.2.1 Scope definition

The first step is to clearly define the audit scope, it's objectives and the analysed perimeter, making sure that the effort is concentrated in the right place.

2.2.2 Meeting

A meeting involving the schools' stakeholders, in order to make everyone aware of who is part of the process, what ENERGE goals are, and what will be necessary from each one of the stakeholders.

2.2.3 Visit

During the visit, it is important to understand how the building is used, but most important, how is it operated. This includes information on which systems are implemented, how the equipment is managed and who is responsible. Continuous exchange between the local ENERGE team and the national ENERGE partner is self-evident.

2.2.4 Document collection

Gathering plans, technical description of equipment (heating system, ventilation, lighting), electricity and heating bills, buildings occupancy, schedules, energy certificates will assist in forming a holistic view of each of the schools.

2.2.5 Measurements

This data collection must follow the ENERGE D.T1.1.2 Metering and Sensor Strategy, although it can go further by adding other additional measurements specifically defined for the studied site.

2.3 Data analysis

Through the analysis of the gathered information from the previous step, it is possible to establish the energy flow and define the largest consumers. Energy certificates may already give a good overview, helping to identify the values of heat and electricity consumption (calculated and/or measured), reference area in m² with a clear definition of the reference area (GFA or NFA), year of construction, potential subdivision of school building, and heating system, etc. Based on building plans, it will be possible to check and calculate the 3 different areas (GFA, NFA, GIA) and then deduce the abovementioned energy characteristics.

From the visit, the understanding of energy flows, the measurements and focusing on largest consumers it is possible to already identify certain simple measures, usually related to operational and maintenance activities, that can lead to interesting reduction in the energy consumption.

The different types of use must be separated, in order to make it possible to understand where the big consumers are. It can be grouped as follows:

- Heating and cooling systems

  The heating system characterisation with detailed information about the production, distribution and transmission provide the necessary information to understand the energy flow, as it is essential to verify the systems' operational modes.

- Hot water

  As per the heating system analysis, it is important to characterize the hot water production, distribution and operation modes. Even though, typically for schools, except for the canteens, it is not of high importance.

- Ventilation

  It is necessary to understand the ventilation modes, the equipment involved and its performance and operational set-points in case of mechanical ventilation. Check what is the share of used electricity for ventilation either by measurement (e.g. by permanent or temporary electric meters as used for instance in ENERGE or even by estimation based on power and use-time). Reduce ventilation operation time to factual use time, wherefore multiple automatization steps are possible.

- Lighting

In this case, one should check operational modes and who is responsible for switching off, if not used, during day and after school. If it is controlled, is it manually, by a bus-system or time-control. Modern systems have presence detection and automatic dimming, to compensate once natural light is not sufficient. Check what is the share of used electricity as detailed above.

- IT

One must check if there are server rooms and permanent IT-services, and in case of positive answer, check what is their share of used electricity.

- Sports halls

Considering that the operation of sports halls are different to the rest of the school building, it is important to analyse its specific consumptions of lighting, ventilation and heating. Again, check of what is the share of used electricity.

- Kitchen

From the number of served meals it is possible to estimate the kitchen consumption. It is an important parameter considering that canteens typically raise the specific electric consumption considerably, e.g. approx. 10 kWh/m^2 where reference surface m^2 is the total conditioned surface and not only the surface of the canteen. It can offer an interesting optimization potential for energy saving after the share of used electricity was identified

- Workshops

These rooms usually have different kinds of equipment, leading to different energy consumption patterns. Due to the large scatter of specific consumption, its electric consumption share should be identified, and machine operation stand-by time minimized.

2.4 Benchmarks

Benchmarks are essential to compare and extrapolate both the collected data and the overall building stock. To compare between the different countries, it is also necessary to define a methodology to neutralize climate effects in NWE, for example by use of heating degree days as weighing factor as detailed in 3.3.2.

2.4.1 Literature Review

The literature review is important to identity relevant references, as stated by Ages (2007)[4] for Germany, to find the regional classification of final energy consumption, and to define a strategy to bring all regions to the same basis, so that they can be compared.

2.4.2 Regional Historical Energy Consumption Data

The analysis of historical energy consumption data of educational buildings in a given region may also be used for determining benchmarks. As educational buildings can differ in both structure and operational mode, it is proposed in Annex I, a simple questionnaire to identify the reasons for consumption variations.

2.4.3 Heat

The total heat consumption and its repartitions must be established, at least for the pilot-schools and for as many as the schools as possible (where information is available), to establish better regional benchmarks.

2.4.4 Electricity

The total electricity consumption and its repartitions must be established, at least for the pilot-schools, and for as many as the information is available), to stablish better regional benchmarks.

2.5 Educational aspect

Gathering on-site measurements to find the characteristics of the pilot buildings is a great opportunity to involve the students and teachers in the process by applying a “learning by doing” approach, i.e. by including them in the data collection and analysis, and giving sense to these numbers, so they can start to understand various orders of magnitude related to energy consumption, and even apply this concept at home.
Another approach is to involve the students in the analysis of the proportion of renewables in the energy sources at the school, and organize workshops to propose strategies to reach higher levels.

[4] AGES (2007): Verbrauchskennwerte 2005, Energie und Wasserverbrauchskennwerte in der Bundesrepublik Deutschland, Forschungsbericht der ages GmbH, 1. Auflage, Münster, 2007 (https://ages-gmbh.ageslogger.de/images/downloads_von_der_homepage/kennwerte/kw2005_inhalt_und_methode.pdf)

3.0 School Building Stock Audit Methodology

The total number of a specific type of building in one study zone defines the stock. There are numerous methodologies to establish these building stocks, with accuracy levels directly related to the quantity and quality of available data. As the data sources vary widely at different administrative levels, it is challenging to apply a single methodology across all building stocks[5]. And considering the multi country context of ENERGE, it is necessary to analyse all available data of any region in the same manner to compare to be able afterwards to develop a common improvement methodology.

3.1 Reference

According to a literature study developed by Hoos (2015), the final heat energy of schools does not directly correlate with year of construction due to subsequent partial or full modernization and renovation activities. Hence, it is better to use energy as classification parameter, instead of the building age. He proposes then to separate buildings into 3 classes, entitled low, medium and high final heat energy consumption, based on literature review, as presented in Table 3.1.

Table 3.1: Building classification according to end-energy for heat, including hot water [6]

End-energy including hot water	$kWh/(m^2/y)$
Low consumption	≤ 90
Normal consumption	90-160
High consumption	≥ 160

3.3 Analysis strategy

The common methodology for defining and assessing the school building stock needs to gather existing literature from different regions and then define a simple, but still approximate method to neutralize climate influences (ref. to par. 3.3.2). Then, assessment of the individual pilot-schools and comparison between NWE-regions becomes feasible.

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[5] Neale, Adam. "Development of a stochastic virtual smart meter data set for a residential building stock - methodology and sample data." Journal of building performance simulation 13.5 (2020):583-605. Web

[6] Hoos, Thorsten, Alexander Merzkirch, Stefan Maas, and Frank Scholzen. "Energy Consumption of Non-retrofitted Institutional Building Stock in Luxembourg and the Potential for a Cost-efficient Retrofit." Energy and Buildings 123 (2016): 162-68. Web.

3.3.1 Literature Review

Hoos in 2013[7] studied the school building energy stock in Luxembourg by analysis of 29 buildings from a total of 45 secondary schools in the country.

His analysis is based on the final energy used for heating, including hot water, divided by the Gross Floor Area (GFA). To check for the type of distribution with only 25 samples but still sufficient accuracy, Hoos (2013) used statistical tools and assumptions for the analysis and the calculation.

Even though the samples were not perfectly normally distributed following the Kolmogorov-Smirnov-Test, the whole building stock can nevertheless be presented by a normal distribution. A “t-test” was used to calculate a confidence interval in which the real mean value of the whole building stock lies within a probability of 95 %[8].

