Typology of Unclassified Buildings and Specifics of Input Parameters for Energy Audits in Latvia

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Abstract. The aim of the study is to analysis renovation solutions for unclassified buildings. According to Latvian law definition, unclassified buildings are prisons, security forces, police and fire services buildings including barracks, warehouse etc. Such buildings has completely different heat gains and heat losses balance and usage profile in comparison to traditional public and apartment buildings. Unclassified buildings could have higher internal heat and moisture loads, more strict requirements to dress code (CLO level), human metabolic equivalent and limited possibility for staff adaptation to IAQ parameters. The one of important factors is safety of energy supply and operation of HVAC systems. Although the energy security is a top priority for unclassified buildings, it should not be a barrier for implementation of renewable energy sources and innovative energy efficient retrofitting solutions in unclassified buildings.

1. Introduction
Currently, standard calculation methods are being used to perform energy audits of unclassified buildings since a specific methodology has not yet been developed and implemented in practice. In this paper, unclassified buildings include: penitentiary institutions, prisons and detention centers, buildings of defense forces, police and fire-fighting services and barracks of these institutions, separately located lavatory buildings, household buildings, individual garages, individual bath houses, cellars, summer kitchens, greenhouses, security buildings, pass office buildings, individual pergolas, sheds not classified elsewhere, etc [1, 9].

Energy audits and the process of determining energy performance of a given building is governed by the Latvian Law on the Energy Performance of Buildings. In addition, Ministers’ Cabinet Regulation No. 348 “The method for calculating energy performance of buildings” introduces the principles and methods used for calculating energy performance.

It is of essence to consider the specifics of use in order to correctly assess energy consumption of a given building. Comparing energy audit calculations and factual measurements in unclassified buildings shows great differences in results. This can be explained by the specific character of unclassified buildings, and by the fact that specific source data should be used for energy performance assessments of such buildings, i.e., heat release volumes, humidity mode, air exchange volumes, hot water consumption, etc.

