Driving Sustainable Practices in Vocational Education Infrastructure: A Case Study from Latvia

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Abstract: A vital component of achieving climate neutrality in the future involves bolstering energy efficiency measures in educational institutions and improving the overall knowledge on sustainable solutions. To achieve fruitful outcomes, the active involvement of various stakeholders, such as managers, teaching staff, and students, is indispensable. By implementing energy-efficient building systems, advancing the use of renewable energy sources, and incorporating sustainable practices into the curriculum, educational institutions can decrease their environmental impact and conserve resources for future generations. Active participation from all stakeholders, including managers, teaching staff, and students, is essential for the success of these efforts. Providing students with a comprehensive education on sustainability equips them to apply this knowledge in their future professions, thus contributing to a more sustainable society. To gain insights into the existing state of sustainability within educational systems, a comprehensive study of educational institutions was undertaken. To assess and compare schools’ sustainability, a composite indicator was developed. The study’s findings reveal that the implementation of mandatory and optional measures can lead to a substantial reduction in primary energy consumption by 39% and greenhouse gas emissions by 34% in educational institutions. The average abandonment costs for mandatory measures are 5.87 EUR/kgCO$_2$/year, but the average value for optional measures is 33.80 EUR/kgCO$_2$/year. It is suggested demonstration projects be implemented in institutions where specialists in RE, mechatronics, building engineering systems, and environmental technologies are trained by showcasing technologies needed for the transition to climate neutrality.

Keywords: composite indicator; energy efficiency; environmental impact; greenhouse gas emissions; optimization; policy; primary energy consumption; renewable energy; survey

1. Introduction

The Sustainable Development Goals (SDGs), adopted by the United Nations (UN) in 2015, include SDG 4 on education. Other goals, such as SDG 7 on affordable and clean energy, SDG 11 on sustainable cities and communities, and SDG 13 on climate action [1], mutually influence sustainable education and building energy consumption. Furthermore, the Paris Agreement, adopted in 2015, strives to reduce the global temperature rise to 1.5 degrees Celsius above pre-industrial levels, with 2 degrees Celsius being the maximum level allowed [2]. Reducing emissions is significant to achieving this goal, and buildings were responsible for 27% of the total energy sector emissions in 2021 [3]. Nevertheless, sustainable education empowers students with the knowledge, values, and skills required for informed decision making and enhancing quality of life while
ensuring the needs of future generations [4], and can thus significantly impact the move towards climate neutrality [5,6]. However, only in recent years has the role of education been emphasized in the context of achieving climate goals [7]. Improved sustainability requires significant transformations in organizations, supply chains, and communities, and this can only be achieved through continuous learning and innovation [8]. Therefore, a strong vocational education system can provide many benefits, such as supporting green growth and boosting labor productivity [9]. A heightened understanding of climate change can inspire students to actively engage in carbon neutrality education, and this result is facilitated by environmental responsibility [10–12]. Teachers can leverage this information to enhance students’ comprehension of the impact of climate change and inspire them to embrace energy-conserving behaviors through educational initiatives that raise environmental consciousness [11].

In addition to promoting sustainable education, educational buildings themselves play an essential role in reducing primary energy consumption and providing a sustainable and motivating learning environment [13]. They have the potential to make a significant impact on reducing greenhouse gas emissions (GHGs) through energy efficiency measures and renewable energy (RE) production [14,15]. Various studies have analyzed the potential energy savings achievable in educational buildings. For example, implementing energy re-habilitation in educational buildings in Spain resulted in a 66% reduction in non-renewable primary energy consumption and a 71% reduction in CO₂ emissions [16]. A multi-objective optimization of scenarios, including district heating and ground-source heat pumps in combination with photovoltaic panels (PVs), provides multiple cost-optimal solutions while resulting in a primary energy consumption equal to or below 170 kWh/m²a [17]. However, investment costs and energy tariffs significantly impact Pareto optimality in energy efficiency and energy production measures [18]. An improvement in building energy consumption grade from level G to B can be achieved through a combination of energy efficiency measures, such as external insulation of building envelopes and installation of new windows and doors, with RE production measures such as PVs, biomass heating systems, combi-solar systems, and replacement of lighting appliances [19]. In a case study of the Kazakh-German University in Almaty, Kazakhstan, retrofitting measures were found to reduce CO₂ emissions by 48–82% [20]. In general, educational buildings have great potential as locations where GHG emissions can be reduced through energy efficiency measures and RE utilization.