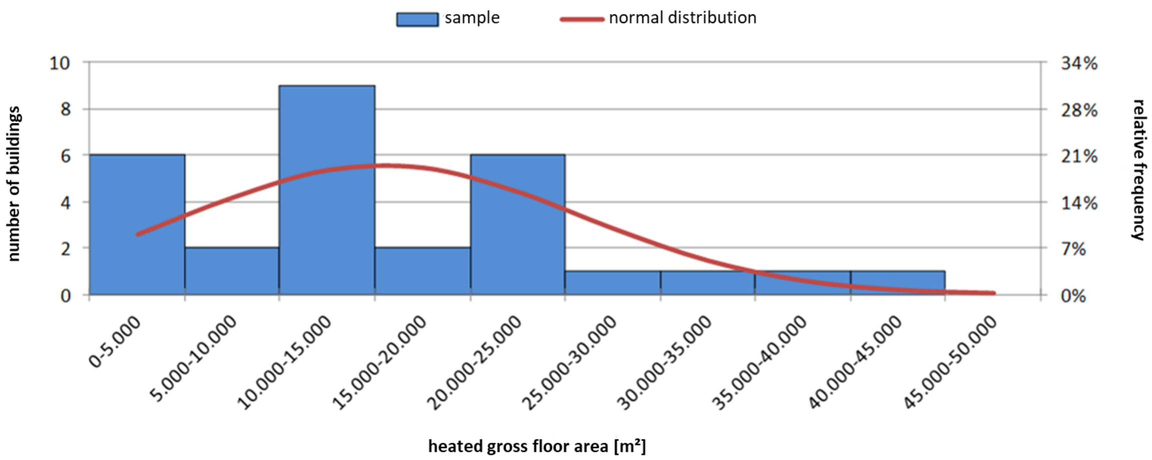

Figure 3.1: Frequency distribution of the heated gross floor area (GFA) of 29 school buildings in Luxembourg

[7] Hoos, Thorsten. Einsparpotential und ökonomische Analyse der energetischen Sanierung staatlicher Gebäude in Luxemburg. Aachen: Shaker, 2013. Print.
[8] Hoos, Thorsten. Einsparpotential und ökonomische Analyse der energetischen Sanierung staatlicher Gebäude in Luxemburg. Aachen: Shaker, 2013. Print.

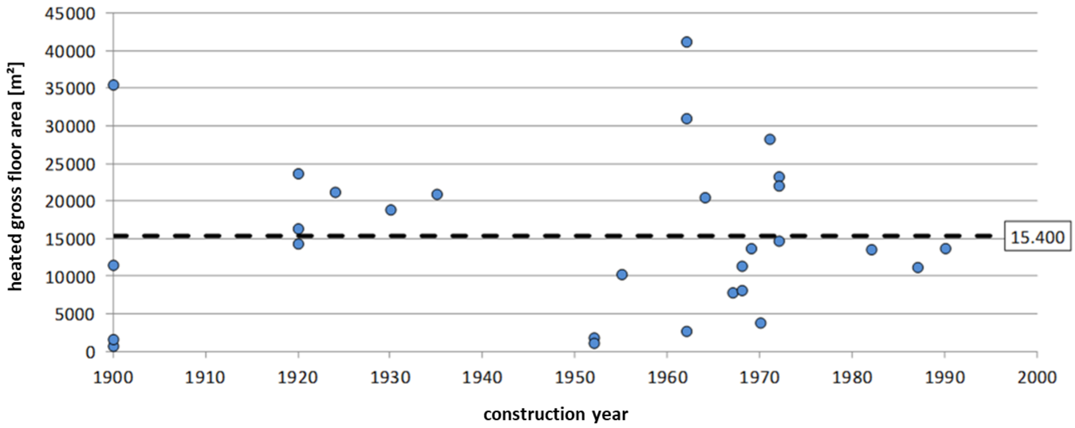

Figure 3.2: Size versus year of construction

In Hoos in 2013[9], the 26 sample schools were analysed for used final energy including hot water for every building group was approximately normally distributed according to the Kolmogorov-Smirnov-Test. The heat demand of buildings with district heating was increased by 10% to account for the process of the heat production to achieve a fair comparison with others, that produce their heat inhouse. The data was climate compensated by the ratio of the long term mean heating degree days $G_{t20/15}$ versus the actual value of this specific year in Luxembourg.

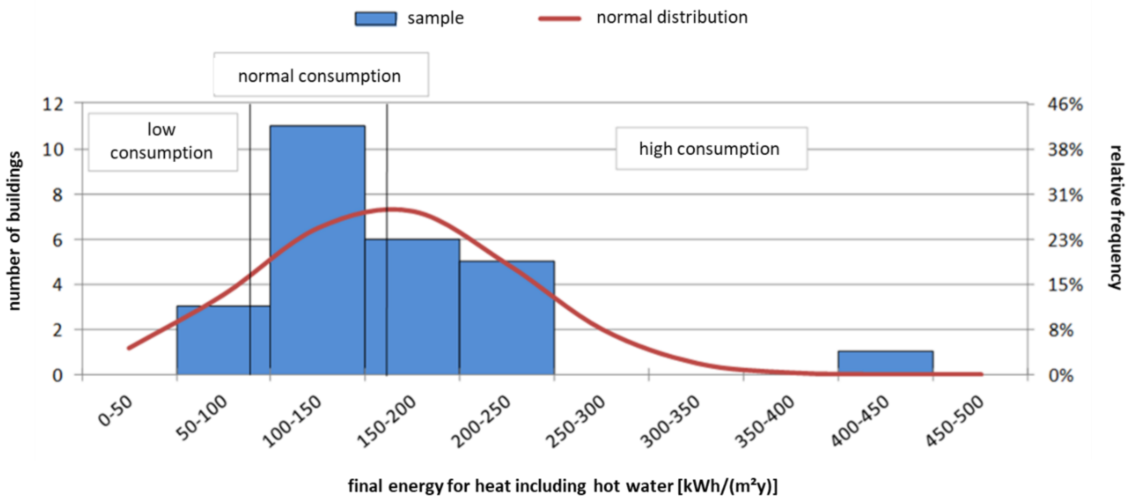

Figure 3.3: Distribution of the final energy, classified according to the final energy consumption referring to gross floor area (GFA)

[9] Hoos, Thorsten. Einsparpotential und ökonomische Analyse der energetischen Sanierung staatlicher Gebäude in Luxemburg. Aachen: Shaker, 2013. Print.

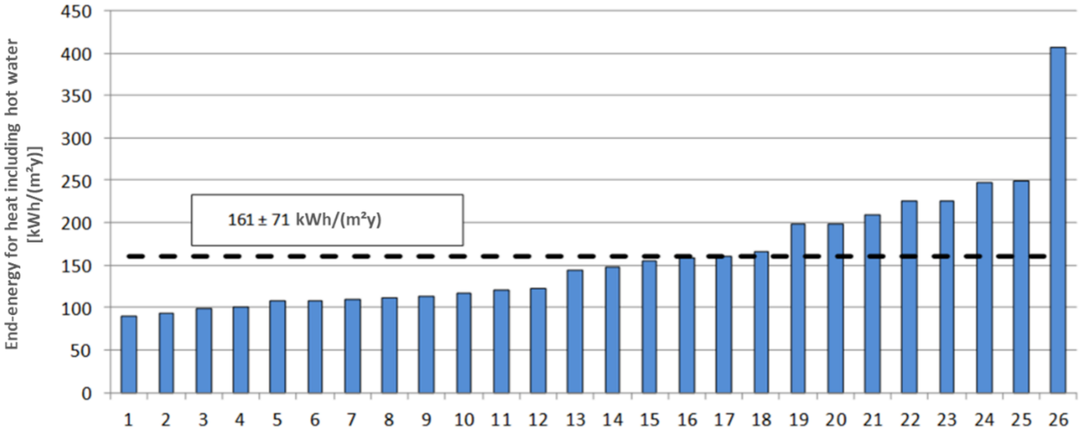

Figure 3.4: Final energy for heating including hot water, referred to gross floor area (GFA)

The same procedure was done to analyse the electricity consumption of the 24 school buildings in the sample.

