To be or not to be a hybridGEOTABS: energy performance of hybridGEOTABS buildings in the EU

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Abstract
GEOTABS is a low carbon technology that provides clean energy for the building sector. However, buildings that implement such systems are typically high insulated and operated with low internal gains, which limits the system application. By expanding the GEOTABS system with a fast-reacting secondary system, this combination is named hybridGEOTABS. Which will extend the applicability of the system to a larger building segment. In this paper we propose guidelines for designers at early design stage for the building properties that can allow for higher shares of GEOTABS (primary system) thus, high primary energy savings. 50,000 buildings simulations showed that GEOTABS can achieve over 60% of primary energy savings in buildings within the EU when compared to conventional system.

Key Innovations
- A methodology that allows assessing of hybridGEOTABS feasibility, based on using data from energy certificates that are translated into building energy models
- Recommendations for the building configurations with high impact of implementing hybridGEOTABS covering three EU climate zones.

Practical Implications
The paper provides designers with a methodology that helps in assessing the energy performance of hybridGEOTABS. Thus, allowing designers and architects to decide for the feasibility of implementing the system at the early design stages. The method is based on the using of general data found in the building energy certificates and transform these data into multi-zone energy models to estimate the energy demand of large amount of buildings. The approach adopted in this research considers the variations of the building design space within 3 EU climate zones.

Introduction
The European parliament has set ambitious objectives towards the decarbonisation of the building stock by 2050 in the directive 2018/844 EU. The built environment contributes with 36% of the CO₂ emissions in the EU. On the other hand, 80% of the final energy used in heating and cooling in the EU are used in buildings (Directive (EU), 2018). The member states started to take rigorous long-term measures to cut down the final energy consumption from the building stock. These measures target an increasing energy-efficiency, setting long term renovation strategies as well as increase the implementation of low carbon heating and cooling technologies which deploy higher percentages of renewables.

GEOTABS is a heating and cooling technology that combines a geothermal heat pump (GEO), and a thermally active system (TABS). The TABS is implemented in the building slabs or ceilings and is able to emit heating and cooling to the different building zones while using temperatures close to room temperature, as a result of its large emission surfaces (Boydens et al., 2013). Therefore, the geothermal heat pump can work very efficiently. The system is considered as a low carbon technology playing an important role in providing clean energy for the building sector due to its high performance and use of renewable energy sources.

The REHVA guidebook no.20 (Boydens et al., 2013) has highlighted the importance of the building design and its properties in efficiently implementing GEOTABS. It includes a set of design requirements for GEOTABS buildings, summarised as; the building shall be a high insulated building with a reduced window to wall ratio, using suitable orientation, in addition to installed shading system and low internal heat gains. However, if architects stick to the aforementioned defined criteria, they will be limited in terms of suitability of their building to implement the GEOTABS technology. Moreover, the most suitable building physical properties for a GEOTABS building may differ for different climate zones in Europe. When a secondary fast reacting system is coupled with the GEOTABS system in addition to an intelligent control system such as a model predictive controller (MPC) this concept is called hybridGEOTABS as explained by Himpe et al. (2018). By implementing such a system, hybridGEOTABS could extend its applicability to cover a larger spectrum of buildings with different properties. However, the more ‘hybrid’ the system is the lower the ‘GEOTABS’ benefits in terms of final and primary energy reduction. Therefore, it is crucial to evaluate the overall energy performance potential of the hybridGEOTABS in addition to, identifying the relationship between building configurations and...
achieving high final and primary energy savings. In this paper, we will present a methodology based on a bottom-up building stock modelling approach explained by Mahmoud et al., (2019). The method implements a combination of building geometrical characteristics and building physical properties to cover the design space within three EU climatic zones and four building typologies. Two scenarios are demonstrated, the first is the hybridGEOTABS scenario, while the second is a reference non-GEO TABS scenario, to evaluate the final and primary energy performance.

Our focus in this paper is on schools building typologies, however the methodology has been implemented and validated for offices (Mahmoud et al., 2019), elderly homes and multi-residential buildings (Mahmoud et al., 2020). The output of this research supports designers and policy makers identifying the potentials of building configurations that can benefit from this technology.