This research paper explores ways to increase sustainability in Latvia’s vocational education buildings through a composite indicator with a specific focus on reducing energy consumption in buildings, increasing the use of RE and providing a sustainable learning environment. Through an examination of 23 educational institutions, the current state of energy management in the educational system is analyzed and optimization of energy efficiency and RE production measures is performed. The composite indicator is used to rank and compare educational institutions based on the selected cost-effective measures and survey results. The research findings provide valuable insights for policymakers and educational institutions hoping to implement sustainable practices and contribute to a more sustainable society.

2. Methodology

The research methodology (see Figure 1) consisted of three key components: an analysis of energy consumption, on-site visits, and surveys, determining the energy efficiency and RE production potential, optimization, and the ranking of professional schools using a composite indicator. The analysis of energy use revealed the current level of energy efficiency in educational institutions and pointed out areas for potential development. Information was gathered about the educational institutions’ current energy efficiency practices, RE sources, and environmental policies through on-site visits and surveys. Each institution consisted of several buildings, e.g., study buildings with classrooms, kitchens, workshops, dormitories, sports halls, and administration buildings. Each building had
a unique construction project with a different area, location, enclosing structures, and engineering communication systems. Most of the buildings were renovated, but four were newly built. The building area ranged from less than 200 m² to 12,555 m² for large educational buildings. Therefore, individual energy efficiency assessment was necessary to identify potential sustainability measures.

From the on-site visits, survey results, and energy consumption and emission data, potential measures were identified. The recommended measures were split into two groups: mandatory and optional. In addition, innovative demonstration projects were suggested to schools that have specific educational programs (e.g., building construction technicians, heat supply and heating systems technicians, car mechanics) to demonstrate innovative solutions for building energy efficiency, installation of RE systems, development of electric vehicles, and similar future technologies.

Further, the energy efficiency and sustainability measures were optimized to select the best available measures due to the limited available budget of vocational education institutions. The potential reduction in total primary energy consumption (both renewable and non-renewable) and annual emissions were calculated for the identified measures. These, when merged with the survey results, were used in a compositive indicator to determine the educational institutions in which measures should be implemented with higher priority. Based on the survey results and developed demonstration projects, the recommendations were given.

This methodology provides a thorough overview of the existing sustainability situation in Latvia’s vocational education system and proposes viable solutions for lowering energy consumption, increasing the usage of RE sources and improving the overall quality of education related to future energy systems.

2.1. Data Gathering

Detailed data were collected to evaluate the energy consumption patterns within the educational institutions and their sub-departments. This comprehensive data set included information from 167 buildings across all 23 educational institutions and constituted building area, monthly heat, and electricity consumption from 2017 to 2022, as well as the source of heating and electricity for each building.

Figure 2 summarizes the obtained energy consumption data for the analyzed educational buildings. The specific energy consumption for most of the buildings was in the range of 48 to 93 kWh/m²/year, which indicates relatively high energy efficiency. Only
for 30% of buildings was the specific energy consumption greater than 100 kWh/m². The preliminary data analyses indicated that most of the buildings had already gone through complex renovation measures, and to further improve the overall efficiency of buildings, it is necessary to identify other potential energy-saving activities, for which the methodology is described below.

![Figure 2. Regression analyses of building-specific energy consumption in relation to total building area.](image)

2.2. On-Site Visits and Survey

The evaluation of educational institutions was performed through on-site visits. During these visits, a survey was given to each educational institution’s representative. The survey consisted of identical questions for each educational institution prepared according to the methodology described by [21].

The survey comprised four distinct categories of questions:

1. Energy use and behavior;
2. Environmental policy and education;
3. Main electricity consumers;
4. Energy efficiency and production measures that have been implemented thus far.

The questionnaire was designed to elicit both technical information on the primary energy consumers in buildings and their operational conditions, as well as more general information on organized environmental activities, environmental topics integrated into educational programs, waste management, and the engagement of teaching staff in sustainability initiatives.