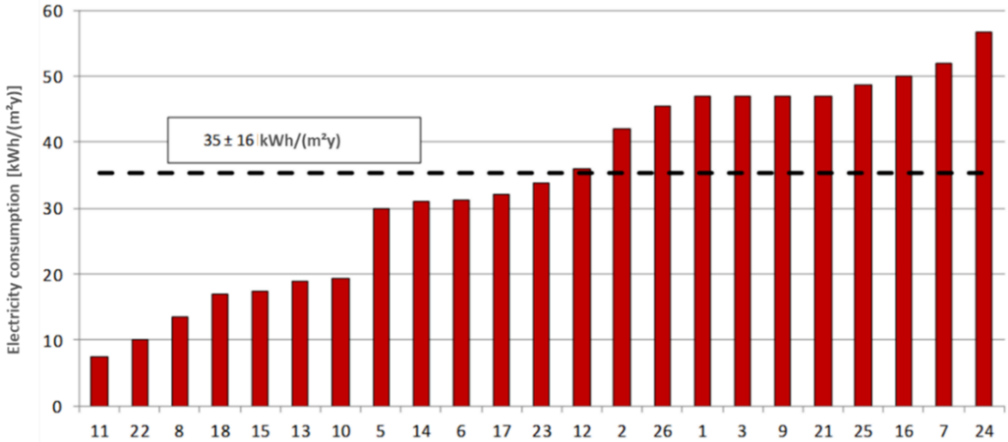

Figure 3.5: Final electricity, referred to gross floor area (GFA)

Table 3.2: Summary of calculated mean values referred to gross floor area (GFA)

	Calculated	Amount of sample buildings
Mean heated gross area of sample incl. 95% - confidence interval	15,400 ± 4,000 m²	25
Mean end-energy for heat use incl. hot water of sample incl. standard deviation	161 ± 71 kWh/(m²/y)	26
Mean end-energy for electricity	35 ± 16 kWh/(m²/y)	24

3.3.2 Neutralizing Climate Influence

Considering the multizone context of the project and the climate variations in NWE, it is recommended to neutralize the effect of the local climate. Therefore, in the present analysis it is proposed to use Heating Degree Days (HDD) for normalization[10], adopting Brussels, in Belgium historical data for the last 20 years as reference. It is important to state that as the final consumption E is not fully proportional to temperature difference between inside and outside of the building, but it's also related to internal or solar gains, thermal inertia or domestic hot water supplies to name just some, meaning that many buildings have a baseload energy usage independent of the weather or ΔT. Although it is a simple approach for a compensation, it is a well-known and widely used framework:

$$E_{vhb} = E_{hb} \times \frac{HDD_{20/15_m}}{HDD_{20/15}}$$

Where E_{vhb} is the normalized thermal end energy consumption of the building for average climate conditions, E_{hb} is the measured thermal end energy consumption of a specific year, $HDD_{20/15_m}$ is the average heating degree days for a long period of time in this region and $HDD_{20/15}$ is the heating degree days of this year.

4.0 Results School Building Stock Audit Methodology

The School Building Stock Audit Methodology was applied to the pilot schools in Luxembourg and the results were compared to the local benchmarks, as follows. In each pilot school in Luxembourg, a different level of the energy audit was performed, according to the available data. The energy audits were done starting from a visit, followed by documentation analysis, benchmarks definition, measurements, and analysis of the operational modes.

4.1 Energy Audit

From the analysis of the information provided by the school building owner Administration des Bâtiments Publics, such as the energy bills to verify the total final energy consumption, the buildings plans to identify the reference areas, and from the reference defined on 2.1.2 Primary energy conversion factor, it was possible to outline the specific primary energy requirement for the Lycée Technique de Bonnevoie (LTB), Lycée Technique du Centre (LTC) and Lycée Technique d'Ettelbruck (LTEtt).

Table 4.1: Final and Primary Energy

	LTB *Average 2017-2020*	**LTC** *2018*	**LTEtt** *Average 2016-2021*
Final Energy kWh/m²/y			
Electricity	39	52	47
Heat including Hot Water	70	142	102
Total	**109**	**194**	**149**

[10] Thewes, Andreas, Stefan Maas, Frank Scholzen, Danièle Waldmann, and Arno Zürbes. "Field Study on the Energy Consumption of School Buildings in Luxembourg." Energy and Buildings 68.PA (2014): 460-70. Web.

Primary Energy kWh/m²/y			
Electricity	77	104	94
Heat including Hot Water	77	156	112
Total	**154**	**260**	**206**

The thermal balance of the Lycée Technique de Bonnevoie building was analysed using the software LESOSAI, following the assumptions of the norm ISO 13790:2008 for educational buildings. As output, the model shows the building's thermal balance, as presented in Figure 4.1, as well as the heating demand of 72 kWh/m²/y, split into a space heating demand of 58 kWh/m²/y and a domestic hot water demand of 13 kWh/m²/y, with 20% of technical losses.

