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Abstract

School buildings are fundamental to transmit civic values and importance of a better environment to future generations. Besides the low consume of energy and exploit of renewable resources, an energy-efficient school also provides a good Indoor Environmental quality (IEQ), very important for the students and teachers. Quite often, the refurbishment of the existing school buildings is approached exclusively in an energy-efficiency perspective. Unlike new buildings, where energy-efficiency goals are much easier to meet through a wider range of solutions leading toward low consumes of energy (sometimes near to zero), in the case of existing ones the morphology and technology of the building represent important obstacles. Since 2010, in the European Union EU (regardless their destination), the refurbished buildings were required to produce their own energy demand from renewable sources. Defined as “nearly Zero Energy Buildings” (nZEB) and introduced for the first time in the EPBD[1] 2010 recast, by producing their own energy demand without generating harmful emissions it was possible to reduce the dependence from the grid, known for transmitting power generated from non-renewable sources such as fossil fuels and nuclear energy.

Albania, a potential candidate to become a member of the EU, has transposed two important directives the EPBD 2010 recast and EED[2] 2012 in its legislation but still not operative. Because of the missing acts regulating the technical aspects of building envelope elements, heating/cooling plants, exploit of renewable resources and in particular the certification of the energetic consume achieved through various labels, that (new or refurbished) buildings obtain. Refurbishment interventions on existing school buildings, performed by public administrations to reduce energy consumption and improve the indoor comfort are the clear example of this unclear energy efficiency framework. Most of the public school buildings of the nine-year cycle were built during the socialist system (known as *Shkolla Tip* [3]). Usually, they have been subject to refurbishment interventions without a clear goal, even though their building technology does not allow a wide range of interventions.

[1] [ENG] Abbreviation for Energy Performance Building Directive

[2] [ENG] Abbreviation for Energy Efficiency Directive

[3] [ALB] Standard Typologies of schools from 1 to 4 storey high for specific context urban, sub-urban and rural

Poor energetic-performance apart, capacity is also a serious problem. The low number of classrooms constrain the split of the didactic activity in two rounds (morning and afternoon), posing an important dilemma between the necessity to refurbish versus the possibility to demolish and build new ones. The nine-year cycle “Hillary Clinton” school, in the Kamza municipality, has been chosen as case because of the necessity to refurbish and increase the capacity. By proposing a set of technological solutions, there will be proved the convenience deriving from the refurbishment and the increase of capacity of the existing school buildings against their demolition and building of a new energy-efficient school with the desired capacity. Furthermore, considering our climatic context and the “sustainability” of our national grid system, the decarbonization of the school building stock in the country may occur sooner than the expected EU goal for 2050. For this reason, the refurbishment proposals will consider two possible scenarios: (i) the refurbishment by preserving the capacity; and (ii) the refurbishment with increase of capacity.

Aim of the research

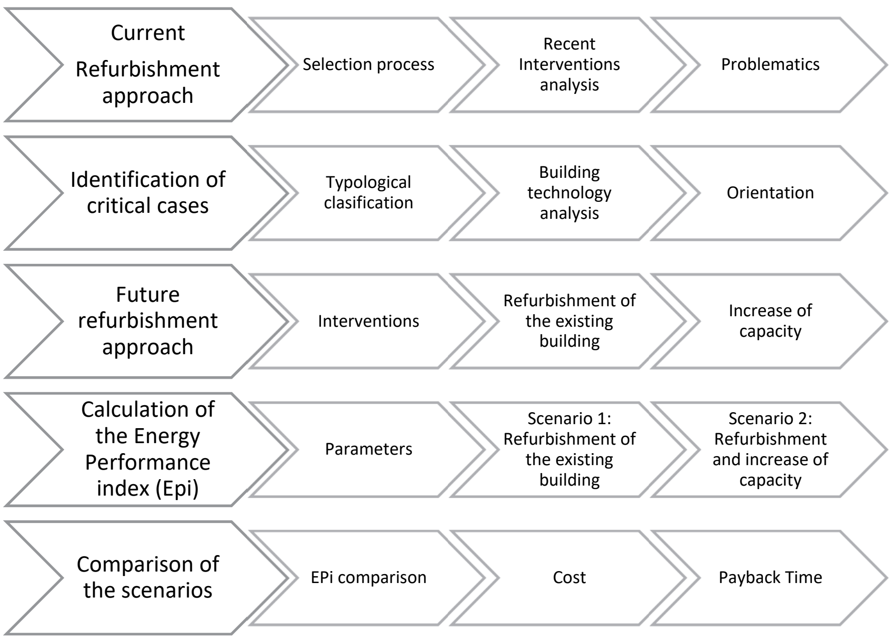

Figure 1 Aim of the research

The research aims to define solutions for the refurbishment and increase of capacity of the existing school buildings in alternative to their demolition and replacement with new ones. Although there has been registered a growing attention toward the development of a national energy-efficiency policy, the absence of a legally-approved energy certification system, building envelope requirements and exploit the renewable resources does not help their refurbishment. The first step, focused in the typological classification and analysis of the building envelope components of the critical cases spotted in collaboration with 15 municipalities that collaborated in the research. The importance of this step is to identify the reasons leading to partial and not deep refurbishment interventions in the existing school buildings as emerged in the six recent renovation cases performed in the recent years in the country. The proposed interventions, ranging building envelope components and up to the control of the indoor comfort, will path the way towards their deep refurbishment in order to make them better learning environments. Another important goal is the promotion of renewable system in order to fulfil their energy demand for heating and power consume without polluting the environment, by giving the recommendations of the type and their possible location. All these interventions, recommended in relation to the typology and the climate context the school building is located, set the criteria and chronology of the interventions in case the execution of a deep refurbishment works at one stage is are not possible. The various configuration concerned with the increase of capacity of the identified typologies will be proposed by using use of dry-construction systems rather than traditional ones, in our case the cross-laminated timber panels known as CLT, well-known for guaranteeing energy performance and short time of construction, too. In absence of national energy certification system, there will proposed a calculation methodology of the Energy performance index (EPi) for both scenarios that can be used as reference in the future.

Importance of the research

The outcomes of this thesis will help public administrations and central government to rethink their past and current approach in the refurbishment interventions of the existing school buildings. The importance of this research stands in the elaboration of interventions in order to improve and energy performance in an nZEB perspective of the existing school buildings' stock in relation to the morphology, technology and capacity problems. Although being more than 50-years old, through a set of specific interventions these buildings can have a “second” life with an improved energetic performance and a better indoor comfort as well. The proposed technological solutions aim to guide future renovations with the conviction that the outcome will better than their current situation. The collaboration with municipalities and the Ministry of Education, Sport and Youth MESY is the base of this research because it permitted to identify the problematics related with the refurbishment of the school buildings in the national territory. By referring to Italian and Greek energy-efficiency laws, it was possible to develop technological solutions based on our climate context that will make look impossible goals like the achievement of low energy consume levels close to zero, possible than ever. In addition, it is an opportunity to improve the indoor comfort and capacity of buildings build with standard building solutions. The introduction of the prefabricated systems to increase of their capacity is another strong reason to extend the life of these buildings without demolishing them. Their refurbishment means also the preservation of an important evidence from the past, where the design of school buildings, besides their problems, have served for many decades in the instruction of many generations.

Keyword

The keywords of the research are: (i) School Buildings; (ii) Sustainability; (iii) Refurbishment; (iv) Indoor comfort; (v) nZEB.

Research questions

The question that the research poses are:

1. Are the existing school buildings in Albania decent learning spaces?
2. Should existing school buildings in Albania undergo to refurbishment or demolished?
3. What the benefits by transforming existing school buildings into nearly Zero Energy Buildings?
4. What the best solution to resolve the capacity problems of the school buildings in an nZEB perspective?

1. Importance of Sustainability and Refurbishment

In this chapter, will be discussed the points of view that various authors have in relation to sustainability, the “green building” definition, energy refurbishment (or retrofit). In the first part, there will be described the increase of attention towards sustainability in architecture in the 70s and its importance in the recent up to now days. The second part, deals with the Green building definition, much debated and sometimes differently defined, describing the different points of view and the criteria a building should fulfill. The third part deals with the refurbishment topic, with main focus on the public buildings and the situation in different countries.