Methods

To assess the energy performance of hybridGEOTABS systems on buildings in the EU, information about the energy demand of buildings with a wide range of characteristics and within different climate zones is crucial. The non-residential building stock is heterogeneous, and data is hard to gather due to the lack of information or the policies towards protecting national data from the public use. For schools, we were able to access data gathered by the Flemish energy agency (VEA) (VEA-EPB database, 2018) in the context of energy performance certification. The data describes the geometrical information of buildings in the last 10 years, which could be used as an indicator for the building construction geometries in the EU. Our approach (Mahmoud et al., 2019) starts from the general geometrical data found in the building energy certificates that is transformed into multi-zone energy models using parametric geometries. The parametrisation of the building archetype takes place in Excel and uses a fitting process developed by (Delghust et al., 2015). The models can then be simulated using building energy simulation programs. The output of the simulations is hourly heating and cooling demands, which will then be used to identify the energy performance for each studied building.

Geometrical data input

116 cases for schools with a gross floor area (GFA) larger than 1,000 m² were analysed and prepared for the fitting process, representing midsize and large school buildings, where hybridGEOTABS could be profitable when implemented. The distribution analysis showed that 90 % of the cases have GFA between 1,000 and 5,000 m², while 85 % of the cases’ volume are below 20,000 m³ and 88 % are with heat loss area below 7,000 m².

Schools’ archetype characterisation and fitting process

The educational sector has a share of 17 % in the non-residential building stock (Atanasiu et al., 2011). The sector consists of primary and secondary schools, universities and research laboratories. In this research we focus on primary and secondary schools. 13 schools’ architectural plans were analysed from the Flemish “Scholen Bouwen” (Scholenbouwen database, 2019). We found that the typical functions found in this typology are classrooms, student restaurants, multipurpose rooms (such as, library, study room and event room), administration offices, services including toilets and circulation. Sports rooms and basements are excluded from the gross floor area since they are not conditioned or conditioned in a different way. The walls account for 8% of the GFA. We summarised the share of each function from the GFA in Table 1.

From the analysis we concluded that the average classroom surface area is around 48m² (6 x 8 m), the width of the corridors is of 2 meter minimum, and the number of floors ranges between one and five. The school archetype characteristics are used as constrains for the geometrical fitting process.

The geometrical data are fitted to modular form, with a central corridor where functions are distributed on both sides Figure 1.

Table 1: Share of school’s functions in the floor area excluding walls

<table>
<thead>
<tr>
<th>Key</th>
<th>Function (Zone)</th>
<th>Share in floor area (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Classrooms</td>
<td>40</td>
</tr>
<tr>
<td>2</td>
<td>Restaurant</td>
<td>15</td>
</tr>
<tr>
<td>3</td>
<td>Multipurpose room</td>
<td>15</td>
</tr>
<tr>
<td>4</td>
<td>Corridors and stairs</td>
<td>20</td>
</tr>
<tr>
<td>5</td>
<td>Administration offices</td>
<td>5</td>
</tr>
<tr>
<td>6</td>
<td>Services</td>
<td>5</td>
</tr>
</tbody>
</table>

Figure 1: School’s typology model zoning

Simulation models input parameters

We selected seven parameters for investigating beyond the GEOTABS design recommendations by Boydens et al., (2013), aiming to cover a wider design space. The parameters are climate, building insulation level, building orientation, building mass, window to wall ratio, shading system, and finally internal heat gains. A summary of the parameters used for the building simulation models are presented in Annex A (Table 4).

Three locations (Warsaw, Brussels and Madrid) were selected to represent EU climate variations as highlighted by the European Environment Agency (EEA), (2012). We excluded climate zones with low density population (an indicator for low dense buildings) i.e., regions in transitional cold climate in Norway and Finland. The regions that fall under this study are found in (Mahmoud et al. 2021a).
The internal heat gains in schools are based on occupancy profiles in relation to the different functions defined in Table 1. The total internal heat gains represent the sum of hourly gains from occupancy, lighting and appliances per meter square during a weekday, and is summarised in Annex A.