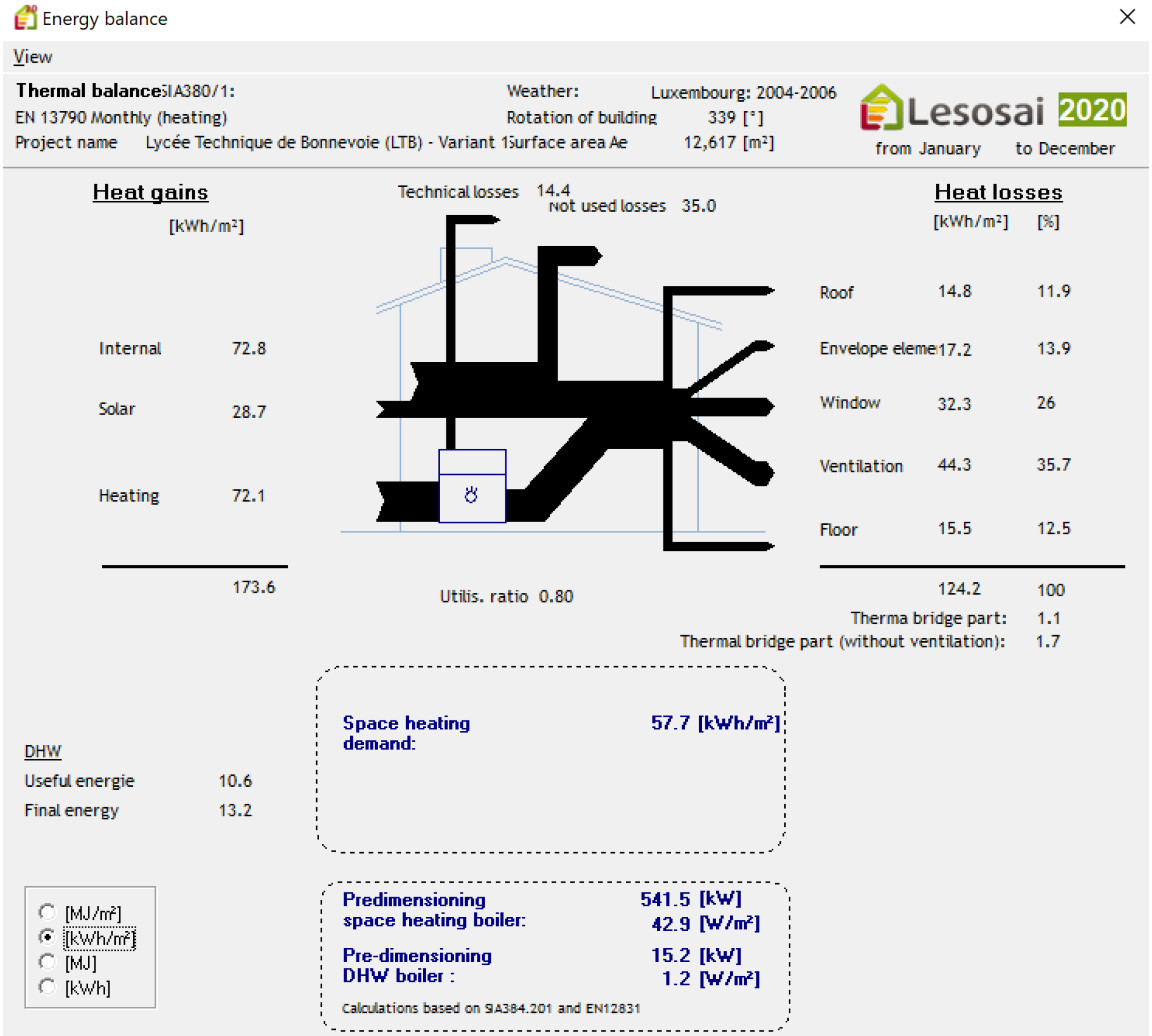

Figure 4.1: Lycée Technique de Bonnevoie thermal balance

4.2 Analysis

Considering that from the comparison between the Gross Floor Area (GFA) and the Gross Internal Area (GIA), ENERGE reference, in the studied buildings, a typical difference of 5% was identified and a correction factor was applied to the previous values, to make it possible to compare to the local literature benchmark, as it's possible to visualise on Figure 4.2 and Figure 4.3.

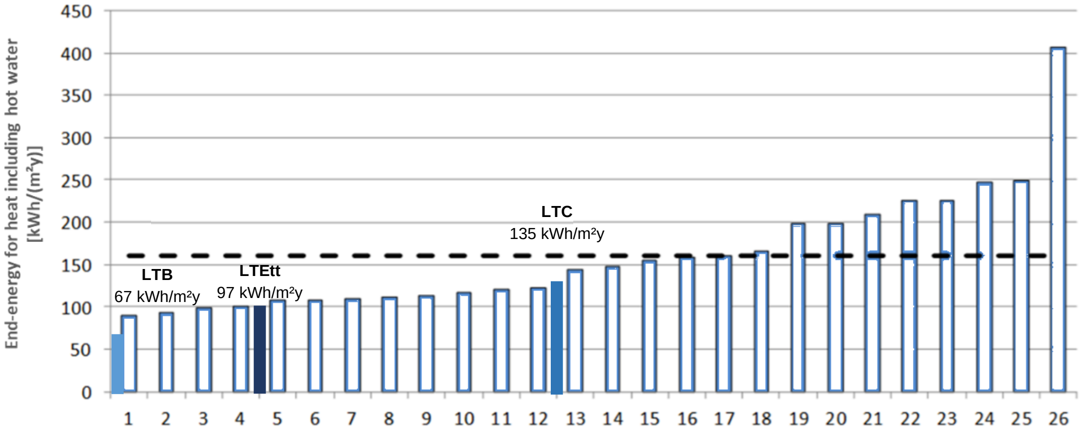

Figure 4.2: Final energy for heating including hot water, referred to gross floor area

From the comparison with the Luxemburgish Benchmarks it's possible to check that for heating, the 3 school buildings are among a normal consumption level, and even though they are not among the newest in the country, they are all placed below the national average. This shows that they have a lower specific consumption when compared with the average in the country, meaning that they have a better energy performance, and thus there is probably not easy to tackle energy savings potential on the heat side, without major renovation.

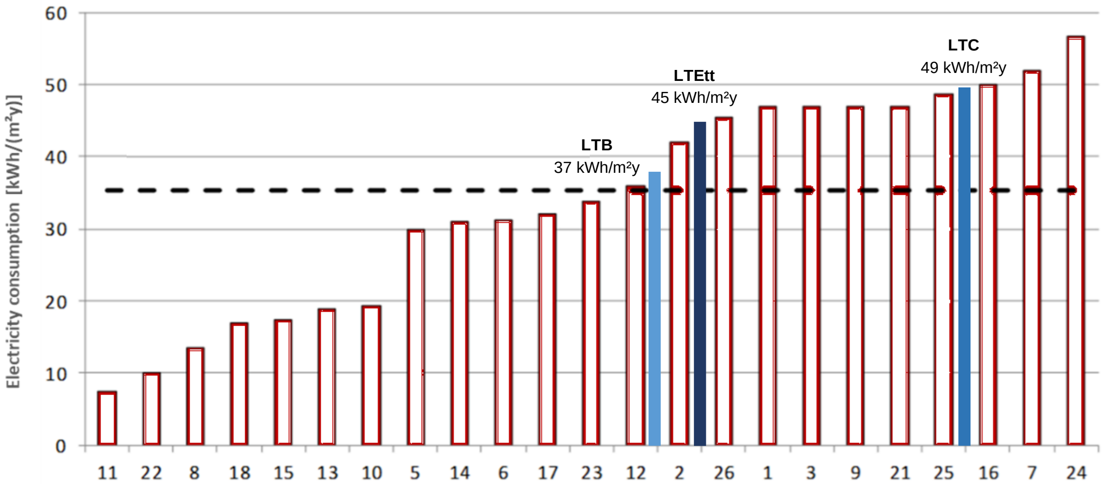

Figure 4.3: Final electricity, referred to gross floor area

As per the electricity consumption, on the other side, for the 3 analysed schools, the specific consumptions are all above the average, indicating that there is potential for savings. From the analysis of the data collected by the electrical meters described on ENERGE D.T1.1.2 Metering and Sensor Strategy, as well as some supplementary measurements using a more portable meter, it was possible to evaluate the electricity distribution within the Lycée Technique d'Ettelbruck, identify the big consumers and where the energy efficiency measures could focus.

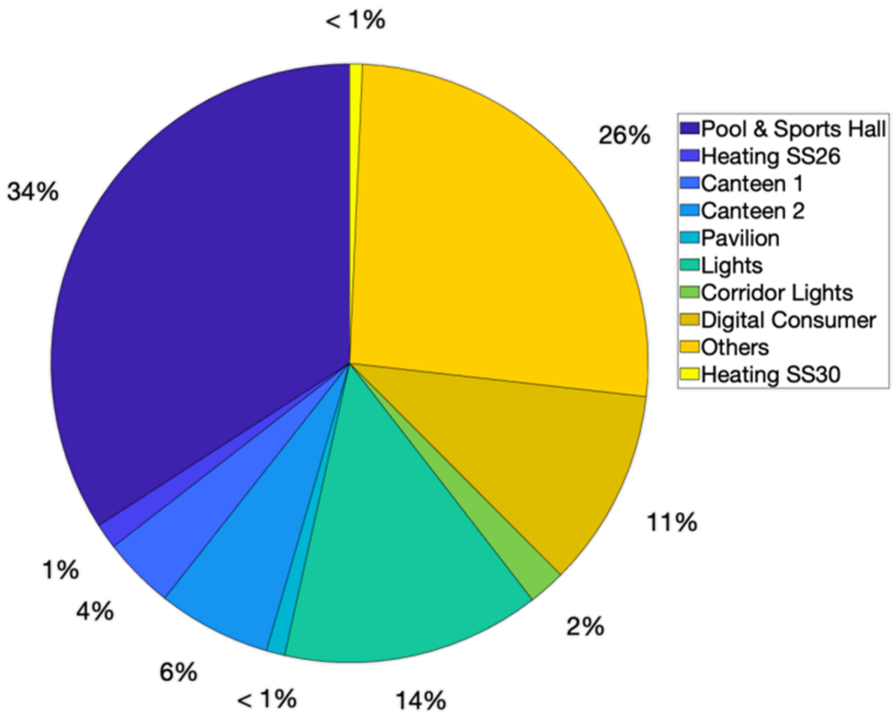

Figure 4.4: Complete Distribution of the electricity from the LTETT[11]

From Figure 4.4 it's possible to see that the swimming pool building represents 34% of the electricity demand of the entire school, due to the ventilation system, as well as the circulators necessary to keep the water levels. Lighting also represent a big part of the school consumption. Counting for 26% of the consumption is the category 'Others', where all other devices such as small vents, boilers, kitchen appliances in the snack lounge, server room air conditioners etc. are represented.