Responses were quantified using a binary scoring system, with positive answers earning a score of 1 and negative answers earning a score of 0 [22]. This systematic approach provided an understanding of the current energy and environmental management practices within educational institutions, which allowed the selection of possible primary energy consumption reduction measures.

2.3. Sustainability Measures

The selection of sustainability measures was based on a comprehensive literature review analysis, energy consumption data, building energy audits, on-site visits, and surveys carried out at each educational institution. To address the identified problems in most educational institutions, similar solutions need to be employed, while individual measures should be tailored accordingly. Various measures can be divided into two groups: (1) measures similar to the majority of educational institutions (mandatory measures), and (2) individual measures (optional measures). Given the available funding, the first group of measures takes priority for financing, while the allocated funds for the second group
of measures represent the difference between the total funding amount and the required funding for the first group. The prioritization of the optional measures is determined through the optimization technique described in the next section. This approach resulted in a targeted selection of cost-effective measures, maximizing their impact on a reduction in energy consumption and a decrease in GHG emissions. The main identified measures are described below.

Further, a cost–benefit analysis was performed to identify measures by quantifying the potential energy savings and necessary investment costs. Table 1 summarizes the cost assumptions for the main identified energy measures.

Table 1. Overview of cost assumptions for main identified measures.

<table>
<thead>
<tr>
<th>Energy Efficiency Measure</th>
<th>Specific Costs</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Appointment of an energy management employee and training</td>
<td>1173 EUR/year</td>
<td>[23]</td>
</tr>
<tr>
<td>Introducing a building management system</td>
<td>7.6 EUR/m²</td>
<td>[23]</td>
</tr>
<tr>
<td>Implementation of environmental policy</td>
<td>1000 EUR per building</td>
<td>Survey results</td>
</tr>
<tr>
<td>Indoor temperature control</td>
<td>0</td>
<td>Building energy audits</td>
</tr>
<tr>
<td>Informative materials</td>
<td>0.01 EUR/m²</td>
<td>[24]</td>
</tr>
<tr>
<td>Mechanical ventilation with recuperation</td>
<td>30 EUR/m²</td>
<td>[23]</td>
</tr>
<tr>
<td>Modernization of lighting</td>
<td>8.9 EUR/m²</td>
<td>[25]</td>
</tr>
<tr>
<td>Wall insulation (inside)</td>
<td>from 9 to 60 EUR/m²</td>
<td>Building energy audits</td>
</tr>
<tr>
<td>Roof insulation</td>
<td>from 0.3 to 2.7 EUR/m²</td>
<td>Building energy audits</td>
</tr>
<tr>
<td>Plinth insulation</td>
<td>4.3 EUR/m²</td>
<td>Building energy audits</td>
</tr>
<tr>
<td>Window replacement</td>
<td>from 28.9 to 88.8 EUR/m²</td>
<td>Building energy audits</td>
</tr>
<tr>
<td>Replacement of heating elements with thermoregulators</td>
<td>7.4 EUR/m²</td>
<td>Building energy audits</td>
</tr>
<tr>
<td>Replacing the heat exchanger</td>
<td>0.03 EUR/m²</td>
<td>Building energy audits</td>
</tr>
<tr>
<td>Renovation of the heat substation</td>
<td>0.8 EUR/m²</td>
<td>Building energy audits</td>
</tr>
<tr>
<td>Installation of new boilers</td>
<td>3.6 EUR/m²</td>
<td>[26]</td>
</tr>
<tr>
<td>Solar collectors</td>
<td>1169.8 EUR/m²</td>
<td>[26]</td>
</tr>
<tr>
<td>Installation of solar panels</td>
<td>308.2 EUR/m²</td>
<td>[26]</td>
</tr>
<tr>
<td>Connection to the district heating network</td>
<td>24.5 EUR/m²</td>
<td>[26]</td>
</tr>
</tbody>
</table>