1.1. Sustainability matters

For many decades, the building’s impact on the environment was underestimated, unless oil crisis and the global warming issues emerged. Nowadays cities are responsible for 60–80% of energy consumption, over 75% of natural resource consumption and emitting 75% of global carbon emissions (Affolderbach & Schulz, 2018, p. 6), and buildings account approximately 30–40% of final energy consumption (Pérez-Lombard, et al., 2008). But (Birkeland, 2002), identifies in the high global urbanization rates the cause that the scarcity of resources (timber, oil, water) and in particular high global urbanization rates do not represent just an environmental threat but a danger for international security.

Harmful gases deriving from the combustion of fossil fuels are responsible for polluting the environment and contribute to acidification of soil and water. For (Hovestadt, et al., 2017), Carbon dioxide CO_2 emissions generated by fossil fuels damage the enviroment and lead to the reduction of eneregetic resoruces (oil, coal), water, food, and space. It is not surprising that when crises emerge, the awarness for the high dependency on fossil fuels is questioned. “During the two oil crisis occurred in 1973 and 1979” – according to (Brophy & Lewis, 2011, p. 1) – “for the first time governments posed the necessity to seek secure sources of energy in order to reduce dependency on imported fuel and society became much more aware about the conservation of energy that years after became the main imperative to green design”. Decrease of the reliance on fossil fuels in the early 70s, for (Williamson, et al., 2003) was made more evident when in the design approaches were used labels like ‘low energy’, ‘solar’ and ‘passive’, proving that the main focus of architecture became the environment. Since then, the label “sustainable” marked a new synergy between climate and design by fulfilling the necessity for an adequate comfort without harming the environment with greenhouse gases (GHG) emissions. If the 70s marked the decrease of reliance of fossil fuels, in the 80s there is acknowledged for the first time in at a global institutional level. The environmental issue and the necessity to set the bases for a sustainable development as stated in the United Nations (UN) report of 1987: “An approach to progress that meets the needs of the present without compromising the ability of future generations to meet their needs[4]”. For (Goodhew, 2016, p. 3) this act is important because of: (i) giving priority to the essential needs of the world’s poor, and; (ii) the idea of limitations imposed by technology and social organization on the environment’s ability to meet present and future needs. If he sees the opportunity for more social inclusion and balance between technology and natural resources, (Jones, et al., 2008) thinks that there should be posed more attention in the : (i) the fair and just intergenerational allocation and use of natural resources and (ii) the preservation of ecosystems across time.

Considering the necessity to save the earth by reducing emissions and consume of resources, sustainability should become an approach in the design process and include various scale of intervention. “Sustainability is no luxury. It is an approach whose time has come”- warns (Gefland & Freed, 2010, p. 18) - meaning that it has to be acknowledged as an important tool, not as an optional one. In order to preserve the natural resources, it is required a radical shift not only focused on our lifestyle. It is clear that no move towards sustainable development can go ahead without radical changes in architecture, construction and spatial planning (Bokalders & Block, 2010). Again (Birkeland, 2002), adverts the necessity for the design education and the design process needs a radical shift in order to become a social and environmental problem solving tools. In this perspective, he lists the issues that designers need to consider starting from: (i) Re-examining human needs, and setting appropriate goals which prioritize ecological sustainability and social equity; (ii) Rethinking the basic nature, methods, and goals of the design process itself; iii) Integration of knowledge from other fields concerned with human and ecosystem

[4] (United Nations World Commission on Environment and Development, 1987)

health; iv) Promotion of new technologies, systems of production, and construction methods that do not rely on natural capital, fossil fuels and harmful chemicals. For (Jones, et al., 2008), there are three important design approaches to implement at three different scales. In the macro perspective scale, sustainable design should focus in the protection of the health and welfare of global ecosystems for current and future generations. In the micro perspective scale, green design is responsible for the people's health and welfare in the built environment. The third one is the environmentally responsible design (ERD), a combination of green and sustainable design with far-reaching benefits for the planet and its inhabitants. Through these, three design approaches, design professionals and the construction industry cannot operate separately anymore, as consequence; sustainability becomes a sequence of processes from the design up to the building process.

For (Graham, 2002), building design should have a major environmental approach every building has an impact in the environment by: (i) establishing a connection with to the Earth; (ii) depending on natural resources; (iii) causing changes to the environment (3) causes environmental change; and (iv) affecting both human and nonhuman life. For (Attmann, 2010), this strong relationship with the environment should influence a design based on sustainable and ecological principles; developing and using advanced green technologies and materials; and promoting and demanding high-performance buildings.

Its relation with planning and design should never be static. Indeed (Williams, 2007, p. 17) affirms: "Sustainability is better thought of as a continuum, as a calculus: $dp \rightarrow S$, meaning design and planning approaching sustainability and because of not being static it is iteratively changing, based on evolving knowledge that connects science and design". However (Williams, 2007) sets an important condition for a sustainable design versus green design, and it the grid-system. Contrary to green design (that is a part of it), sustainable design relies entirely on sustainable resident clean energies without exploiting non-renewable resources even when in emergency and natural disaster, a thing that green design does not. The independence from the grid (unplugged from it) means avoiding: (i) growing cost of fossil fuels; (ii) their low efficiency in terms of net energy produced; and (iii) to contribute for global warming. Contrary to the Authors mentioned above, (Maczulak, 2010, p. 13) does not identify design and education as keys to solution of the scarcity of resource. A synergic cooperation among people in large and small ways, can introduce sustainability in energy production, transportation, construction, and other industries in order to stimulate them to find methods for using resources in a sustainable manner.

For this purpose, the non-renewable sources (oil, coal, and natural gas) largely used during 20th century, will be replaced by six energy sources (solar, wind, wave and tidal action, geothermal, hydrogen, and biomass) representing the real and important change. Convincing people about the benefits of exploiting renewable sources should not be underestimated because sometimes there is adverted a sort of skepticism by them. (Sassi, 2006), emphasizes the importance of successful and sustainable architectural design examples as demonstration tools to help people realize the benefits. Worried of the absence of a sustainable and contemporary way of thinking among people may grow skepticism around the importance of sustainability, they can serve the cause especially when reflecting the local culture.

1.2. Green building Definition. Importance of refurbishment

Defining if a building is “Green” or not, is subject to many contradictions. For many authors technical aspects and benefits deriving from them are key factors in the acquisition of this label, but almost all agree that a “Green” building should have a strong relation with the local context and especially consume fewer resources. The requirements for a building to be defined, as “Green” are not only restrained to the low consume of energy and power demand produced from renewable sources. The construction process and properties of the materials have an important influence in the acquisition of this label. If in the 70s, to describe the sustainable approach towards the environment were used labels like “low energy”, “solar”, “passive”; a “Green” building was labelled as “earth-sheltered”, “self-sufficient” and “ecological” (Williamson, et al., 2003). Decades after, (Keeler & Vaidya, 2016) uses the labels: “integrated,” “living,” “efficient,” “high-performing,” “elegant,” and “restorative”. As common in his projects, Frank Lloyd Wright remarks the importance of the connection between building and nature in his statement: “Study nature, love nature, stay close to nature. It will never fail you - (Maczulak, 2010, p. 138)”. Even though technology devices were incomparable from those we possess nowadays, his statement is very meaningful because by studying and identifying potentials of

Table 1. Taxomy of architecture referring to (Attmann, 2010) – graphics: the Author

Main	Category	Major Components	Sub-terms
Green architecture	Sustainable architecture	**Elements** Materials & Technologies	• Durable • Economical • Low-maintenance • Recyclable
		Resources	• On-site conditions • Cost-effectiveness • Accessibility • Natural Forces
		Environmental	• Healthy • Habitable • Social/Inst. • Capacity • Security and Safety
	Ecological architecture	**Elements** Materials & Technologies	• Clean • Earth resources • Biodegradable • Low-embodied Energy • Renewable
		Resources	• Resource share • Soil/Landscape • Site selection • Water • Resources/ Use • Waste management
		Environmental	• Pollution • Global • Stewardship • Land use
	Performance	**Elements** Materials & Technologies	• Efficiency • Effectiveness • Productivity
		Resources	• Economic • Eco-behaviour • Design
		Environmental	• Adaptability • Functionality • Environmental Quality

the context, there can be achieved an optimal indoor quality by avoiding non-renewable resources (pollution) and non-eco-friendly materials (waste). Maximization of daylight, distribution heat and cooling, ventilation, use natural water flow, and decomposition of wastes are important to respect the surrounding environment but in particular to its occupants. (Karolides, 2011), emphasizes the importance of a holistic approach by programming, planning, designing, and constructing (or renovating) buildings and sites. In this case, the integrated design approach, based on the analysis and exploit of the local resources, becomes the main condition to label a building as “Green”, not the building intended as an outcome. The rational use of local resources through this multi-step process has a low environmental impact and guarantees the adequate comfort to the users.