It is important to state that the school is already working to replace the lighting with LED devices, but also, there's an increase in the use of electronic devices, due to the so-called "iPad-Classes", which require not only the charging of the devices, but also the operation of an enlarged network infrastructure.

[11] Fluhe, Gilles. Analysis of electric energy consumption of LTETT in Luxembourg within the NWE-project ENERGE. Masters thesis - University of Luxembourg - UL (2022)

4.3 Comfort Aspects

As buildings exist for the main role of sheltering their users against the harsh external environment conditions[12], it is essential to consider comfort aspects when proposing strategies to reduce energy consumption. In order to guarantee comfort levels are not impacted by the energy consumption reduction strategies, the comfort levels are being monitored at the pilot schools using indoor climate sensors, following the ENERGE D.T1.1.2 Metering and Sensor Strategy. From Figure 4.5 to Figure 4.12 it's possible to see the monitoring of comfort aspects at Lycée Technique de Bonnevoie (LTB) and Lycée Technique du Centre (LTC) from March to December 2021.

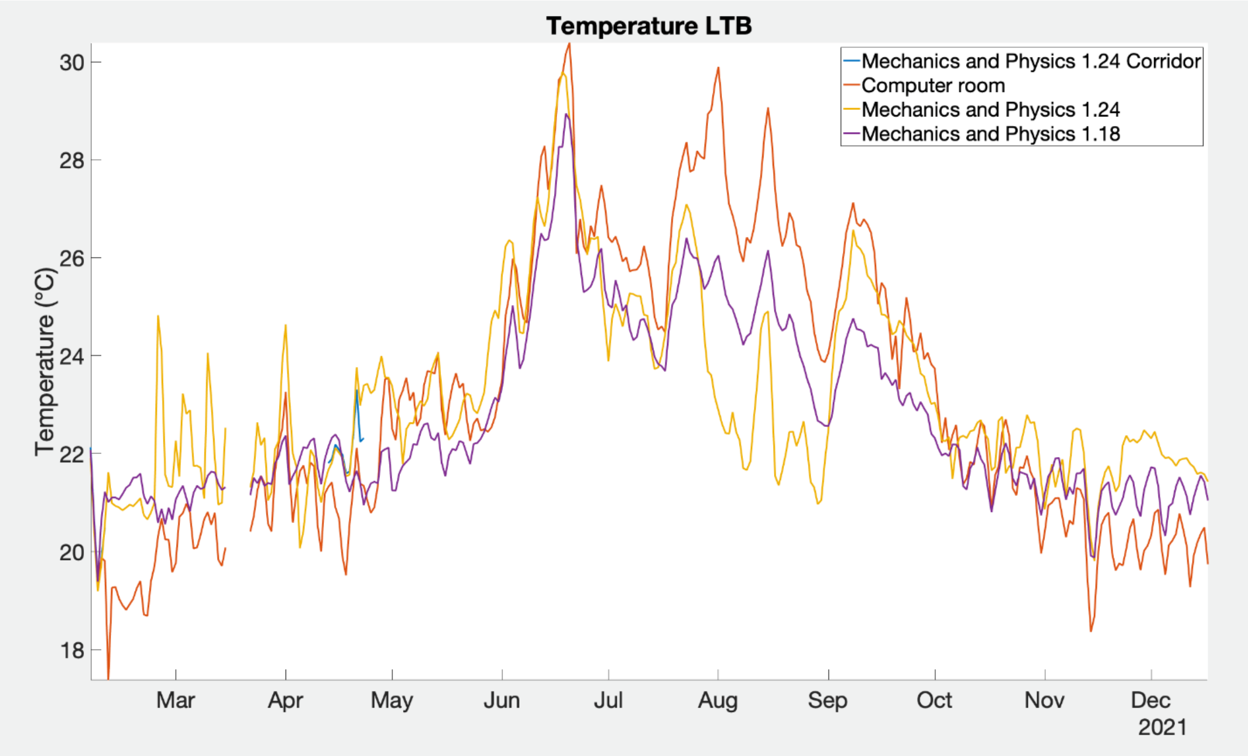

Figure 4.5: Temperature monitoring at LTB from March to December 2021

[12] Roulet, Claude-Alain. Santé Et Qualité De L'environnement Intérieur Dans Les Bâtiments. 2ème éd. Mise à Jour Et Complétée. ed. Lausanne: Presses Polytechniques Et Universitaires Romandes, 2008. Print.