Two profiles have been identified: a high density and a low density occupancy profile. Schools have holidays periods that are taken into consideration in the model. It is assumed that during Christmas and the Easter holidays the school is completely closed. For the summer holiday it is assumed that the occupancy is reduced to only 10% of the designed occupancy value to account for summer activities that takes place during this period. The school is occupied for 5 days a week from 8:00 am till 15:00 pm and from 15:00 pm till 17:00 pm, with a 50% lower capacity of students in the second period. A one-hour lunch break from 12:00 pm till 13:00 pm is taken into consideration, where all the students are present in the school restaurants. The multipurpose room is occupied one hour before lunch from 11:00 am till 12:00 pm and from 13:00 pm till 15:00 pm with 20% of students and from 15:00 pm till 17:00 pm with full capacity.

The ventilation flow rate is calculated based on the occupancy schedule and the number of occupants per zone. There is no ventilation flow rate during the unoccupied periods.

**Building energy models**

Models were created in Dymola program using Modelica modelling language and the OpenIDEAS library (Baetens et al., 2015). The models have 8 zones (for the ground floor), 5 zones (for the intermediate floors) and 7 zones (for the last floor) following the zone functions as shown in Figure 1. The number of zones per each floor is constrained by the share of each function explained in Table 1. Each building stock geometry described in the building stock database is varied with 432 different parameter combinations as summarised in Annex A. This has resulted in about 50,000 building models. Each model has an ideal heating and cooling system with a fixed set point temperature of 24°C, in addition to a ventilation system with a heat recovery of 85% efficiency.

**hybridGEOTABS Sizing**

In a hybridGEOTABS system, different shares of the demand are assigned to either the primary (GEOTABS) or secondary system based on the simulated heating and cooling demands. A load splitting algorithm developed by Sharifi et al. (2019,2020) is able to identify the parts of the load that are covered by GEOTABS, that is the baseload, and the residual loads to be covered by the fast-reacting secondary system. The algorithm allows for finding the optimum share of each system at every time step as the basis for defining the optimum size of primary and secondary systems. It takes into account the load shifting capabilities of the TABS (thanks to its high thermal inertia), the main effects of a near optimal control strategy and the preference of using GEOTABS as the most sustainable part of the system. Additionally, the algorithm allows an indoor temperature fluctuation in the range of ±1°C from the model set temperature. Geothermal borefield imbalance affects negatively the efficiency of the geothermal heat pump (GSHP). Therefore, the algorithm takes into account achieving a balance in the geothermal borefield, where the heat injected is in the range of 40 to 60% of the total heat extracted and injected from/to the field (Sharifi et al. 2021). Thus, for heating or cooling dominated buildings lower share of GEOTABS are assigned, whereas the opposite (higher share) holds for buildings with balanced demands. The baseload algorithm was then applied to the simulated heating and cooling demand curves for the 50,000 school buildings outputs.

**Energy performance assessment**

The energy performance assessment is based on comparing two scenarios in terms of the final energy and the primary energy. The first scenario is hybridGEOTABS, where TABS is coupled to the GSHP as primary system to cover heating and cooling and achieve balance in the ground, while the rest of the demand is covered by two secondary systems: a condensing gas boiler (CGB) for heating and an electric compression chiller (EC) for cooling. Both systems are sized in accordance with the outputs of the baseload splitting algorithm. The hybridGEOTABS scenario is compared to a reference scenario non-GEOTABS where a CGB covers all the heating demand, while an EC covers the entire cooling demand, and all heating and cooling are injected as convective heat fluxes in the space. This allows to assess the improvements in energy performance by covering a share of the heating and cooling loads with GEOTABS.

The final energy is calculated from dividing the energy covered by each system by its efficiency summarised in Table 2. For cold and moderate climate zones, we assumed that in the “hybridGEOTABS” scenario, all the cooling energy covered by the “primary system” can be provided using passive cooling. Whereas, for the warm climate, the cooling energy covered by the “primary system” is provided by a reversible heat pump using the efficiencies provided in Table 2. The heat pump efficiency is expressed by the Seasonal Performance Factor (SPF), while for the electric chiller its efficiency is expressed by Energy Efficiency Ratio (EER). The primary energy is calculated from multiplying each source’s final energy with its primary energy conversion factor (see Table 3).