Table 2. Goals of green architecture referring to (Ching & Shapiro, 2014)– graphics: the Author

Main	Goal	Tasks
Green architecture	Environmental	• Reduction of GHG emissions • Carbon sequestration through biological processes. • Reduce extraction of coal, natural gas, and oil. • Reduce pollution of air, water, and soil. • Protect clean water sources. • Reduce light pollution that can disrupt nocturnal ecosystems. • Protect natural habitats and biological diversity. • Prevent unnecessary and irreversible conversion of farmland non-agricultural uses. • Protect topsoil and reduce the impacts of flooding. • Reduce use of landfills. • Reduce risk of nuclear contamination.
	Health & comfort	• Improve indoor air quality. • Improve indoor water quality. • Increase thermal comfort. • Reduce noise pollution. • Improve moral.
	Economic	• Reduce energy costs. • Improve productivity. • Create green jobs. • Increase marketing appeal. • Improve public relations.
	Political	• Reduce dependence on foreign sources of fuel • Increase national competitiveness • Void depletion of non-renewable fuels: oil, coal, and natural gas. • Reduce strain on electric power grids and risk of power outages
	Social	• Follow fair labor practices • Provide access for the disabled • Protect consumers. • Protect parklands. • Preserve historic structures. • Provide affordable housing.
	Human spirit	• Deep connection to and love of the Earth and nature. • Be self-reliant. • Satisfy the quest for beauty

(Yudelson, 2008), uses the term “revolution” to describe the impact it had on changing people mind about the devastating impact cheap fuels have and the fully payed-off with “soft” benefits including energy, water savings and productivity gains., despite the initial “hard” construction costs. For some author, the label “Green” is more complex and has to accomplish several tasks, too. For (Ching & Shapiro, 2014) a “Green” building, as the outcome of “Green Architecture” has a strong symbolic and a six-goal mission to accomplish. It has a symbolic because of representing: (i) a dream come true; (ii) a new and a rich field; (iii) integration with nature, and; (iv) a countrinously-envolving concept. If the first and third point are shared by (Karolides, 2011) and (Yudelson, 2008), in the second and fourth points it is required the same goal as (Williams, 2007) evoked for sustainability, in order to get better and better.Regarding Its mission, it includes the realization of six important goals (see Table 2) is related to the following aspects: (i) environment; (ii) health and comfort; (iii) economic; (iv) political; (v) social; and (vi) human spirit. In each goal, there are several tasks, proving that the range of solutions a “Green” building provides goes beyond the energy consumption and environmental issue. Indeed, it is an opportunity to create green jobs, social inclusion, affordable housing and contribute for the preservation historic structures. For (Attmann, 2010), the label “Green” is obtained by considering these three main categories: (i) Sustainable Architecture; (ii) Ecological Architecture and (iii) Performance. Each category includes its elements, resources, and environmental goals that a building should fulfil the respective sub terms or requirements (see Table 1).Sustainable architecture and its elements, measure the stability of the building in a technological, material, ecological, and environmental point of view. The “sustainability” of elements include properties such as durability, recyclability and contained costs. The building should involve an efficient use of the site resources, resulting with low construction, transportation and operational costs once it is ultimate.

The indoor environment besides being safe, healthy and habitable by avoiding several risk and diseases may help to enhance a sense of community and awareness toward the environment. Ecological architecture is concerned with how ecological properties affects the building, its occupants, and the environment. The manufacturing process is very important because the materials used in the building process have to be non-pollutant, low-embodied energy renewable and biodegradable. Pollution of soil and ground water must be avoided. Third, the performance represents the measurable outcome of the functional, structural, and environmental qualities of the building. It also determines how well the building supports the needs of its users. Savings in energy, water, costs and resources are the main indicators to comprehend the performance of the building and it also its capability to interact with the natural resources by protecting and preserving them. After describing these three main categories, suddenly (Attmann, 2010) affirms:

“The definition Green is an abstract concept, and the level of greenness of building is determined based on the level of interaction between three main categories (each one is nevertheless independent and mutually exclusive): sustainability, ecology, and performance, where each one includes three major components that are furtherly divided in the respective sub-terms. For any building to be considered as an example of Green Architecture, it should include all of the categories in various degrees. If one of these subcategories is missing, then the building cannot be considered sustainable, even though it has sustainable qualities”.

Therefore, it emerges that: (i) “Green” label is difficult to achieve; (ii) complexity of the score process and (iii) the effectiveness of this score for existing buildings. The first consideration affirms that hardly a building can fulfil all the ranked criteria of the three major categories although it is not excluded it does. As long as (Ching & Shapiro, 2014) when describing the symbolic of “Green” building affirmed that it is a countrinously-envolving concept, may be this limit is not that impossible thanks to new technological improvement of building materials and plants. Depending on the will to be fully “Green”, there might be initial “hard” costs as stated by (Yudelson, 2008) but followed with even softer benefits and performance. The second consideration is concerned with the building process, remarking the high attention toward the environment since the design, construction, activity and demolition and not exclusively to the final product. In case of existing building where the renovation/refurbishment interventions the label “Green” can be impossible to achieve they level of greenness may not, but with the presence of each category as

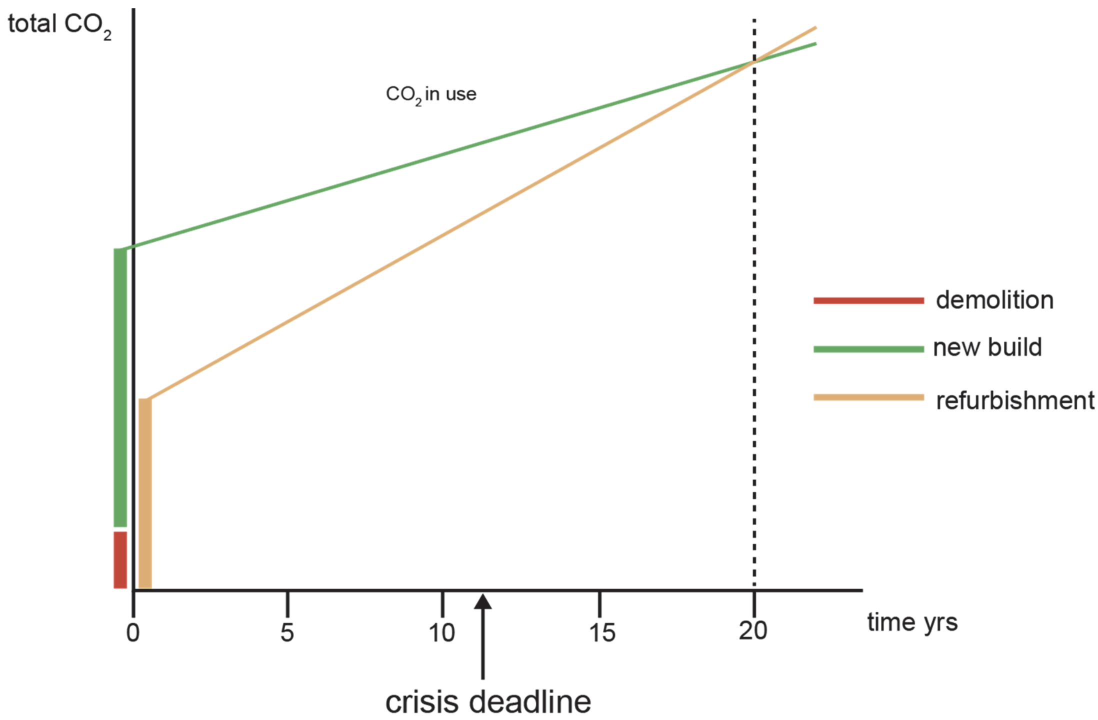

Figure 2 Refurbishment vs New building: CO_2 emission comparison – source: (Baker, 2009)

(Attmann, 2010) remarks. In light of this, regardless the typology and destination, a "Green" building must accomplish these main tasks: (i) avoid waste (site-demolitions, construction/packaging, building users); (ii) use low-embodied energy construction materials and reduce use of soil, water and energy during construction and occupant use; (iii) reduce energy and carbon dioxide (CO_2) emissions for heating and cooling, lighting, and plug loads; (iv) Provide a "healthy" indoor environment (avoid volatile organic compounds VOC, proper ventilation and daylight control).