The laws and regulations that are in force in the Republic of Latvia do not directly specify the data required for performing energy audits in unclassified buildings: calculation temperatures, air exchange volumes, heat releases, operation modes, energy consumption for lighting, hot water consumption, etc. Thus, it is necessary to use the already existing data and adapt it to the specific needs. Table 1 provides...
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| Law or regulation | Regulatory scope | Application to unclassified buildings |
|-------------------|-----------------|---------------------------------------|
| LBN 002-15 “Thermo-mechanics of Building Envelopes” | Tables 1 and 2 of the Standard lay down standard and maximum coefficients of thermal conductivity for building elements and the linear thermal bridge; Appendix 2 of the Standard specifies room temperatures and minimum air exchange volumes, depending on the type of use of premises. | LBN 002-15 “Thermo-mechanics of Building Envelopes” This Code can be applied for performing energy audits in barracks or staff’s residential premises as well as separate auxiliary premises such as lavatories and shower premises. |
| LBN 211-15 “Residential buildings” | | |
| LBN 231-15 “Heating and ventilation of residential and public buildings” | Article 92 of the Standard lays down that air quality and desirable parameters in the respective premises should be determined in accordance with the LVS EN ISO 7730:2006 Standard. Article 96 of the Standard sets forth that ventilation capacity must be sufficient in order to provide fresh air supply, satisfactory comfort levels or technological conditions in the service area. Indoor contaminant sources are assessed in accordance with LVS EN ISO 7730:2006 Standard. Article 97 of the Standard lays down that if the only indoor contaminant source is human occupants, then the absolute minimum of fresh air supply must be 15 m³/h per person. | This Standard can be applied to all unclassified buildings, depending on their type of use, in order to determine the minimum ventilation air volume if specific calculated air volumes are unknown. |
| LBN 208-15 “Public Buildings” | Appendix 2 of the Standard regulates the permissible orientation of windows, depending on the type of use of premises. | The Standard can be used for assessing sunlight influx via glazing, depending on the building’s type of use. |
| LBN 221-15 “Internal water mains and sewage of buildings” | Appendix 4 of the Standard lays down the average and maximum hot, cold and total water consumption, depending on the building’s type of use. | The Code can be applied for determining the energy consumed for preparing hot water, assuming administrative buildings, headquarters and learning premises as administrative buildings, and assuming barracks as guide and scout camps with dining facilities where raw products are processed, and automated washing machines are used. |
| LBN 003-15 “Construction Climatology” | The Standard lays down calculated and average outdoor air temperatures during the heating season, heating season length, sun radiation on differently orientated surfaces during cloudless weather in July, depending on the city. | The Standard can be applied to all types on unclassified buildings if their heating periods substantially differ from standard structures due to specific structural solutions, for example, barracks in the shape of tents. |
Law or regulation | Regulatory scope | Application to unclassified buildings
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LVS CR 1752:2008 “Ventilation of buildings – criteria for designing indoor environments” | The Standard regulates the necessary temperatures for premises, ventilation air volumes, airflow velocity in working areas, and permissible noise levels. It also provides guidelines regarding the amounts of heat volumes released by human bodies metabolically, as well as clothing levels, depending on the clothing one wears. | Table 1 of the Standard can be used for determining the necessary air volumes in learning premises of unclassified buildings, cafeterias and headquarters, considering them as office buildings.
LVS EN ISO 7730:2006 “Ergonomics of the thermal environment. Analytical determination and interpretation of thermal comfort using calculation of the PMV and PPD indices and local thermal comfort criteria” | The Standard regulates how one should characterize and determine thermal comfort levels for human beings, depending on the outdoor air temperature, radiation temperature, airflow velocity and air humidity. | The Standard can be applied to all unclassified buildings in order to forecast or characterize thermal comfort levels for indoor premises.
ISO 9972:2015 “Thermal performance of buildings. Determination of air permeability of buildings Fan pressurization method” | Lays down methodology for performing air permeability inspections in buildings, or their parts, using calibrated ventilators in order to create pressure differences between indoor premises and the outdoor environment. It is possible to use the U.S. Army Corps of Engineers Air Leakage Test Protocol for Building Envelopes for the needs of unclassified buildings [3]. | 
ISO 6781-3:2015 Performance of buildings. Detection of heat, air and moisture irregularities in buildings by infrared methods | Provides a qualitative method for determining thermal anomalies in building envelopes through thermographic inspection (infrared method). This method is applied to identify heat properties, including air leakage, of elements included in external building envelopes. Does not apply to determining thermal insulation of structures and actual volumes of air permeability. | 

Considering the development of the construction industry in the territory of Latvia, it is possible to distinguish four time periods, and categorize buildings according to them. Category 1 is pre-war buildings (built before 1940), Category 2 is buildings built between 1945 and 1970. Category 3 includes buildings built between 1971 and 1990. Buildings built after 1991 fall into Category 4.

A total of 67 buildings were analysed; 27 of them were buildings used by police services whereas 40 buildings belonged to the fire-fighting services – see Figure 1 and Figure 2 below.

![Figure 1](Image)

**Figure 1.** Apportionment of police buildings.
2. Factors Influencing Energy Performance of Buildings

It is of essence to consider the specifics of use in order to correctly assess energy consumption of a given building.

In order to accurately determine annual energy consumption, all types of energy consumption must be considered [4], [5]. From the acquired sum, one must subtract internal influxes that come from sunlight and other sources of heat, such as human beings, equipment, lighting and hot water pipes. Figure 1 below provides a summary of all factors that influence the total energy consumption of a building and that should be considered when performing energy audits. Specific factors that are characteristic particularly in the case of unclassified buildings are outlined separately.

![Figure 2. Apportionment of fire depot buildings.](image)

3. Classification of Use of Unclassified Building Premises

In order to correctly determine the annual indoor temperature mode and to determine the necessary air exchange volume as well as to identify the thermo-mechanical properties of building envelopes, it is necessary to determine the specific character of the use of a building’s premises.