<table>
<thead>
<tr>
<th>Type of production unit</th>
<th>efficiencies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat pump (heat production) SPF</td>
<td>6.00</td>
</tr>
<tr>
<td>Heat pump (Cold production) SPF</td>
<td>5.00</td>
</tr>
<tr>
<td>Gas boiler (heat production) SPF</td>
<td>0.95</td>
</tr>
<tr>
<td>Electric chiller (Cold production) EER</td>
<td>3.00</td>
</tr>
<tr>
<td>Passive cooling (Cold production) SPF</td>
<td>20.0</td>
</tr>
</tbody>
</table>

**Table 3. Primary energy conversion factors**

<table>
<thead>
<tr>
<th>Source</th>
<th>PE Total (-)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural gas</td>
<td>1.1 (International Organization for Standardization, 2017)</td>
</tr>
<tr>
<td>Electricity (EU2020)</td>
<td>2.0 (Hamels, 2021)</td>
</tr>
</tbody>
</table>
Results and discussion

Heating and cooling demands

The distribution of the estimated ideal heating and cooling demand output of 50,000 cases of school’s simulations are presented in Figure 2. The heating demand interquartile range is 14 to 64 kWh/(m²a) with a median of 35 kWh/(m²a) while for the cooling demand the interquartile range is 13 to 43 kWh/(m²a) and a median of 25 kWh/(m²a). The low cooling demands are explained as a result of the low occupancy due to the school summer vacations. The violin diagram shows the probability density of the data at different demand values. We see that the heating demand output has a multimodal distribution with three distinctive groups. The different groups are a result of varying the different parameter within the database. In the next paragraphs we will explain the effect of the parameters on identifying groups with lower demands and groups with higher demands.

GEOTABS share and energy performance

The share of energy covered by both “primary” and “secondary” systems is presented in Figure 3. GEOTABS has shares in all schools’ buildings in the three climates as low as 2% and up to 98%. Higher shares above 60% covered by GEOTABS are achieved in 60% of the cases in Brussels, in 58% of cases in Warsaw, and in 37% of cases in Madrid. Higher shares of GEOTABS are a result of buildings properties which lead to achieving balance in energy demand (i.e., a school building in Madrid with medium/low insulation with low window to wall ratio and shading system). Whereas shares of 5% or less GEOTABS are found in heavily heated or cooled buildings (i.e., a school in Madrid with high insulated building, large glasing surfaces and no shading which will lead to high cooling demands peaks that requires more intervention of the secondary system.

When comparing the two scenarios non-GEOTABS to hybridGEOTABS, as expected the hybridGEOTABS has lower final and primary energy consumption in the three chosen climates as presented in Figure 4. The hybridGEOTABS scenario would cut the median yearly final energy demand per floor area for up to 90% in Brussels, followed by 83% in Warsaw and 77% in Madrid compared to a non-GEOTABS scenario as shown in Figure 4 (a). Warsaw has the largest variance for final energy demand among cases with an interquartile range of 40 - 125 kWh/(m²a) and a median of 60 kWh/(m²a) for the non-GEOTABS scenario, while for the hybridGEOTABS scenario it has an interquartile range of 5 - 100 kWh/(m²a) with a median of 10 kWh/(m²a). Madrid has the lowest interquartile range of 30 - 60 kWh/(m²a) and a median of 45 kWh/(m²a) for the non-GEOTABS scenario, while for the hybridGEOTABS scenario it has an interquartile range between 10 - 30 kWh/(m²a) and a median of 15 kWh/(m²a). The primary energy follows a similar trend as the final energy in the three different climates as shown in Figure 4 (b). The median annual primary energy per floor area could be reduced by 63% in Brussels, followed by 61% in Warsaw and finally 45% in Madrid.

The probability and distribution of the final and primary energy savings from implementing hybridGEOTABS are presented in Figure 5. In Warsaw the final energy is negatively skewed towards higher savings, with 50% of the cases with final energy reductions above 60% similar to Brussels. The interquartile range lies between 20 - 80 with a median of 60% final energy savings. For Brussels, the interquartile range is between 30 - 80 % with a median of 60% similar to the trend in Warsaw. While for Madrid, we see an almost uniform distribution, with a flattened peak, where 25% of the cases has 60% or more final energy savings. The interquartile range is found between 20 - 60% with a median of 40%. The median primary energy savings in Madrid is 30%, while in Warsaw and Brussels it reached 53%. The overall median savings in final and primary energy for Madrid are lower than in Warsaw or Brussels. What defines the amount of the savings differs as a function of the building’s properties.