2.4. Optimization

The optimization of optional measures was carried out on Microsoft Excel Spreadsheet Software [27] using a data solver tool, with an evolutionary optimization technique [28]. Evolutionary optimization refers to a group of algorithms developed after a biological evolution, following natural selection, reproduction, and mutation [29]. It works by having a set of candidate solutions to a problem and applying operations that resemble natural evolution selection, recombination, and mutation to produce new solutions. The objective is to discover the optimal solution to the problem by repeatedly enhancing the set of candidate solutions through these operations [30]. The optional measures were represented as binary variables, with a value of 1 indicating that the measure has been applied and a value of 0 indicating otherwise. This is called binary decision making [31]. The optimization aims to maximize the reduction in primary energy consumption. The available budget was EUR 19.14 million. This budget was divided into three parts: EUR 203 thousand for demonstration projects, EUR 10.4 million for mandatory measures, and EUR 8.54 million for the optimization of individual measures. The objective of the optimization was to determine the most effective combination of available optional measures that would reduce energy consumption while staying within the EUR 8.54 million budget constraint.
Ranking Educational Institutions

The ranking of the 23 educational institutions was performed with a composite indicator, using a Simple Additive Weighting (SAW) technique that considered three critical factors. A factor can be considered a “Benefit attribute” if an increase in its value is desirable, and a “Cost attribute” if otherwise [32]. These factors were as follows:

- The number of survey points achieved during an on-site visit, which is a benefit attribute and given a weight of 0.1;
- The reduction in primary energy consumption per euro invested; this is a benefit attribute, and was assigned a weight of 0.45;
- The required investment in euros to reduce annual emissions by one kilogram; it is a cost attribute, and was also given a weight of 0.45.

By taking these three criteria into account and weighting them, an overall ranking of the educational institutions was performed, providing an objective evaluation.

The SAW method is a multi-attribute decision-making procedure that is based on a weighted summation of the normalized values for each alternative on all criteria [33]. The objective is to find the highest score, and therefore the best alternative. This method normalizes the decision-making matrix to a comparable scale. This method is mainly used to solve multi-criteria decision-making problems.

A decision matrix is an \((m \times n)\) matrix in which each element \(x_{ij}\) represents the value of alternative \(A_i\) based on the decision criterion \(C_j\). The alternatives are represented by \(i = 1, 2, 3, \ldots, m\) and the criteria are represented by \(j = 1, 2, 3, \ldots, n\). Each element has a numerical weight \(w_j\) assigned for each criterion [33,34].

The first step is to normalize the decision matrix using Equation (1) for the benefit attribute and using Equation (2) for the cost attribute [33].

\[
\begin{align*}
    r_{ij} &= \frac{x_{ij}}{\text{Max}(x_{ij})}, \\
    r_{ij} &= \frac{\text{Min}(x_{ij})}{x_{ij}},
\end{align*}
\]

where \(r_{ij}\) is the normalized value of the \(i\)th alternative for the \(j\)th criterion.

The overall score for each alternative is calculated by multiplying the normalized data for each criterion by its weight. The weight is subject to constraints in Equations (3) and (4). The result of the overall score is shown in Equation (5) [33].

\[
\begin{align*}
    \sum_{j=1}^{n} w_j &= 1, \\
    0 &\leq w_j \leq 1, \\
    S_i &= \sum_{j=1}^{n} w_j r_{ij},
\end{align*}
\]

where \(S_i\) is the overall score of the \(i\)th alternative.

The alternatives are ranked based on their overall scores, with the alternative with the highest overall score being the best [33].

3. Results

3.1. Applied Measures

The on-site visits and survey results indicated that most educational institutions face similar issues. During the on-site visits, renovation and improvement points were identified, and measures were chosen appropriately, taking into consideration the needs and specifics of each institution. The most common measures are described below.

Appointment of energy managers and introduction of the EMS

Each educational institution has an employee responsible for energy systems and engineering communications. During visits, it was observed that these employees have
varying levels of knowledge about energy conservation and the operation and regulation of different systems. The motivation to save energy also varies among these employees. On the other hand, in other institutions, a lack of motivation correlated with a lack of knowledge.

The appointment of energy managers would allow the achievement of significant energy savings and determine those responsible for energy system maintenance and implementation of energy-saving activities. Defining and implementing the functions of the energy manager require a change in attitude and management processes. For now, the technical staff in educational buildings are mainly responsible for the smooth operation of equipment without the goal of seeking energy efficiency improvements. If possible, there should be a motivation system based on linking the obtained energy savings with remuneration. Alternatively, it would be possible to introduce an energy manager position in the responsible ministry, who would oversee the energy management of all institutions. The creation and implementation of an EMS would ensure a 15–30% reduction in energy consumption in those educational institutions where the functions of the energy manager or BMS have not been implemented. In other institutions, energy savings could reach 5–10%.