Improving energy-efficiency and indoor comfort conditions is not that easy in the case of existing buildings where internal layout and building technology represent serious obstacles. For (Williams, 2007, p. 121) existing buildings, represent a considerable challenge to sustainability, as long as they need considerable design renovation work to make them approach sustainability or by making them marginally energy efficient ones. The benefits deriving from the application of sustainable design principles in the renovation process go beyond energy efficiency by including: (i) natural ventilation and daylighting; (ii) abandon of nonrenewable resources; (iii) creation of a healthier and participatory environment for users (iv) redesign the existing structure can function unplugged. Energy-efficiency is one of the major outcomes from refurbishment but not less important is the reduction GHG emissions. This process is regulated by building energy codes, providing cost optimal energy efficiency retrofitting guidance linked to general maintenance and retrofit, defining requirements for system performance and integrating renewable technologies.

Refurbishment interventions aim the modernization, overhauling and the shift into an acceptable functional state (Watt, 2008), involving non-structural interventions and modification to its interior layout (Giebeler, 2009, p. 13), but without eventually extensions to the existing building to guarantee major improvements to commercial or public buildings (Douglas, 2006). This type of interventions have as a main goal an improvement of the building's performance (Watson, 2009) and upgrade to the current standards because of change in users' demands or new technical regulations, where there is required the knowledge of both current and historical construction methods (Giebeler & Kahlfeldt, 2009, p. 16). However, the interior layout cannot be an obstacle for the needs of current or future tenants and even if the refurbishment intervention will improve its energy standard (Richarz & Schulz, 2013). The range of refurbishment interventions for energy-efficiency improvements includes: (i) intervention in the building envelope; (ii) replacement of the heating plants; (iii) replacement of external transparent and opaque components: doors and windows; (iv) replacement of lighting fixtures; (v) openings for indoor ventilation; and (vi) eventual integration sun-screening elements. Depending on the goal, deep interventions permit the achievement of the best outcomes in terms of energy consumption and indoor comfort but implying higher costs. However, it is possible to perform specific interventions that may bring tangible benefits in terms of energy efficiency by containing costs. When performing refurbishment interventions the considerations end to energy saving and limited emissions in the atmosphere when the building is completed. There are many benefits from refurbishment are even more compared to the demolition and rebuild hypothesis there are fewer materials and less energy for demolition and transportation, even if being more labour-intensive than new build (Brophy & Lewis, 2011, p. 20).

Before choosing for demolition and new building, there should be considered the transportation costs, that may be unsustainable in case of remote location. Besides avoiding unnecessary transportation and materials costs, this approach is particularly advantageous in the reactivation of the historic buildings. (Keeler & Vaidya, 2016), consider it crucial to the creation of sustainable, human-friendly cities by creating also a “sense of place”. An important contribution in the debate refurbishment versus new building (including demolition) in an environmental perspective is given by (Baker, 2009) when analysing both processes in period of 20 years. As illustrated the graph in Figure 2, refurbishment intervention has a lower environmental impact, because of the lower carbon emission, waste disposal (demolition) and the embodied energy (new construction elements), whereas the new building becomes the lowest emitter after 20 years. In case of the break-even time beyond the environmental crisis (or emission reduction target) time, the life-cycle emission is irrelevant and the refurbished building is the best choice.

Even though the new building, including or not demolition process, can achieve a higher level of greenness, the refurbishment of existing building is more sustainable in environmental, urban and social point of view. Regarding public buildings, where internal layouts and building technology are different compared to past, the necessity for example for open-space plans or glass facades guaranteeing a higher amount of light compared to load-bearing wall structures. Obviously, the building systems guaranteeing these benefits represent initial “hard” costs as stated by (Yudelson, 2008) but followed with “soft” ones when the building is operative. However, if the internal layout of the existing building is suitable for a certain the desired use, even though mismatching with the original function the building was built for, the refurbishment is the best solution, building technology permitting. In the EU, refurbishment (deep or partial) is a top priority and stimulated by various directive and even incentives to lower energy consumption and consequently emission in the atmosphere. The first important act was the approval in 2002 of the Energy Performance of Buildings Directive (EPBD) also known as the EPBD 2002/91/EC. Since then, existing buildings got a key role in the reduction of dependency from imported nonrenewable sources and CO_2 emission in the atmosphere. Among the main points of this directive regarding refurbishment were: (i) definition of major interventions in terms of cost and consistency; (ii) definition of partial intervention; and (iii) floor area eligibility for major interventions. A major renovation had to: (a) economic condition- cost more than 25 % of buildings value[5]; (b) consistency condition - more than 25 % of the building undergoing to renovation; (c) Priority- public building with total floor area over 1000 square meters. Partial renovation should be cost-effective and focused to those parts of the building highly relevant for its energy performance in to improve of the overall energy performance. The floor area criteria for public buildings was revised various times in order to extend the range of action to those buildings whose floor are did not exceed 1000 square meters. In 2010, the EPBD recast, known as the (2010/31/EU), posed an annual refurbishment percentage target of 3 % for public buildings, with a total useful floor area under 500 square meters that in 2015 was lowered 250 square meters.

Besides transposing the directives into the respective legislation, the EU member countries had to approve the further acts to activate the directive. The refurbishment of existing building, or renovation as defined in the EPBD recast, cannot occur in absence of a legally approved energy certification system and building codes setting the U-values building envelope elements have to respect. The limitation of heat

[5] excluding the value of the land

loses is not the only measure but it includes the replacement of the plant with highly efficient ones running by renewable source. To stimulate private intervention there are given incentives by the state in order to increase the energy finance in all the buildings not only in privates ones. Unlike its first version of 2002, the EPBD recast pushed further the refurbishment goal by requiring building to produce their own demand and not to just limit their loses. The nearly Zero Energy Buildings, that will be discussed next, aimed the increase of the level energy efficiency by relying less possible from the grid and it recalls the condition that (Williams, 2007) posed for the sustainability of the building which is the independence from the grid that is run by non-renewable fossil fuels.

1.3. nZEB. A further level of energy efficiency in the EU

In the beginning of the 90s, the EU posed important goals in terms of energy efficiency and reduction of emissions. New and Existing buildings, largely responsible for high consume of energy and GHG emission because of exploiting systems run by non-renewable had to become the solution and not a cause. The first act that paving the path toward energy efficiency, introduced in 1989 and implemented in 1993, was the Specific Actions for Vigorous Energy Efficiency (SAVE) directive. According to (Ries, et al., 2009) it brought six innovations: (i) energy certification of buildings; (ii) separate billing for heating, hot water and air-conditioning based on actual consumption; (iii) third-party financing for energy savings in the public sector; (iv) necessity for the thermal insulation for new buildings; (v) Inspection of boilers; and (vi) energy audits in big industrial insulations. The EED, EBPD were followed by 2020,2030 and 2050 climate & energy frameworks (see Table 3) highlight the focus on energy efficiency and reduction of GHG emissions. However, energy efficiency is not meant just reduction of heat loses but in particular the high exploit of renewable resources to produce clean energy, too. It represent an evolution or like (Ching & Shapiro, 2014) when describing the "Green building as "a countrinously-envolving concept", because the energy-efficient building is not any more just a low-energy one (end of 20th century) to building that produces its own demand from renewable sources (beginning of the 21st century). Low-energy buildings are be divided into two categories or "approaches" according to (UNEP, 2007): (i) those being part of concept of 50%;

Table 3. Chronology of directives approved in the EU for energy efficiency and refurbishment - graphics: the Author