The specific character of the use of premises largely corresponds to that of offices and public buildings. The key difference that one must consider when performing energy audits is the higher intensity of harmful releases and heat releases.
Table 2. Specifics of unclassified buildings

| Room type               | Public buildings                                                                 | Specifics of unclassified buildings                                                                 |
|-------------------------|----------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------|
| Administrative rooms    | Office premises and related auxiliary premises                                   | Special clothing, higher CLO value of uniforms, limited opportunities to use passive ventilation and cooling solutions. |
| Storage buildings       | Stationary goods, supplies, office equipment                                      | Explosive materials, ammunition, food products.                                                      |
| Garage                  | Motor vehicles                                                                   | Trucks and armored cars. Car repair shops (limited opportunities to carry out repairs in civil repair shops), painting shops. |
| Eating house            | Various types of food, steady flow of visitors                                    | Large number of simultaneous visitors; strict dietary requirements. Higher air exchange and water consumption. |
| Hotels and dormitories  | Predictable and steady water consumption                                         | Higher hot water consumption due to higher work, exercise and workout loads. Higher population density in barracks. |

4. Energy Consumption of Unclassified Buildings

The unclassified buildings include buildings like barracks and fire departments which mainly have shared bathrooms and kitchens. Hot water consumption of these types of building is similar to dormitories. However, differences in hot water consumption should be carefully evaluated in further studies. The main differences in hot water consumption between dormitories and unclassified buildings with shared showers could be more active shower use in unclassified buildings due to higher working and training loads, clothing type, different food preparation principles, room cleaning requirements etc.

Specifically performed measurements showed that the average annual total energy consumption for police departments is 252 kWh/m² while for fire departments 317 kWh/m². It must be noted that the energy consumption is increased for newer fire department buildings. Measurement results for another group of similar purpose buildings showed that the average annual heat energy consumption (heating and hot water preparation) for the period 2010–2017 is 121 kWh/m² for fire departments and 112 kWh/m² for police departments. In both cases energy consumption for fire departments is higher than for police departments, which can be explained by architectural peculiarities of this type of buildings. Annual differences in heat energy consumption can be explained not only with different climate conditions, which correlates between fire and police departments. Also fluctuations in annual heat energy consumption for each building represents one of the mostly important characteristics of special purpose buildings, when heat energy consumption is not only function of building’s thermal performance and outside air temperature but also is strongly influenced by user behavior, which varies and depends on the task assigned to operational personnel and other human factors.

Figure 4. Annual heat energy consumption of police departments.
During the survey of heat energy consumption of special purpose campus, it was concluded that majority of the buildings have unevenly distributed heat energy consumption, which is explained with purpose of the building and random use when it is necessary. Some of buildings are used as warehouses for very different purposes and special thermal requirements, which sometimes do not need additional heat supply. Heat energy meters were installed only in the buildings where heat energy consumption was constant or regular. Heat energy mostly is needed for buildings which are used by people or local staff, such as gym, swimming pool, dormitories, study rooms etc. Outside temperatures will have certain influence on the heat energy consumption for any buildings but in this case occupancy profile and envelopes thermal performance has a decisive influence. Average heat energy consumption before the renovation activities was average 204 kWh/m² but after refurbishment heat consumption was reduced more than one half and averaged at 110 kWh/m².

5. Thermal comfort for a person in uniform

The key parameters that influence thermal comfort are the parameters of the surrounding environment and a human being’s individual parameters. Individual parameters of a human being depend on his/her physical activity level and type of clothing. Clothing insulation has a direct impact on several important factors.

An employee who is dressed according to the required dressing code will feel warmer than an employee working in a civilian office and wearing casual clothing, given the same parameters of room temperature and relative humidity. This can be explained by higher thermal insulation of clothing. If employees are continuously experiencing increased heat, then it is more difficult for them to concentrate and perform their duties in relevant quality. It has been widely proven that employees’ productivity is much higher in a comfortable environment. On the other hand, in buildings where employees are obliged to wear uniforms with at increased thermal insulation level it might not be necessary to maintain standard temperature levels. Employees’ comfort level may stay optimal also at a room air temperature that is 2–3 degrees lower, thus saving resources by using less thermal energy.