**Introduction of a BMS**

Only some educational institutions have installed building management systems (BMSs) that allow for obtaining energy consumption data, analyzing them, and taking measures to reduce energy usage. In most educational institutions, heating radiators are only partially equipped with thermostatic regulators. This is either because they are not installed due to system incompatibility and the need for system reconstruction, or because they are installed but students remove the thermostat heads. In some educational institutions, it is necessary to replace old heating substations with new ones to enable automatic heating regulation.

According to the European standard [35], BMSs are divided into four categories: A—high energy efficiency control; B—semi-optimized control; C—standard control; D—no automation. A class A BMS can provide a 30% reduction in energy consumption in those educational institutions where no energy manager functions or no BMSs have been implemented (compared to class D), but in other institutions, it results in 20% savings (compared to class C).

This measure should be carried out together with the creation of an EMS since the BMS is a tool that ensures the daily operation of the energy manager, as many functions are performed automatically, and the number of man-hours required for manual work is significantly reduced.

**Improving the operation of the mechanical ventilation system**

The use of mechanical ventilation systems in some educational institutions poses difficulties, and in some they are only partially utilized. Challenges include increased noise levels that disrupt the educational process, high costs, lack of information about daily usage, physically inaccessible equipment, improper use of air filters, and the inability to operate the systems in individual rooms while others are occupied.

In educational buildings where mechanical ventilation systems are installed, an audit should be carried out to assess the difficulties encountered by building users when using equipment and find a solution to eliminate them (e.g., installation of air silencers, air pre-filters, a frequency converter on the supply and exhaust fans). Some of the recommended measures do not reduce energy consumption, but they are essential to achieving optimal air quality in the classrooms. Energy savings can be achieved through several improvements in ventilation systems:

- Installation of a heat utilizer: a 50% reduction in heat consumption for ventilation;
- Training of personnel, preparation of technical information and instructions for use: depending on the situation, energy consumption may decrease or increase, since it depends on how the equipment has been used before (if it is used rarely, then consumption may increase, by improving indoor air quality; if it is used inappropriately, then energy consumption may decrease);
• Provision of access to ventilation units: depending on the situation, energy consumption may decrease or increase, as it depends on how the equipment has been used in the past;
• Installation of valves in each of the rooms that provide variable airflow, depending on the level of CO₂ in the room, and a frequency converter on supply and exhaust fans: it is possible to achieve a 30% reduction in energy consumption for ventilation in those educational institutions where the functions of an energy manager have not been performed or there is no BMS, and in other institutions, the savings could reach up to 20%. If a BMS is installed, this measure does not need to be carried out separately.

This measure should be taken simultaneously with the establishment of an EMS for buildings and the introduction of a BMS.

**Replacing lighting bulbs with LED bulbs**

In most educational institutions, only a partial transition has been made from traditional light bulbs to LED lights. Some institutions gradually replace them using accumulated funds.

In all educational institutions where this has not been carried out, it is necessary to replace the inefficient light bulbs with LEDs and carry out the installation of light sensors in places where it is needed. Replacing light bulbs will reduce the total electricity consumption by 10% if 50% of the bulbs in the institution need to be replaced.

**Installation of solar panels**

Solar energy technologies have been installed in several educational institutions, but only one institution utilizes them for energy generation, while the others do not use them. Therefore, in all educational institutions, where the roof structures of buildings allow it, solar panels should be installed to cover part of the building’s electricity consumption. The installation of solar panels will reduce the primary energy factor from 2.5 to 1 and reduce the CO₂ emission factor from 109 g CO₂/kWh to 0 gCO₂/kWh [36].

**Establishing an environmental policy**

Environmental policies or their elements have been partially implemented in some educational institutions, while the majority have not implemented them. Environmental issues are incorporated into various subjects in some educational institutions.