EU Directive/Framework	**Energy efficiency requirements and goals to EU member states**	
SAVE (93/76/EEC)	• **Thermal Insulation:**	– Thermal insulation of the new buildings in a long-term in relation to climatic conditions/ climatic areas and the intended use of the building.
EPBD 2002 (2002/91/EC)	• **Definition** • **major renovation interventions:**	– Cost renovation > 25 % Value of the building (excluding the value of the land) and affecting: building shell, and/or energy installations such as heating, hot water supply, air-conditioning, ventilation and lighting). – More than 25 % of the building shell undergoes renovation.
	• **Definition partial renovation interventions:**	– Limited intervention to those parts of the existing building highly relevant for the energy performance of the building and cost-effective in order to lead to the improvement of its overall energy performance.
	• **Priority major renovation:**	– Public Buildings with total useful floor area >1.000 m^2 total useful floor area over undergo major renovation
2020 climate & energy framework	• **20% cut in GHG emissions (from 1990 levels)** • **20% of EU energy from renewables** • **20% improvement in energy efficiency**	
Recast EPBD 2010 (2010/31/EU)	• **Renovations**	– Minimum energy performance requirements to be met in every full or partial renovation intervention.
	• **Nearly zero-energy buildings (nZEB)**	– by 31/12/ 2020, all new buildings must be nearly zero- energy buildings (nZEB); – after 31/12/2018, new buildings occupied and owned by public authorities must be nearly zero-energy buildings.
EED 2012 2012/27/EU	• **Energy savings for 2020:**	– < 1.474 Mtoe of primary energy – < 1.078 Mtoe of final energy
		– 1,5 % of the annual energy sales to final customers by volume starting from 01/01/2014 to 31/12/2020.
	• **Renovations**	– From 01/01/2014, each Member State has to renovate 3% of the total floor area of heated and/or cooled buildings owned and occupied by its central government each year to meet at least the minimum energy performance. – The 3 % rate includes buildings with a total useful floor area > 500 m^2 owned and occupied by the central government of the Member State and starting from 09/07/2015 it is lowered to 250 m^2.
2030 climate & energy framework	• **40% cut in GHG emissions (from 1990 levels)** • **32% of EU energy from renewables** • **32,5% improvement in energy efficiency**	
EED 2016	• **Energy savings for 2030:**	– < 1.483 Mtoe of primary energy – < 1.086 Mtoe of final energy
		– Saving 1,5 % of the annual energy sales to final customers by volume starting from 01/01/2021 to 31/12/2030
2050 climate & energy framework	• **80-95% cut in GHG emissions (from 1990 levels)** • **75% of EU energy from renewables** • **41% improvement in energy efficiency**	
EPBD 2018 (EU 2018/844)	• **Renovations**	– Elaboration of a long-term renovation strategy by each EU member to support the renovation of the national stock into a highly energy efficient and decarbonised building stock by 2050. – Facilitation of the cost-effective transformation into nZEB's of public and private, residential and non-residential. – Each EU member shall encourage, high-efficiency alternative systems, in so far as this is technically, functionally and economically feasible, and shall address the issues of healthy indoor climate conditions, fire safety and risks related to intense seismic activity.

and (ii) those concept of 0% (Zero-Energy or Passive House). In the first approach are included those building consuming half of heating energy achieved by performing specific interventions (thermal insulation, high performance windows, air-tight structural details and a ventilation heat recovery system) mainly from partial renovation/refurbishment interventions. On the other hand, the 0% approach are included those buildings (new and refurbished) whose energy consumption is almost or equal to zero. The passive house standard largely applied in North-European context have as prior measure the limitation of heat loses and consequently the heat conservation. Nowadays, Zero Energy buildings are identified by the acronym ZEB but there also other subcategories (or labels) defining those buildings that achieve energy consumption close to zero such nZEB (nearly Zero-Energy Building) or NZEB (Net-Zero-Energy buildings). The most common features are: (i) self-sufficient energy production; (ii) exploit passive energy systems; (iii) exploit of trees' shade for cooling; (iv) exploit of the surrounding vegetation as added insulation; (v) orientation of openings towards South to capture sunlight and heat; (vi) cross-ventilation from open windows and skylights; and (vii) .natural lighting through skylights.

“A new discipline called zero energy architecture seeks to create zero energy homes, offices, museums, nature centers, and classrooms”-says Anne Maczulak (Maczulak, 2010, p. 18). If electricity is 100 % renewable there will not just be nZEBs but also climate neutral buildings (Voss & Musall, 2013), but conservation of power produced from renewable sources is difficult for nZEB buildings by making indispensable the connection to the grid. Precisely this reason, (Hootman, 2013) splits the Net Zero Energy definition in two main concepts. The Net, means in the annual balance the energy from renewable exceeds sources the (non-renewable) energy from the grid. Second, “Zero Energy” should be achieved when building uses the “clean” energy produced from renewable sources during its operation, not when inactive. It represents the real goal of NZEB, the (performance) that is measurable in terms of avoided CO_2 emission and real cost savings. (Torcellini, et al., 2006), and (Keeler & Vaidya, 2016) remark two important aspects in relation to NZEB, about the definitions and renewable energy location options. As illustrated in Table 4, a NZEB building can be defined as: (i) Site energy; (ii) Source energy; (iii) Cost; (iii) Emissions.

Table 4. NZEB definition and classification- source: (Keeler & Vaidya, 2016); graphics: the Author

NZE definition	*Pros*	*Cons*	**Renewable Energy Location Option**			
			NZEB A **Building footprint**	**NZEB B** **Site boundary**	**NZEB C** **Off-site**	**NZEB D** **RECS**
Site energy	• Easily measured on-site with meters and utility bills. • Easy to understand and communicate • Encourages energy efficient building design	• Requires more on-site electricity to offset natural gas use • Does not differentiate between fuel types for their emissions or other environmental impacts • Values energy import and exports equally, not accounting for additional export costs	Difficult Limited area for generation harvesting biomass is unlikely	Possible More area and generation and biomass	Easy More area and generation and biomass	Easy No geographic restriction on acquiring RECS
Source energy	• Easier NZE goal to reach since on-site generation is valued higher • Includes fuel distribution and generation impacts • Values each fuel used at site differently	• Easy to implement • Does not differentiate between fuel types for their emissions or other environmental impacts • Site-to source conversions needed • Not easy to understand and communicate	Possible When on-site renewable generation is valued higher	Possible When on-site renewable generation is valued higher	Difficult When biomass is used in large quantities	Easy No geographic restriction on acquiring RECS
Cost	• Easy to implement and measure • Values and allows demand response control • Verifiable from utility bills	• Volatile energy rates make prediction of performance and comparison from year to year difficult	Difficult Depends on utility purchase rates	Difficult When biomass is used in large quantities	Difficult When biomass is used in large quantities	Possible If RECS are cheap, or bought in large quantities
Emissions	• Easier NZE goal to reach • Accounts for non-energy differences between fuel types such as pollution and greenhouse gases • Allows for inclusion of embodied impacts and extension to other scopes like vehicle emissions	• Accounting is dependent on emissions information from utilities, which is likely to be historical data	Possible When on-site generation has favourable emission factors	Difficult When biomass is used in large quantities	Difficult When biomass is used in large quantities	Possible When the RECS have favourable emission factors

In a NZEB site energy, the energy produced within the site's boundary by exploiting the renewable resources is enough to fulfil the buildings demands, weather conditions and site's area permitting. In the NZEB Source Energy, the supply from the grid is accepted, becoming the main parameter of comparison versus the renewable energy produced by the building. The Cost NZEB, occurs when the (renewable) energy produced on site is exported to grid, permitting the building's owner to level the costs of the energy that he purchased from the grid. It is measurable through bills but there is the risk of the weather fluctuations and up/downs related to the energy prices year by year. The Emission label, certificates the production of the renewable energy has avoided emission and at least leveled the emission generated by the energy of grid. The risks related to weather conditions and site's size make the achievement of the first label very difficult. However, even if the grid supply is allowed the produced renewable energy should exceed it in order prevail in amount, cost and emissions avoided. The renewable energy location option includes also the possibility to consider individual and multiple buildings (Torcellini, et al., 2006). The four options include the building's footprint, site, offsite and Renewable Energy Certificates RECs and the possibility to obtain the four definitions mentioned above.

Applied only for individual buildings, with NZEB A option expects the production of renewable energy within the building's footprint. All the four definitions are possible, but the building's footprint should be sized the right to facilitate the production of a bigger amount of renewable energy to compete against the grid. Unstable weather and footprint apart, the NZEB B option, applied to individual or multiple buildings, involves vast areas. There are higher possibilities to obtain one more definitions, unlike the biomass scenario where the cost and emission definitions are difficult to achieve. NZEB C options, valid for individual and multiple buildings, increases the possibility to obtain one or more definitions, because it is possible to produce energy offsite. The last, NZEB D label, allowing the purchase off-site energy (optionally) and thanks to the Renewable Energy Certificates (REC's), only the source or emissions definition are possible to achieve.