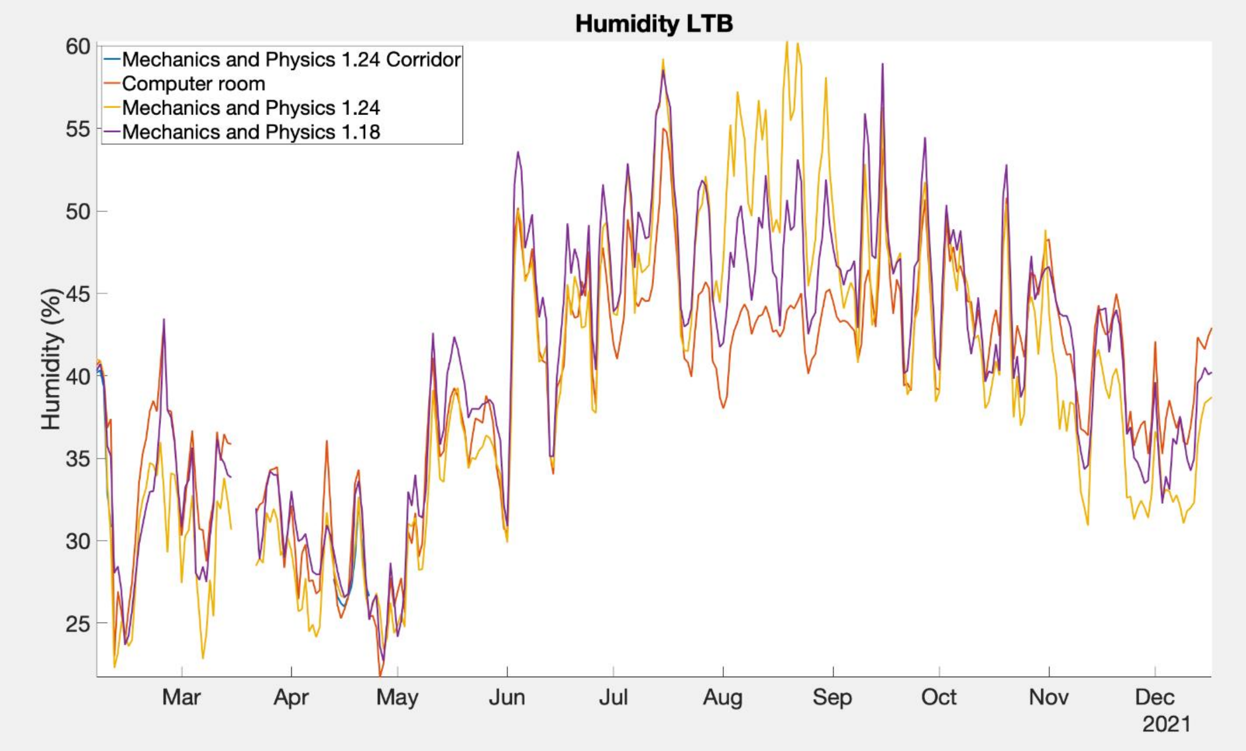

Figure 4.6: Humidity monitoring at LTB from March to December 2021

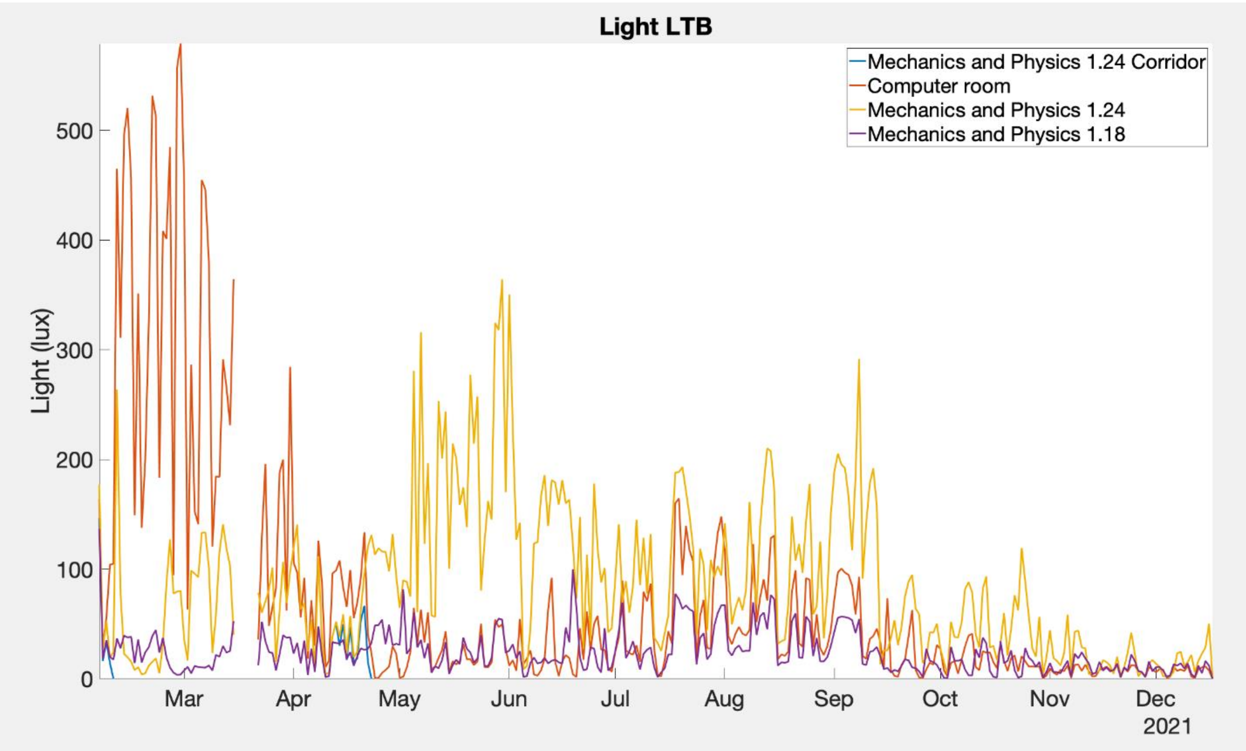

Figure 4.7: Light level monitoring at LTB from March to December 2021

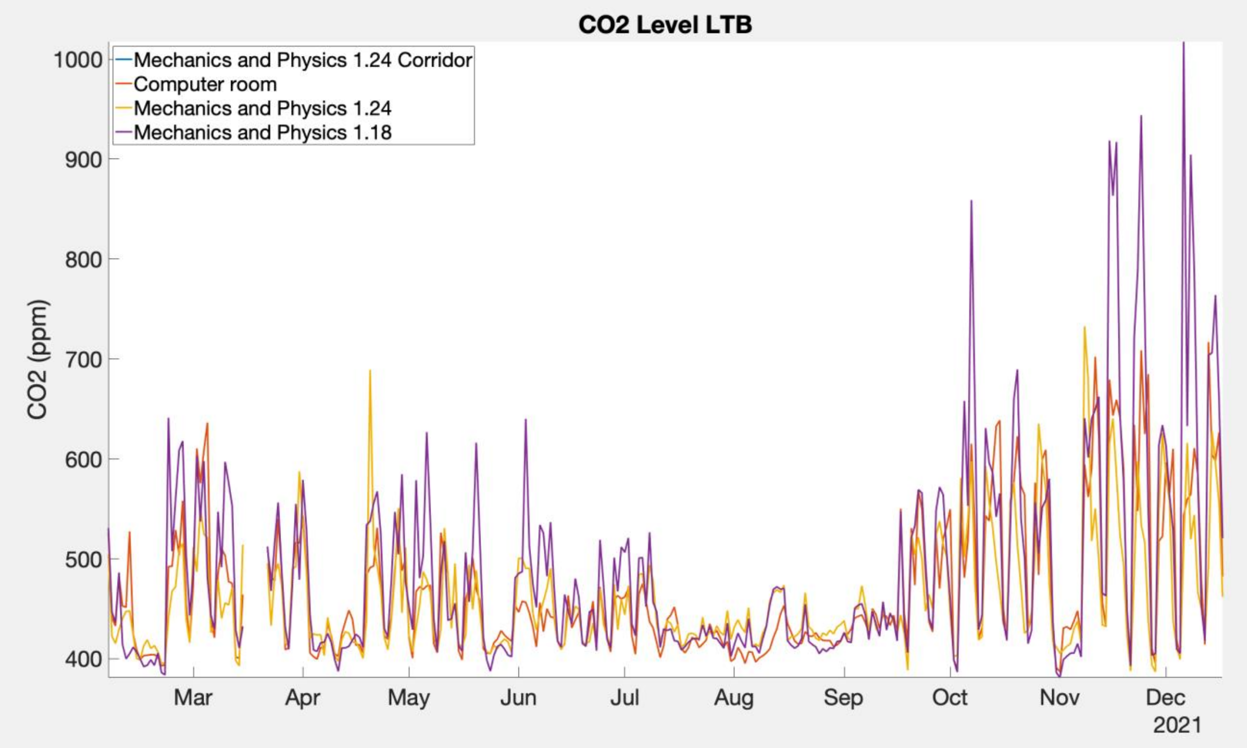

Figure 4.8: CO_2 monitoring at LTB from March to December 2021

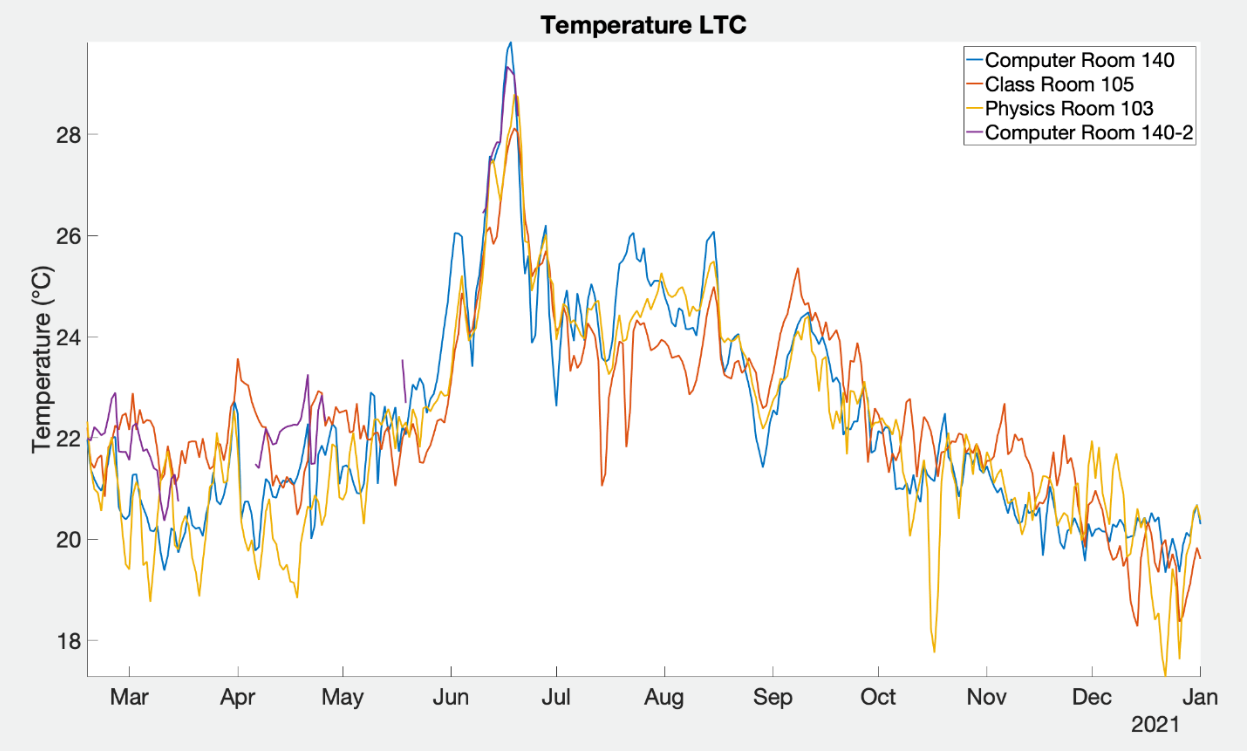

Figure 4.9: Temperature monitoring at LTC from March to December 2021

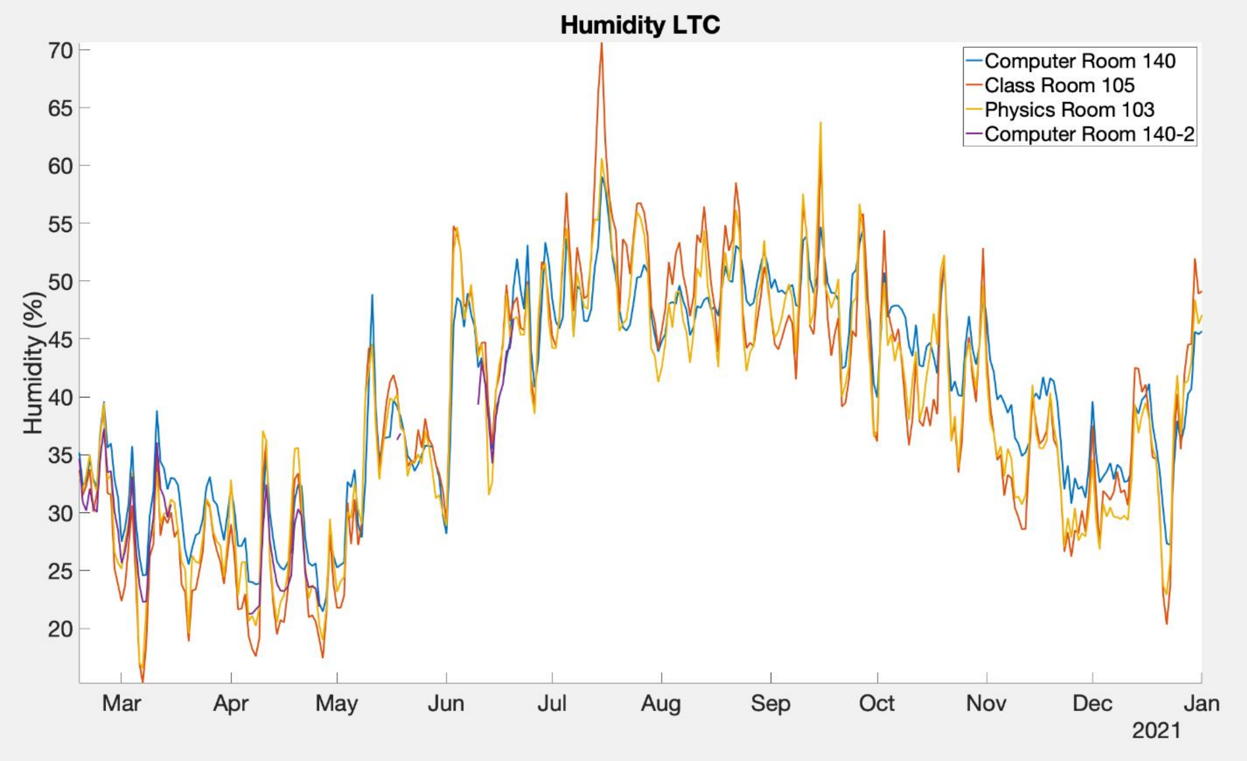

Figure 4.10: Humidity monitoring at LTC from March to December 2021

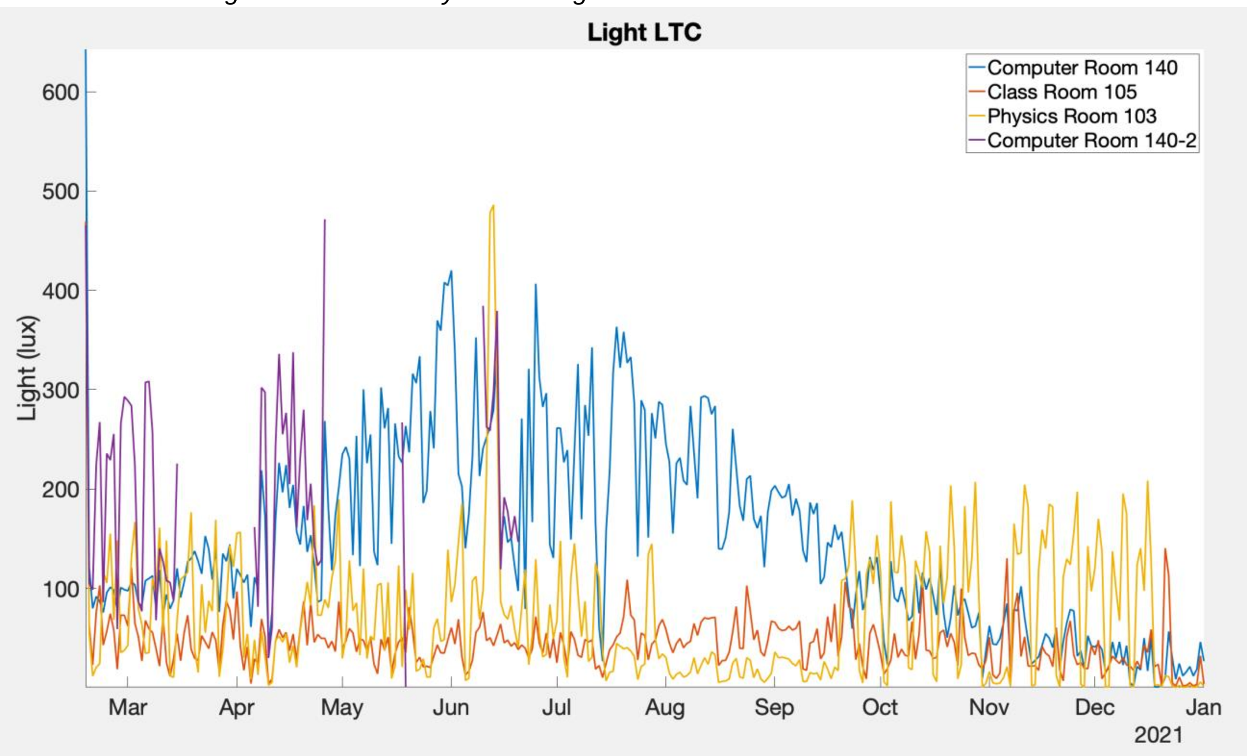

Figure 4.11: Light level monitoring at LTC from March to December 2021

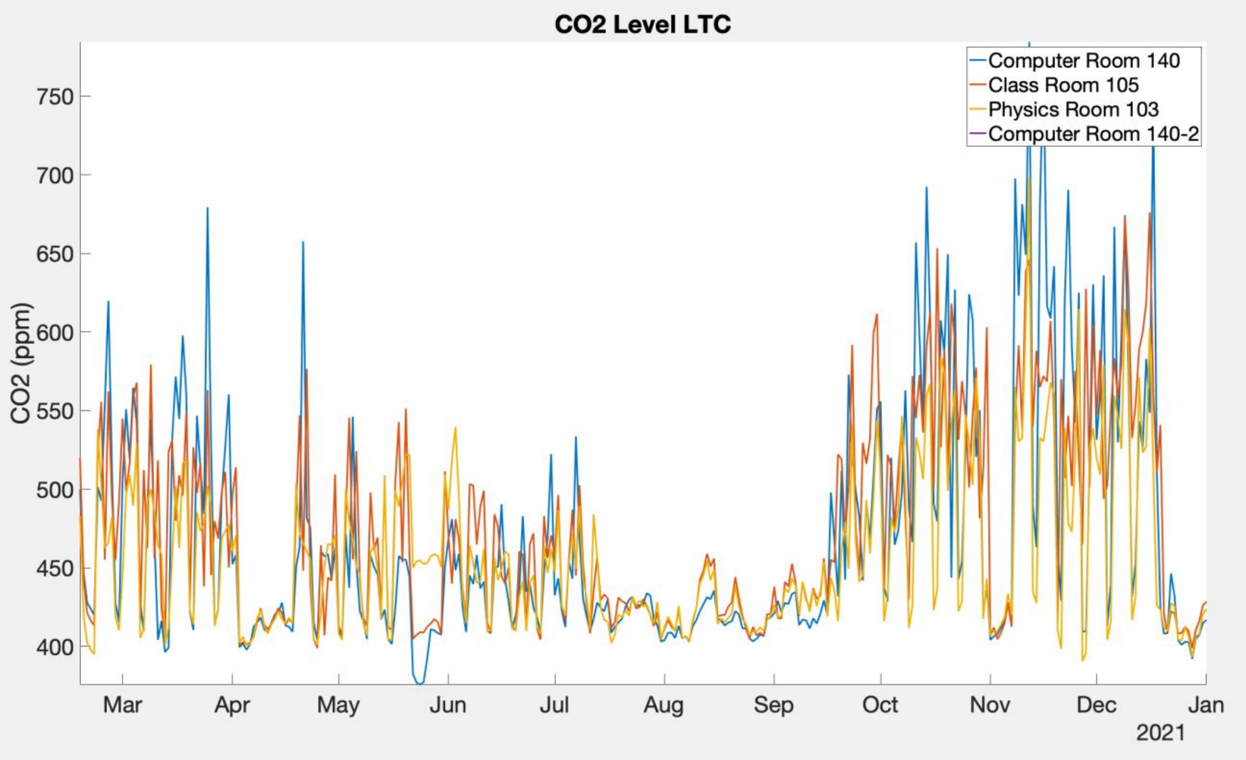

Figure 4.12: CO_2 monitoring at LTB from March to December 2021

5.0 Conclusion

Once the specific heat and electric consumption is known, the specific primary energy consumption can be calculated with the weighting factors (1.1 for heat and 2 for electricity). In Chapter 3.1, Figure 3.4 and Figure 3.5 we find data from literature for older secondary schools, for instance for Luxembourg, allowing us to assess the pilots in the country. Furthermore, we can see that for this region, a "good" building (the lower third) in the same category consume less than 120 kWh/m^2 of heat and less than 20 kWh/m^2 of electricity leading to 120 kWh/m^2 x 1.1 + 20 kWh/m^2 x 2 = 172 kWh/m^2 of primary energy per gross m^2. Assuming now that Gross Internal Area (GIA) is roughly 95% of Gross Floor Area (GFA), we can define 172 kWh/m^2 / 0.95 ≈ 180 [kWh/m^2] as primary energy threshold value for a "good" older school. In the same manner we find for the "average" values for primary energy in a school to be 260 kWh/m^2 ± 115 kWh/m^2. As a reminder related to comfort aspects, energy savings strategies should not reduce comfort level for building users.

6.0 Opportunities and implications for ENERGE