Comfort temperature most commonly ranges between 15 and 28 degrees Celsius. However, this range is much narrower for human bodies. U.S. ASHRAE standards lay down that the temperature in premises where human occupants work wearing regular clothing typical to office settings (long-sleeve shirt and pants with the assumed thermal insulation of 0.6 CLO) must be between 22.2 °C and 25.5 °C [6]. This data shows that the range of the comfort zone for a human body’s optimal thermal regulation is only ~3.3 °C. Outside of this zone, a human body’s thermal comfort is ensured by putting on additional clothing, or removing it. Any changes in thermal insulation by 0.18 CLO compensate the change of 1 °C of air temperature.

Clothing insulation effect is expressed in ‘CLO’ units which were historically introduced in the 1940s. Considering the fact that military uniforms have specific properties and they differ from civilian clothing, CLO values of particularly this type of clothing are necessary for calculations. The table below provides thermal insulation data for elements of typical U.S. military uniforms in various conditions [7]. This data can be largely applied to other countries’ armed forces uniforms as well in order to obtain a general idea of the total thermal insulation level in various combinations.

| CLOTHING                        | i_m  | clo  | i_m/clo |
|---------------------------------|------|------|---------|
| Cold-Dry                        | 0.43 | 4.30 | 0.10    |
| Cold-Wet                        | 0.40 | 3.20 | 0.13    |
| Utility Fatigues                | 0.41 | 1.40 | 0.29    |
| Battle-Dress Uniform            | 0.41 | 1.34 | 0.31    |
| Chem. Prot. Overgarment (without mask, hood, gloves) | 0.34 | 1.97 | 0.17 |
| (MOPP IV with mask, hood and gloves) | 0.30 | 2.44 | 0.12 |
| (MOPP IV, plus body armor, ground troops) | 0.29 | 2.20 | 0.13 |
In order to determine thermal comfort of military staff in office conditions, one must consider the specific character of military clothing and CLO values. For this purpose, military uniforms of soldiers of the Armed Forces of the Republic of Latvia can be compared to the uniforms of U.S. soldiers whose approximate CLO value is 1.4 [7].

Using the thermal comfort tool developed by the University of California (Berkeley) [8], one can determine the compliance of indoor climate and clothing thermal insulation to the requirements of ASHRAE 55/2017 and EN-15251 “Indoor Environmental Criteria” [6]. Assuming the indoor air temperature of 25 °C and clothing CLO value of 1.4, we see that the given criteria fall outside of the comfort zone (see Figure 5).

![Figure 5. Comfort zone when wearing a military uniform at indoor air temperature of 25 °C, 50% relative humidity and clothing CLO value of 1.4 (left) and Comfort zone when wearing a military uniform at indoor air temperature of 20 °C, 50% relative humidity and clothing CLO value of 1.4 (right)]

6. Conclusions
1. Specific methodology for carrying out energy audits in unclassified buildings currently does not exist; regular calculation methods are applied in such cases assuming approximate source data values for air exchange volumes, indoor temperature, hot water consumption and the volume of human occupancy. These values are assumed on the basis of instructions given in the existing construction regulations, standards or regulatory documents of other countries.
2. In order to perform energy audits in unclassified buildings more accurately, one must consider several factors that are not taken into account during the existing standard calculation procedure: adjusted indoor temperatures considering the CLO level of uniforms, additional ventilation volumes for discharging contaminants, additional fumes from heavy machinery, higher ratio of server rooms and computers, additional hot water consumption due to active workouts and on-duty tasks.
3. Total of 92 unclassified buildings of various types was reviewed within the scope of the report. The average age of analyzed buildings in 2018 was 53.4. The average age of buildings used by the police services was 49.7 years, the average age of fire-fighting buildings was 55 years whereas the average age of buildings used by the Armed Forces was 54.8 years.
4. Thermal insulation level of clothing (CLO) has a direct impact on soldiers’ productivity both in field conditions as well as indoors at relatively calmer working conditions.
5. ANSI/ASHRAE 55-2017 standard lays down that optimal clothing insulation is 0.5 CLO during warm weather and 1.0 during cool weather. In turn, analysis of total clothing insulation levels of soldiers who work indoors shows that the insulation exceeds 1.6 CLO. According to the available data, uniforms without undergarments and boots provide a clothing insulation level of 1.34 CLO.
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