![Figure 2: Ideal heating and cooling demand distributions of school’s typology](https://example.com/figure2.png)

![Figure 3: Comparison between the probability and distribution of the share [%] of energy covered by GEOTABS and secondary system in the hybridGEOTABS scenario](https://example.com/figure3.png)
Building configurations with higher energy savings

In this section we will highlight the crucial parameters and building properties that can achieve high savings and low energy consumption per square meters as well as the limitations of achieving such results. The primary energy is used as an indicator for the school’s energy performance. A general overview of the primary energy savings is shown in Figure 6. The primary energy is broken down in terms of climate, insulation level and window to wall ratio. We see that primary energy savings are as high as 75% and as low as 5%. Very few cases in Madrid have no savings (2%), this can happen, as the energy use by TABS may be higher than the ideal demands due to its high thermal inertia. However, due to the high efficiency of the GSHP this compensated for at the primary energy level for most of the cases, except for those few cases in Madrid where the share of GEOTABS is very low, thus, GEOTABS is not suitable. Those cases are for buildings that don’t have shading systems installed combined with medium or large window to wall ratios and they are cooling dominant buildings with no or negligible heating demand.

We analysed the cases with highest Primary energy savings above 60% and total primary energy lower than 25 kWh/(m²a) and named it ‘high savings category’. The parameters fall under this category gives the designers at early design stages an indication on the influential parameters towards achieving higher shares of GEOTABS, hence primary energy savings. 23% of the cases presented in this paper fall within this category, 53% of which located in Brussels, followed by 45% in Warsaw and 10% in Madrid. In this category the energy covered by the GEOTABS is higher than 70% of the total energy demand. Figure 7 shows the ‘high saving category’ for buildings with shading (a) and buildings with no shading (b).

In Madrid ‘high savings category’ appeared in the buildings with high, medium and low window to wall ratio, low insulated envelope and shading, it also appeared in buildings with low window to wall ratio, medium insulation with shading (see Figure 7(a)).
We can see the high influence of shading as well as the window to wall ratio in warm climate. Low window to wall ratio is recommended for warm climate, however for cases with high transparent surfaces, shading system has the ability to cut down the influence of the solar gains efficiently. For buildings with low window to wall ratio, we see that due to the smaller exposed transparent area in the envelope, there could be a room for buildings to still have high primary energy savings while no shading system is implemented (see Figure 7(b)), however this is for only very few cases where there are low internal heat gains. We see that the high insulated group of buildings has disappeared from the ‘high savings category’ in Madrid. Even if the primary energy for this group of buildings is quite low (see Figure 6(b)), for such warm climates high insulated envelope traps the heat inside the building, leading to cooling dominated building, thus imbalance in the borefield (as explained in hybridGEOTABS Sizing section). This will result in a lower share of GEOTABS and lower primary energy savings.
In Brussels and Warsaw (see Figure 7) low insulated buildings do not appear in the ‘high savings category’. This is due to the high energy losses and the low airtightness of the buildings which will be compensated with more heating demand. ‘high savings category’ appeared in buildings with high and medium insulation, and not only for low and medium window to wall ratio but extended for cases where buildings have high window to wall ratio. Shading has an important role, but it doesn’t have the same influence in moderate and cold climates as it has in warm climates. We see that in Brussels for buildings with high window to wall ratio, and no shading only buildings with medium insulation group could achieve high savings. On the other hand, high insulation envelope buildings have disappeared from this category. We can conclude that in warm climate, shading system, insulation level and window to wall ratio have quite remarkable impact on the primary energy savings, while in moderate and cold climate the insulation level has the highest influence. Thus, for a hybridGEOTABS buildings, the designer shall give a high importance in the decision-making process towards those parameters at the early design stage.

The methodology presented in this paper used schools as a show case for its implementation and analysis for the profitability of the use of hybridGEOTABS in terms of final and primary energy, other typologies were fitted using the same workflow (Mahmoud et al., 2020). The presented results assume that all the properties combinations have equal probability within the three different EU locations before implementing weighting factors. The results were extrapolated on the EU building stock levels taking into consideration weighting factors for each properties probability with each climatic zone as documented by Mahmoud et al. (2021b).