From the results obtained in Luxembourg is interesting to see that it gives an indication on where the energy saving actions should focus, representing an important step to build the ENERGE Methodology, together with the remaining deliverables. The implementation of this Building Stock Methodology allows to stablish an overview of the scenario for a specific building category and in a particular region. As an educational aspect, it is essential to involve the students on the energy audit stage, in the analysis of the data, comparison with benchmarks, as well as in the definition of the energy savings strategy. This action helps not only to bring awareness on the subject, but also to enhance the engagement levels of the stakeholders.

6.1 Opportunities for future ENERGE activities

Even when ENERGE is completed, the teachers, directors, concierges and building owners should continue with the efforts to monitor and save energy. We have just detailed in the conclusions that the ratio between “good” and “average” older school in Luxembourg is 172/260 ≈ 70% whereof a large part can be influenced by behaviour of all enumerated stakeholders, if they act synchronously and push in the right direction. Perhaps comfort levels may also be increased, as according to Roulet[13], there is astonishingly no correlation between Building Sickness Index (BSI) and Energy Index. This means that contrary to public opinion, indoor wellbeing does not increase with increasing use of energy, once a minimum is achieved.

[13] Roulet, Claude-Alain. Santé Et Qualité De L'environnement Intérieur Dans Les Bâtiments. 2ème éd. Mise à Jour Et Complétée. ed. Lausanne: Presses Polytechniques Et Universitaires Romandes, 2008. Print.

Annex I

<table>
<tr><th colspan="8">General</th></tr>
<tr><td>Name of the building</td><td colspan="3"></td><td colspan="4" rowspan="6">Picture</td></tr>
<tr><td>Building type</td><td colspan="3"></td></tr>
<tr><td>Address</td><td colspan="3"></td></tr>
<tr><td>Contact person</td><td colspan="3"></td></tr>