It is necessary to establish an environmental policy and a plan for its implementation, which determines how various measures related to environmental aspects are implemented in an educational institution, reducing the overall environmental impact of the educational institution. The existence of an environmental policy demonstrates to learners, employees, and the public that it is an environmentally friendly institution that understands and demonstrates its responsibility for reducing its impact on the environment. This includes three aspects:

- Whether the learners in the educational institution have a healthy and sustainable quality of life (e.g., indoor microclimate and air quality, food quality, outdoor quality).
- How well the educational institution prepares learners for work in the 21st-century economy, which is on the way to climate neutrality, and ensures the development of learners’ citizenship to live in a world where the challenges and opportunities related to environmental problems are increasingly gaining importance.
- How environmentally friendly the policy of the educational institution is (e.g., with respect to energy consumption, waste management, water circulation, preservation of biodiversity, environmentally friendly habits, reduction in impact on climate, adaptation to climate change).

This measure would reduce energy consumption, which depends on the behavior of individuals, such as their water consumption, use of a bicycle or public transport as opposed to a car, and room temperature regulation, as well as reduce environmental pollution by reducing the amount of waste, impact on biodiversity, air pollution, etc.

The mandatory measures for each of the 23 educational institutions comprised several components aimed at increasing energy efficiency and reducing the environmental impact of the institutions. These measures included the introduction of an EMS and appointment of
an energy management employee, the installation of a BMS, implementing PVs, providing informative materials on-site highlighting energy-saving measures, and the adoption of an environmental policy. These mandatory measures aim to create a more sustainable and environmentally friendly environment for educational institutions while reducing their energy costs.

The optional measures were tailored to the individual needs of each educational institution and aimed to further increase energy efficiency and reduce energy consumption. Some of the specific measures included upgrading the lighting system, modernizing the boiler house, adding insulation to the attic and inner walls, switching from individual heating to more efficient district heating, installing a ventilation system, transitioning from natural gas to renewable biomass in the boiler house, and renovating the heating unit. These measures offered additional opportunities for the institutions to decrease their environmental impact and conserve resources for future generations. The applied optional measures are provided in Figure 3.

![Figure 3. The number of implemented optional measures in educational institutions.](image)

Figure 4 shows the comparison of calculated primary energy savings per necessary investments for different analyzed educational institutions. The mandatory energy efficiency measures led to higher energy savings per capital investment due to improved energy management, which does not require high financial support. The average energy savings from these activities would bring 1.99 kWh/year/EUR invested. However, the same value for optional measures is 0.6 kWh/year/EUR, showing that the identified measures would require a higher amount of investment to reach the same energy savings compared to mandatory measures. For some buildings, the energy savings are even negative due to the installation of mechanical ventilation, which would require extra energy consumption but, on the other hand, would improve the overall air quality.
abandonment costs, 
EUR/kgCO2/year
Educational institutions 
Mandatory measures Optional measures

Figure 4. Comparison of primary energy savings from mandatory measures and optional measures.

The results for the indicated CO2 abandonment costs can be seen in Figure 5. Emission reduction can be achieved through energy consumption reduction and the installation of RE technologies. The average abandonment costs for the mandatory measures are 5.87 EUR/kgCO2/year, but the average value for optional measures is 33.80 EUR/kgCO2/year.

Figure 5. Comparison of CO2 abandonment costs for mandatory measures and optional measures.

3.2. Demonstration Projects

In Latvia, specialists in RE, mechatronics, building engineering systems, and environmental technologies are trained in 9 out of 23 educational institutions. These institutions have demonstration projects designed to enhance educational programs by showcasing technologies needed for the transition to climate neutrality [37] and incorporating them into their education process. This hands-on approach provides students with practical experience in fields such as RE, mechatronics, and environmental protection, preparing them for careers in these areas, and aligns with SDGs [38].

The demonstration project system includes small-scale RE sources, energy storage technologies, the consumer side of energy use, and technologies to improve energy effi-
ciency in heating, cooling, and electricity consumption. A smart control system is also included. The demonstration project system is given in Figure 6.