As introduced previously, in the ZEB family it also included the nearly Zero Energy Buildings (nZEB) is described in the (EPBD, 2010): "Referring to buildings with very high energy performance requiring nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby." Precisely in the 2010, the EPBD recast, introduced for the first time the mandatory nZEB target: (i) after 31/12/2018, for new buildings occupied and owned by public authorities; and from 31/12/ 2020, extended to all new buildings. As common for

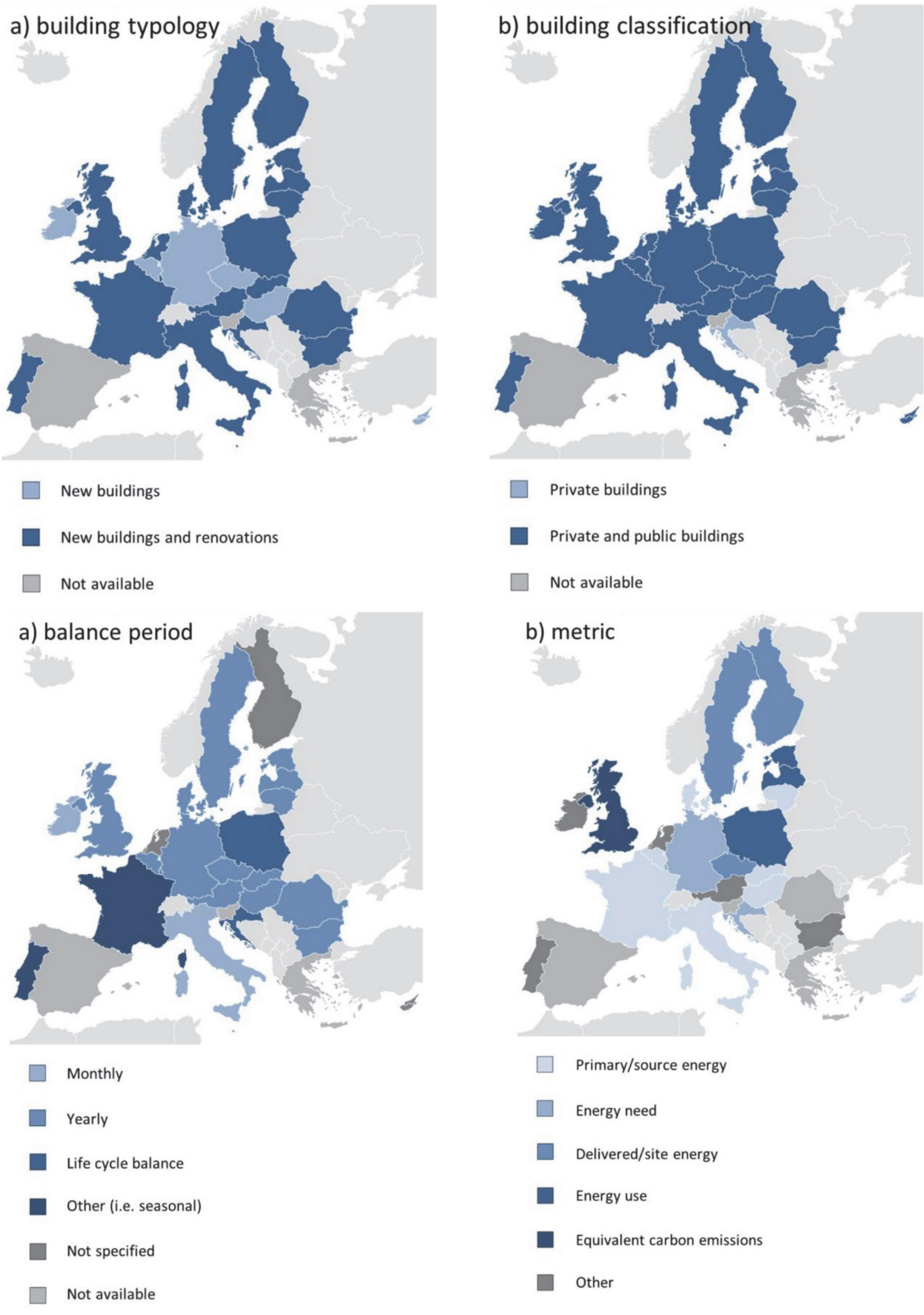

Figure 3 Specifics nZEB national plans of EU member states -source: (D'Agostino, et al., 2016)

past EU directives, once transposed to the national legislation, the next step consisted in the elaboration of the national nZEB plan for residential and non-residential, including its metrics, usually the primary energy use expressed in kWh/square meters per year. Besides aiming the same goal, EU member have not the same metrics in the definition of the nZEB label. The most common criteria are:

(i) reduction, expressed in percentage from the reference building; (ii) energy label class (e.g., A class) of the national energy performance system (iii) minimum levels (as share) of renewable energy for the energy consumption. In the United Kingdom, Norway, and Spain, carbon emissions are the main indicator, or even complementary indicator to primary energy use like in Austria and Romania (Berardi, 2018). Until 2013, the diffusion of nZEB building in EU was not promising, but the next year there was a turning point with the wide range of policies and measures taken by each state. (Bertoldi, 2018). In 2016, refurbishment interventions and their respective metrics were included in the nZEBs national plans for residential e non-residential buildings (D'Agostino, et al., 2016). Even in this case the metrics are different: (i) primary energy use (kWh/square meters per year) in Austria, Bulgaria, Denmark, Latvia, Romania; (ii) reduction in percentage of primary energy in Czech Republic and France; (iii) meeting the highest label of energy efficiency in the national level in Italy and Lithuania.

The promotion of nZEB represent two main aspects: the energetic and environmental issue. The first aspect represent a redefinition from a low-energy building consuming less energy (after refurbishment) into a building that produces its own demand counting on renewable sources. Unlike the PassivHaus standard common for North-European countries, where the main goal was to limit heat loses and use the less possible the heating plant run by non-renewable sources, they produce their own demand for heating and power but exploiting the renewable site sources. Precisely this condition becomes the key to turn new and refurbished nZEB buildings as environmental friendly because there is avoided the grid that supplies power from non-renewable sources, in poor word the main cause of pollution. The climate & energy framework (2030 and 2050) and the EPBD 2018, strongly rely in the importance of nZEB refurbishment, because by "greening" the existing buildings means independence from the grid and a change for the energetic panorama of Europe by shifting totally towards renewable with a share of 75 % in 2050 with consequent decarbonization of the building stock, too.

2. The nZEB school building

In this chapter there will be discussed the sustainable school topic but not only in an energy efficiency point of view. School buildings require high amounts energy for heating, cooling and in particular, for lighting, but the indoor air quality cannot be scheduled as a less important. Considering that, the performance of students and teachers during didactic activities requires optimal (natural and artificial) lighting, indoor temperature and air quality. For this purpose, in the first part there will be a general overview on Sick Building Syndrome SBS. The second part will deal with the sustainable school's definition by analysing the points of view of several authors. The third part, will deal the refurbishment of existing school building and the analysis of four nZEB case studies.

2.1. The SBS

Attention toward the reduction of the energy consumption in buildings and promotion of use of renewable sources aimed to reduce the use of non-renewable sources and the reduction of GHG and CO_2 emissions. Influencing positively the "outdoor" environment does not mean to not consider the importance of good and healthy "indoor" one. Non-residential buildings (offices, schools, hospitals, theatres etc.) are places where productivity is very important and where activities performed indoors need, optimal IEQ referred to good lighting and air quality.