**Perspectives**

The database at hands describes the geometrical and building physical variations of large spectrum of school building that are found in the building stock. This database is extended to cover other typologies, offices, elderly homes and multi-residential family documented by Mahmoud et al. (2020). The output of the workflow presented in this paper gives key indications about the share of GEOTABS and energy performance of the system for the whole database. These results are grouped with the components sizing and the CO₂-emissions to create decision trees and rule of thumbs allowing architects and HVAC- designers to assess the feasibility of hybridGEOTABS for the project in hand at early design stage. The decision trees and rules of thumbs are available in Mahmoud et al. (2021b) and Sharifi et al. (2021). Additionally, this pre-simulated database is used as an input for a web-developed tool “available on www.hybridgeotabs.eu”, which allows the designer to compare their project of interest to a similar case from the data base for a quick assessment of the hybridGEOTABS feasibility, as well as comparing it with other HVAC-solutions. The tool is documented by Boydens et al. (2021). Thus, we offer architects and designers easy to use tools based on dynamic simulations, which can replace the need for detailed simulations, thus decreasing the engineering costs at early design stages.

**Conclusion**

In this paper we have shown the overall methodology for modelling and simulation of schools building stock. The methodology started from gathering geometrical information available in building energy certificates, followed by a geometrical fitting process, were all the general geometrical data gathered of buildings in the building stock were fitted to 3-dimensional building geometry (archetype). This process resulted in multizonal information that were used in building energy simulation (BES) models. The variety of geometries for the schools building typologies were multiplied by a variety of building physical parameters covering 3 climates, to be able to represent the building stock in the EU. By using dynamic multi-zone building energy simulations, the variety of cases in the building stock is modelled and simulated, resulting in hourly heating and cooling demands for each of the cases for one year. The simulations have resulted in around 50,000 building energy models with their demands outputs. hybridGEOTABS system has a high potential in reducing the final and primary energy for more than 60% from buildings in Europe. The window to wall ratio, as well as building insulation have high influence on amount of primary energy savings for warm climates, while insulation level has the highest influence on the primary energy demand in moderate and cold climates in the EU. Thus, at early design stages designers shall take those parameters with importance when implementing such a system in their projects.

**Acknowledgement**

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**References**


## Annex A

**Table 4: Summary of the parameter’s assumption used in the building simulation models**

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Location</strong></td>
<td></td>
</tr>
<tr>
<td>Cold climate</td>
<td>Warsaw</td>
</tr>
<tr>
<td>Moderate climate</td>
<td>Brussels</td>
</tr>
<tr>
<td>Warm climate</td>
<td>Madrid</td>
</tr>
<tr>
<td><strong>Window to wall ratio</strong></td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>20%</td>
</tr>
<tr>
<td>Medium</td>
<td>40%</td>
</tr>
<tr>
<td>High</td>
<td>60%</td>
</tr>
<tr>
<td><strong>Orientation (large facade)</strong></td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>South</td>
</tr>
<tr>
<td>High</td>
<td>West</td>
</tr>
<tr>
<td><strong>Shading System</strong></td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>No Shading system</td>
</tr>
<tr>
<td>High</td>
<td>External screen is on when solar radiation on vertical windows reaches 150 W/m²</td>
</tr>
<tr>
<td><strong>Envelope performance</strong></td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>Envelope U-value 0.5 W/(m²K)</td>
</tr>
<tr>
<td></td>
<td>Window U-value 2.5 W/(m² K)</td>
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<tr>
<td></td>
<td>Glass g-value 0.6</td>
</tr>
<tr>
<td></td>
<td>airtightness n_{Ep} 5.0 h⁻¹</td>
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<tr>
<td>Medium</td>
<td>Envelope U-value 0.27 W/(m²K)</td>
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<td></td>
<td>Window U-value 1.5 W/(m² K)</td>
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<td>High</td>
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<td>Window U-value 0.8 W/(m² K)</td>
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<td>Glass g-value 0.4</td>
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<td></td>
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<td><strong>Building mass</strong></td>
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<td><strong>Internal heat gains per hour during weekday</strong></td>
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<tr>
<td>Low</td>
<td>Classroom zone 33.0 W/m²</td>
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<tr>
<td>High</td>
<td>42.0 W/m²</td>
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<tr>
<td><strong>Ventilation flow rate</strong></td>
<td>Constant per person 36 m³/h/person</td>
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<td><strong>Set temperature</strong></td>
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