![Diagram of Demonstration Project System](image)

**Figure 6.** Demonstration project system scheme.

The demonstration project should be small and include the following:

- RE technologies (e.g., solar panels 2.4 kW, tree of solar panel 1.8 kW, solar collectors 1 kW, wind generator 1 kW, biogas tank 100 L and gas combustion plant 1 kW, biomass boiler 10 kW);
- Energy storage technologies (e.g., hydrolysis plant, hydrogen storage tank, fuel cell: 10 kW; hot water storage tank 100 L; lithium-ion batteries 1 kW);
- Energy consumers (electric vehicles (scooters, cars, mopeds); solar-powered air-cooling unit; heat pump);
- Technologies for improving the energy efficiency of final energy consumption: technologies for reducing heating and cooling consumption (mock-up of the building (2 m³), smart water distributors, heat recovery from sewer water with a heat exchanger 200 W, efficient household electrical equipment, ventilation unit with efficient heat utilizor and motors with frequency converters);
- Smart control system with class A building control system and renewable energy management, data reading and monitoring system, Internet of Things.

**Reduction in primary energy consumption and Emissions**

The introduction of mandatory and selected measures could lead to a substantial decrease in energy consumption, primary energy consumption, and annual emissions. The energy consumption decreased by 9.7 GWh/year, which is 25% of the total energy consumption; the primary energy consumption also decreased by 21.5 GWh/year, which is 39% of the initial primary energy consumption, and the annual emissions also decreased significantly, with a decrease of 2.5 ktCO₂/year, which is 34% of the total annual emissions before the implementation of sustainability measures. Decrease percentages in educational institutions ranged from 11 to 66% for annual GHG emissions and 20%–55% for primary
energy consumption. The pre-implementation and post-implementation values for these measures are demonstrated in Table 2.

Table 2. Energy consumption and emission data before and after implementing sustainability measures.

<table>
<thead>
<tr>
<th></th>
<th>Energy Consumption, GWh/Year</th>
<th>Primary Energy Consumption, GWh/Year</th>
<th>Annual Emissions, ktCO₂/Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before</td>
<td>38.4</td>
<td>55.2</td>
<td>7.41</td>
</tr>
<tr>
<td>After</td>
<td>28.7</td>
<td>33.7</td>
<td>4.91</td>
</tr>
<tr>
<td>Absolute decrease</td>
<td>9.7</td>
<td>21.5</td>
<td>2.5</td>
</tr>
<tr>
<td>Percentage decrease, %</td>
<td>25%</td>
<td>39%</td>
<td>34%</td>
</tr>
</tbody>
</table>

3.3. Educational Institution Ranking

The composite indicator results are shown in Figure 7. The results are given as a percentage. Institution No. 20 had the highest result at 95%. Institution No. 7 had the lowest result at 8%. The educational institutions are listed in descending order by their composite indicator result. The highest-ranking educational institutions scored a high number of points in the survey and implemented various energy efficiency measures and utilized RES before this study, and the main benefits came from implementing mandatory measures. Educational institutions with the lowest and middle scores should additionally implement optional measures. This results in a lower ranking because the reduction in primary energy consumption and emissions per investment of optional measures compared to mandatory measures is lower. The lowest-ranking educational institutions have not implemented or improved their mechanical ventilation systems, resulting in a smaller decrease in primary energy consumption and emissions compared to the decrease achieved with other measures.

![Figure 7](image_url)

**Figure 7.** Composite indicator ranking of educational institutions based on the sustainability criteria.

4. Discussion

There is a dilemma in balancing the need for energy efficiency with the requirement for proper ventilation systems in educational institutions. On the one hand, the aim is to reduce energy consumption through energy-efficient building systems and the use of RE sources.
On the other hand, it is important to maintain proper indoor air quality for the health and safety of students and staff, which often requires energy-consuming ventilation systems and equipment [39–41]. Thus, educational institutions mandated to install ventilation systems rank poorly according to composite indicator criteria.

The interviews and survey were conducted with representatives of educational institutions. Afterwards, building and energy system inspections were carried out during the on-site visit. During these inspections, it was found that the information given during the interviews was not accurate. The representatives may have given positive answers to present their institution favorably and to avoid negative feedback. Nevertheless, it is possible that they sincerely believed the information they were presenting was true [42–44]. Regardless, it is important to consider the potential biases and motivations of the interviewees when analyzing the authenticity of their responses.

During the on-site visits to the educational institutions, some representatives showed a comprehensive understanding of the EMS and energy sources in the educational institution, while others proved otherwise. Energy illiteracy can result in poor decisions regarding energy use and management or neglect of energy efficiency measures, and lead to reliance on inefficient energy sources [45–47]. Therefore, it is important to ensure that representatives are educated on sustainable practices in educational institutions [48]. Further research could be conducted on representative energy awareness levels and educational institutions’ energy consumption.