If in the 80s attention towards sustainability grew at the global level, in these it was definitely recognized the existence of the Sick Building Syndrome or SBS. This definition refers to a set of symptoms that affect a significant number of building occupants during the time they spend in the building and diminish or go away during periods when they are not in the building. The symptoms cannot usually belong to specific pollutants or sources within the building (Sassi, 2006, p. 97). Poor levels of air quality, lighting and building control, when encountered within a building lead to the creation of an unhealthy environment directly related to physical, chemical and biological properties of a building. Chemical and biological disease agents (formaldehyde gas, building materials, dust mites etc. are considered as indoor air pollutants, not easily detectable by the building occupants, affecting the physiological health of an individual. Temperature, humidity and lighting levels have an import building on the buildings indoor comfort, and if below the norm can have physiological effects, such as Seasonal Affective Disorder (SAD) hypothermia or heat exhaustion. It can be encountered in 10–30 % of modern buildings may cause SBS (Bokalders & Block, 2010, pp. 3-4). The poor indoor comfort is an outcome of several inappropriate decisions during the design and construction phases and the lack of adequate maintenance to the building during its operation. The buildings site characteristics sometimes may trigger unexpected indoor problems if not properly evaluated. The presence of radon, moisture on the ground or the location in an area with high traffic, noise, air pollution, etc. are very important considerations because they imply increase of cost for expensive design solution to guarantee acoustic comfort and the appropriate air quality as long as the surrounding environment does not facilitate it. Building materials and finishes must guarantee a good technological quality and not release Volatile organic compounds (VOCs), fibers or allergens and to be immune from moisture problems that threaten the indoor quality and can speed the degradation of the building.

During its operation, periodic maintenance and frequent cleaning are very important for keeping costs low and by preventing accumulation of dirt. Ventilation systems, installed to provide heating and cooling for the indoor spaces, should keep at optimal level of relative humidity, temperature and by preventing odors. Indeed, high ventilation rates and better control of temperatures can improve office and school work performance. In the United States, it was estimated that the potential reductions in health care costs and improvements in work performance, from providing better Indoor Air Quality IAQ, were estimated up to more than $100 billion (Keeler & Vaidya, 2016, pp. 208-209). Since its first recognition, the SBS erased the common perception of buildings as low-energy consumers rather than places were people have to be comfortable and healthy above all. In light of this the examples of new and refurbished “Green” buildings enforce even more this conviction that nothing can be more worthy than users health and no better opportunity to improve productivity. Alexis Karolides has no doubt about it: “Green buildings are fundamentally better buildings” -and consequently- “it’s time for them to become the norm, not the exception”. (Karolides, 2011, p. 24). For (Armstrong & Walker, 2011) providing healthy and comfortable indoor spaces in green buildings brings benefits such as: (i) rise of the property’s value; (ii) rise of productivity among building users (iii) employees are more attracted and stimulated to retain; (iv) valuable public relations owner-tenant.

Guaranteeing a good indoor quality, affects the energetic demand of the building and there is no doubt about it. In the existing school buildings, where natural ventilation is expected, it represents a benefit for the IEQ and loos of heat during cold months in an energetic point of view. Precisely this aspect, is highly relevant in the annual budget and in order to reduce heat loses there are installed heat recovery units, providing also mechanic ventilation. The integration of these units in existing school building is not easy at all, especially in load-bearing wall structures. The lighting system, besides including the use of energy-saving lighting fixtures, should also designed for a better illumination of the classrooms, coupled with a balanced natural lighting. Posing the attention on illumination and ventilation in the refurbishment of school building (including in an nZEB perspective) as aspects to include becomes very important, because health and productivity deserve attention no matter energy savings.

2.2. The sustainable school

A sustainable school building is more than an energy efficient building. New or refurbished, it provides a good IEQ very important for the performance and health of student and teachers. Before lighting fixtures and heating systems where introduced, the maximization of daylight and natural ventilation into the classrooms was fundamental in the school design, an important evidence of their approach toward sustainability. In the existing school buildings worldwide, in particular those built after the end of WWII, there are encountered serious problems in terms of IEQ and energy efficiency, requiring interventions to improve the situation.

"Sustainability has become another norm of school design"- says (Qian, 2010, p. 3) and continues- "including materials selection, daylighting, energy conservation and overall building flexibility. However, Qian identifies three important aspects that the new Modern school designs incorporates such as: (i) quality-control is always first; (ii) sustainability is in; and (iii) schools are the new center of community residents' life. A sustainable school, as a daylight environment including good IAQ, (Keeler & Vaidya, 2016) has an important influence on the student performance , and when combined with high-performance glazing and automated electric lighting controls it also contributes to considerable energy savings (Ford, 2007). For (Gefland & Freed, 2010), a sustainable school defines the bond between school and community, where the design choices reflect the values of the community, a goal possible through: (i) a Community-based planning and (ii) an integrated design approach. Once policies and priorities are developed according to the community's main necessities (habitat's preservation, energy efficiency, or indoor air quality), the school becomes a symbol for the citizens. The integrated design approach, is essential produce a good sustainable design without enormous and sacrificing important indoor parameters such as IAQ, lighting or acoustic comfort.

For (Curtis, 2003), It represents an important model for students to acknowledge the importance of sustainability in some of its distinguishing aspects such as energy efficiency, resource efficiency, health, and educating children and staff with regard to green practices. It is very important for students to comprehend the environmental impact of this kind of school buildings (Scott, 2010), measured in terms of CO_2 emissions, water and electricity consumption and harvested rainwater (Marsden, 2007). In terms of energy efficiency, it is a high-energy conservation building and by means its cost are high. The calculation of the payback, a crude tool for (Kliment & Perkins, 2000) is useful to comprehend its worth. It is considered a worthwhile investment if it is less than seven or eight years but even if ranging from ten to twelve years adequate it is acceptable. A weighted analysis or a SWOT[6] is necessary if the construction of a new sustainable school implies the demolition on old one, and again (Kliment & Perkins, 2000) suggest to consider: (i) the cost of renovation; (ii) the expected building's life; and (iii) the cost of a new building.

In the USA, the design approach of the school buildings in six[7] different periods, is considered by (Baker, 2012) as: "A careful research, standardization and calculated design"- each one with a different approach towards sustainability. An important lesson from the US is that the refurbishment of the school building initiated in the 70's immediately after of the oil crisis to improve their energy efficiency, should be done on regular bases. Otherwise, the bill to pay when the situation becomes critic, large financial efforts are required, as it occurred in the in 1995 where $112 billion were necessary to bring the nation's school facilities up to "good overall condition" (Baker, 2012, p. 21). Since then, the projects including the renovation and construction of new school building had to accomplish the requirements introduced in the LEED (Leadership in Energy and Environmental Design) building rating system in order to be considered as "Green". Referring to (Kats, 2018), a "Green"

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[6] [ENG] SWOT - Strengths, Weaknesses, Opportunities, and Threats

[7] (i) end of 19th century until 1930; (ii) Progressive Era (1930-1945); (iii) Post-war boom (1945-1960); (iv) The "Impulsive" Period (1960-1980) (v) declines of the 1980s and (vi) the New Movements of the 1990s and 2000s;

schools uses 33% less energy compared to conventionally designed schools, because of insulated building envelope elements, efficient lighting system and efficient heating and cooling systems, too. The US Green Building Council (USGBC), the most important institution in the USA encouraging the diffusion of Green buildings defines the “Green School” as: “ A school building or facility that creates a healthy environment that is conducive to learning while saving energy, resources and money” (USGBC, 2019, p. 3)- in the report “Greening our Schools”, there was also made an important statement: “Green Schools do not have to be New Schools”. In particular, this statement highlights the importance of refurbishment as valid intervention to give a second life to existing school buildings with the same cost-effective measures used for the construction of the new ones. The renovation/refurbishment of school building is an opportunity to create new jobs. Because of the high energy required from the processes and activities within a year, the benefits from an eventual refurbishment intervention can be very positive in the reduction of the running costs and CO_2 emissions (Baker, 2009). In terms reduced costs, (Qian, 2010) also acknowledges it, but for him by refurbishing an existing school building it is preserved the “sense” of place. Attending classes in a familiar space, with improved indoor quality and lower energy consumption will be different than attending the classes in a new structure (non-familiar to students and teachers).

2.3. nZEB refurnished school. State of arts

Many programs aiming the transformation of existing school buildings into green ones have promoted in many countries worldwide. Despite enormous economic efforts required for cause, the improvement of the indoor quality is not a secondary goal in comparison with the energy-efficiency goals. Also important it is the refurbishment of the existing school buildings to contribute in the reduction of greenhouse gases, by exploiting renewable sources. International experience in this field highlights the importance of national strategies followed with actions to program the refurbishment of existing school buildings at annual rate and with specific design guidelines in order to achieve the expected outcomes.

