Collective overview of the literature

When looking at the energy consumption by buildings that are non-residential, we can say that the schools are one of the most important consumers. Most of the energy is used for heating and lighting, yet many discomfort hours are experienced in schools.

Depending on the type of the building and its characteristic features and including climatic zone, some strategies are more relevant than the others. This is proven by the study: [ASDRUBALI 2021]

To reduce discomfort hours retrofit solutions are introduced. There are main cathegories throughout which retrofit scenarios are implemented. Those are:

1. **ENVELOPE**
   These changes are especially effective while implemented on the buildings with lightweigth construction.

   "Using XPS, the monthly energy needs for heating did not vary significantly (-7.81% to - 4.97%). In comparison, by substituting the windows (-89.79% to -72.82) from April to January which is the most cost-effective intervention to reduce annual energy demand. "[ASDRUBALI F 2020]

   "The external insulation is more advantageous than the internal one, mainly because it is more efficient in reducing the energy demand during the heating period. [CARBONARI 2019]

2. **LIGHTNING**
   Depending on the WWR, and standards, different concentrations of artificial light is present in different schools. Since they are important consumers of electricity, their improvement can lead to important energy savings and escpeciallc reduction in primery energy ratio.

   „The L2 can reduce PEC by about 43% to reach 92.03 kWh/m2a." [MOAZZEN 2020]

3. **HVAC**
   Together with the change of the envelope and lightning, the internal load is affecting differently indoor space. This means that building systems should be recalibrated in order to avoid dissipation of energy.

   It has been noted that the calculation of the energy savings for heating is actually achieved to a greater extent (even in 81.9% for building A1 or 79.7% for building A2) if the modernization (insulation) of the external building partitions is combined with modernization (in particular hydraulic balancing) of the heating installation. On the other hand, for the group B buildings in which only thermal insulation of the external partitions was done and no retrofit works of heating system (in particular hydraulic balancing) were performed afterward, the calculated level of energy savings for heating purposes was only attained at 52.8% and 58.9% for buildings B1 and B2, respectively. [CHOLEWAI 2019]

   "Mechanical Ventilation had a positive impact, on controlling the indoor pollutants such as CO2 and particulate matters, and it proved to be energy efficient." [STABILE 2019]

   "Under-ventilation is caused by improperly selected equipment, lack of commissioning, incorrect fan control settings and maintenance issues". [CHAN 2020]

Collective overview of the literature

SLANKAMENAC, PONNALA, WESLEY, JING, NANDA 2021

Most of the time retrofit scenarios are based on „packages“ where the scenarios are combined to achieve the best possible outcome.

“The most effective energy efficiency is replacement of the existing air conditioning equipment which reduces electric demand for cooling by 29%. Next, reductions of 21.5% in adding thermal insulation to the school’s exterior walls and roof. Adding window insulation film is the least effective energy efficiency of 5.8% reduction. Combination of these resulted in 57% reduction in the annual electricity consumption.” [ALDAWOUND 2020]

In reality, the „Packages“ are formed in relation to the school budget. Sadly, not many studies were covering a problem of maintanance needs.

„Schools' low budget is a problem that managers are encountered. Thus the high retrofit cost can prevent taking proper actions.“ [MOAZZEN 2020]

Besides energy savings, there are many more parameters that should be taken into account while choosing the retrofit scenario to be applied like:

- CO_2 emission
- General Cost
- Payback Period
- Primary Energy Ratio

To get a comprehensive view of the benefits every case scenario would bring, the parameters mentioned previously could be compared in the scattered graphs for the final decisions like in Moazzen has done it at the end of his study *[MOAZZEN 2020]*. It is important to take into consideration every impact since some retrofit scenarios may look like the best ones from one point of view, while from the other they are not reasonable.

The interesting question is raising if we are looking towards the future. Will the systems implemented be able to control the changes in the future? How the CC and UHI will affect the school at first, but also retrofit scenarios that we would like to implement? This point of view was intoduced in [AKKOSE 2021]’s work.

“However, classrooms in the future climatic conditions of the 2050s and 2090s are predicted to suffer from overheating; for more than half of the occupied period in 2050 and more than 70% of the time in 2090.” - (HERACLEOUS 2018)

In [STEPHEN 2021]’s work, a night purge was introduced as efficient way to maintain indoor comfort during summer, but the main concern of its’ use was the safety. On the other hand, the limitations of natural ventilation in terms of acoustic comfort were mentioned too. Now, we can realise that, even though some strategies are efficient, thay have their own limitations, which are rarely taken into account.

Still, there are other strategies that are not so commonly used, but were introduces by some papers.
Phase change materials are one of them. The paper [PARK 2020] confirms energy performance of educational building retrofitted with PCM shading decreases the cooling energy consumption by 44%. As a limitation in winter the shading system increases heating energy consumption by blocking the insolation.

Collective overview of the literature

SLANKAMENAC, PONNALA, WESLEY, JING, NANDA 2021

The problem about retrofit strategie is the limitation of climatic zone. Extreme climates make harder to regulate indoor conditions, which is implying usage of air conditioning.

"Taking into account the thermal perception of children and considering very hot climates it is possible to evaluate the installation of high efficiency air conditioning systems to manage the peaks of temperatures". [TAGLIABUE 2020]

[Dall'O 2020] evaluate the economic convenience limits in energy retrofit investments. The question is: to what extent it is convenient to upgrade existing buildings?

When a longer time frame is considered, the most interesting interventions are the ones related to renewable energy generation (i.e., solar energy) because they can provide a higher reduction of energy consumption and greenhouse gas emissions at the end of the building life [ASDRUBALI 2019]

Overall, like always, it is a trade-off between important parameters. There is not just one correct answer, but there are more of them depending on which point of view we are looking from and this is emphasized in one of the steps in [MOAZZEN 2020] paper.