<tr><td>Phone number</td><td colspan="3"></td></tr>
<tr><td>E-Mail</td><td colspan="3"></td></tr>
<tr><th colspan="8">Building information</th></tr>
<tr><td>Year of construction</td><td></td><td>Extension</td><td colspan="2"></td><td>Renovation</td><td colspan="2"></td></tr>
<tr><td>Construction method</td><td colspan="7"></td></tr>
<tr><td>Gross floor area</td><td></td><td>m^2</td><td colspan="5"></td></tr>
<tr><td>Gross volume</td><td></td><td>m^3</td><td colspan="5"></td></tr>
<tr><th colspan="8">Special building areas</th></tr>
<tr><td>Sports hall</td><td></td><td>m^2</td><td></td><td>m^3</td><td></td><td colspan="2"></td></tr>
<tr><td>Swimming pool</td><td></td><td>m^2</td><td></td><td>m^3</td><td></td><td colspan="2"></td></tr>
<tr><td>Classroom block 1</td><td></td><td>m^2</td><td></td><td>m^3</td><td>Use</td><td colspan="2"></td></tr>
<tr><td>Classroom block 2</td><td></td><td>m^2</td><td></td><td>m^3</td><td>Use</td><td colspan="2"></td></tr>
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<tr><td>Workshop 2</td><td></td><td>m^2</td><td></td><td>m^3</td><td>Use</td><td colspan="2"></td></tr>
<tr><td>Canteen</td><td></td><td>m^2</td><td></td><td>m^3</td><td></td><td colspan="2"></td></tr>
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<tr><td>Heating</td><td></td><td>Power</td><td></td><td colspan="3">Heat transfer + Temperature regulation</td><td></td></tr>
<tr><td>Cooling</td><td colspan="7"></td></tr>
<tr><td>Ventilation</td><td colspan="7"></td></tr>
<tr><td>Air conditioning</td><td colspan="7"></td></tr>
<tr><td>Lighting (classroom)</td><td></td><td>Power</td><td></td><td colspan="3">Presence detector/ daylight sensor</td><td></td></tr>
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<tr><td>Final energy heating</td><td></td><td>kWh/m²y</td><td></td><td>kWh/y</td><td colspan="3"></td></tr>
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<tr><th colspan="8">Comments</th></tr>
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