The expenses regarding sustainability measures can have had a significant impact on the results. For this study, measures with a positive discounted payback time during their economic life were selected. Changes in energy tariffs can create financial incentives for educational institutions to adopt or reconsider the adoption of energy efficiency measures. These changes can also impact behavior related to energy conservation. Similarly, changes in the price of energy efficiency can impact affordability, return on investment, and competition among providers and manufacturers, potentially leading to changes in the availability of products and services, and changes in the price of energy efficiency measures can impact the speed of their implementation, resulting in delays until the prices become cost-effective [49–51]. Therefore, educational institutions need to select measures according to their availability and needs.

The only measure regarding climate change adaptation taken so far by some educational institutions is planting trees for shading and cooling. Although trees additionally provide carbon sequestration and biodiversity, these answers have not been given by the representatives of educational institutions. Representatives were not interested in adaptation to climate change because they do not see any benefit as of this moment. If the educational buildings are not adapted to climate change, students and staff may face health risks, such as exposure to a hot indoor climate and air pollution [52]. This can also result in a decreased quality of education. Increasing resilience to climate change demands understanding, organization, collaboration, and foresight from educational institutions [53]. Education and awareness of climate resilience could be provided to representatives and students to improve the resilience of educational buildings [54–56]. Hence, educational institutions must deliver more effort regarding climate change adaptation.

5. Conclusions

This research paper aimed to explore strategies to increase sustainability in Latvia’s vocational education system by conducting a comprehensive assessment of potential energy efficiency and sustainability measures. The effectiveness of these measures was quantified using a composite indicator.

To accomplish this, a thorough assessment of 23 educational institutions was conducted to examine the current state of energy management in the educational system. Optimization of energy efficiency and RE production measures was then carried out.

The composite indicator was used to rank and compare educational institutions based on the provided measures and survey results. Our analysis revealed that primary
energy consumption was reduced by 39%, while annual emissions were reduced by 34%. The reduction in primary energy consumption and annual GHG emissions in individual educational institutions ranged from 20 to 55% and 11 to 66%, respectively.

This research paper proposes using a composite indicator to compare educational institutions based on their current energy efficiency and environmental practices, as well as the efficiency of their implementation of energy efficiency and RE production measures. The composite indicator enables the comparison of current practices and future sustainability measures in a single result.

The results reveal that educational institutions with higher composite indicator scores perform better than those with lower scores. Specifically, the investment variable in the composite indicator criteria can be used to allocate investments to prioritize implementing mandatory or selected measures when financial constraints arise.

The composite indicator can be used as a decision-making tool to identify educational institutions that require financial incentives to implement energy efficiency and RE production measures. By focusing on the highest-ranking educational institutions, financial resources can be allocated more efficiently to achieve the best possible outcomes.

In conclusion, the composite indicator is a valuable tool for evaluating and comparing energy efficiency and environmental practices in educational institutions. The results of this research paper suggest that financial incentives for implementing mandatory and selected measures should be allocated to educational institutions with the highest composite indicator scores to ensure the most effective allocation of resources. Further research is necessary to evaluate the long-term effectiveness of this method. Based on the composite indicator results, it is recommended that educational institutions implement the mandatory measures suggested in this study. These measures aid in managing energy consumption by changing the paradigm shift in traditional energy consumption behaviors, such as requiring educational institutions to switch to an automated EMS. The inclusion of PV systems provides a beneficial reduction in primary energy consumption during the summer months and is included in the mandatory measures together with an improved EMS. The identified optional energy efficiency measures can be used as further solutions in educational institutions to decrease energy consumption and increase energy efficiency, but these measures are less financially efficient compared to the mandatory measures.

Demonstration projects have been tailored to specific educational institutions in Latvia. This system is potentially different from projects based on the climate, available resources, and learning environment implemented in other educational institutions. Further studies could include the effects of implementing demonstration projects and analyzing the change in students’ attitudes towards sustainability. Different measures could be applied to educational institutions, and sensitivity analysis on selected measures could be performed.

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