2.3.1. Advanced Energy Design Guide for K-12 School Buildings (USA)

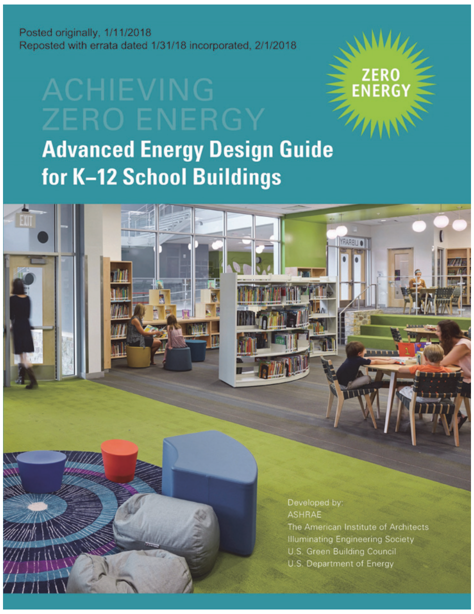

Figure 4 Cover of the Advanced Energy Design Guide for K-12 School Buildings: Achieving Zero Energy- source: (ASHRAE, et al., 2018)

It initiated in 2008 with the initial goal to achieve 30 % energy savings, updated in 2011 (50 % energy savings) up to the most recent version published in 2018 (zero energy consumption), represent an important initiative leading to the reduction of energy consumption and the improvement of the Indoor quality in the US school buildings. Although being elaborated for new constructions, the design guidelines are valuable and equally applicable to existing school renovation, remodeling, and modernization projects (ASHRAE, et al., 2008), (ASHRAE, et al., 2011), (ASHRAE, et al., 2018). In order to achieve the 30 %, 50% energy saving and zero, the strategy is based in three main pillars: (i) integrated design; (ii) training of building users; (iii) monitor of the building. The importance of integrated design is very important in the identifying cost-effective and energy-efficient leading to energy savings. Not least important is the education of the users, making them aware about the benefits from the reduction of heat loses during the activities performed in the school.

Depending of on the climate zone, it advices designers how to properly: (i) exploit site characteristics; (ii) design the building envelope; (iii) daylighting and artificial lighting; (iv) HVAC and in particular (vi) exploit of renewable resources. There are also included drawing for the solution of thermal bridges and preventing the classrooms' overheating with the adequate sun screening strategies.

2.3.2. School of the Future

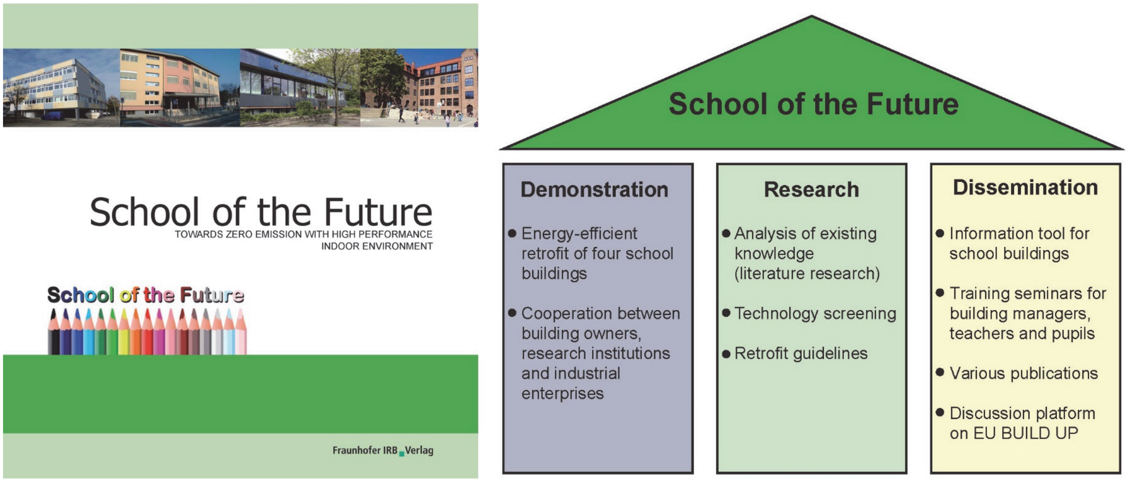

Figure 5 Cover and guidelines “School for future” programme- source: (www.school-of-the-future.eu)

Launched in 2011, as a demonstration project included in the Seventh Framework Programme of the European Union, with the main goal to promote the transformation of existing school buildings into energy-efficient ones (Erhorn-Kluttig, et al., 2016). Including 4 school buildings in four different EU countries, the main goals included: (i) Reduction of the heating demand by at least 75% (ii) Reduce of the total energy use by factor 3 (i.e. by two thirds); and (iii) Improve the indoor environment to enhance pupils' performance.

The required energy included space heating, domestic hot water (DHW), ventilation, lighting and the residual use of electricity. The zero energy goal was possible to reach in any of them because the cost of the necessary interventions was over the envisaged cost of Euro 100 per square meter. The programme was based on three pillars: (i) demonstration; (ii) research; and (iii) dissemination. All the four cases were carefully detailed in three reports (Design[8], Building Diaries[9] and Final Demonstration Building[10]).

2.3.3. Building Better Schools: Investing in Scotland’s Future

In January 2009, the Scottish Government announced measures leading to the decarbonization of school estate, part of the national strategy to reduce GHG emission of 42% by 2020 and 80% by 2050 (Government, 2009). With a cost exceeding £ 2 billion, the programme aimed the transformation of existing schools

[8] A report featuring the design and planning phases of the retrofitting projects.

[9] Contains descriptions and images documenting on-site inspections by the national researcher teams to report on the progress of the construction works and the implementation of key measures.

[10] The final report on the completed retrofi ts summarizes the initial situation, the planning, the implementation and the evaluation.

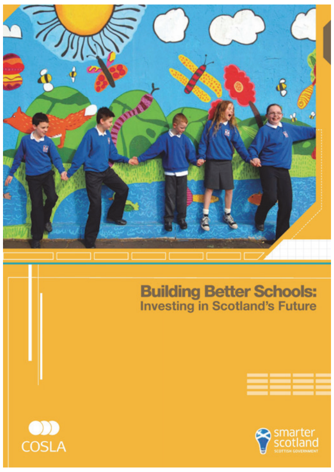

Figure 6 Cover "Building Better Schools" programme- source: (Government, 2009)

into sustainable ones with high social values. The future school estate of the country was going to become smarter, greener, healthier, safer and wealthier. The program did not include any design suggestion to achieve a desired level of energy efficiency. Through this programme, it was also promoted the construction of new schools in contemporary to the refurbishment of the existing ones by adopting a holistic approach.

2.3.4. BSF-Building Schools for the Future (UK)

Announced in 2003, this 15-year programme (2005-2020) aimed the renovation of 3,500 English secondary schools. With an overall cost of £ 45 billion, it aimed to rebuild 50 percent of the school estate, remodel structurally 35 percent, and refurbish the rest (NAO, 2009). The program is based on: (i) Sustainability- reduce emissions, waste and monitoring the amount of energy consumed, harvested rainwater, reused WC wastewater and recycled materials from students; (ii) Design-creating spaces that promote more socialization between students; (iii) Flexibility and Adaptability – ease possible changes in future of their layout; (iv) New teaching methods-Increase performance and motivation in students. Because of the imposed austerity measures imposed by the government, it was stopped in 2010. During this period, 559 secondary schools were replaced or significantly renovated (Burman, et al., 2018).

2.4. The nZEB school building. State of arts and examples

The nZEB goal goes beyond a normal refurbishment intervention, resulting with a better energetic performance and use of renewable resources to reduce GHG and CO_2 emissions. When dealing with existing school buildings, considerations cannot be limited to the energetic performance as long as performance and productivity of the users (students above all) is extremely important. However, the interventions in the existing school buildings are limited and sometimes impossible to permit the refurbished building the achievement of the nZEB label. In the EU, each member state has its own definition and the metrics (on primary energy use or emissions avoided) to achieve the nZEB label for new and existing (refurbished) buildings. Despite counting few examples of refurbished school buildings, several programs have been promoted to diffuse this refurbishment approach with very encouraging results, too.

The Zero Energy Mediterranean schools, also known as ZEmeds[11] (2013-2016) co-funded by the European Union under the Intelligent Energy Europe (IEE) Programme (call CIP-IEE-2012), aimed to encourage member states to convert their building stock into nZEB, as affirmed in the EU energy policy. Through the elaboration of 10 refurbishment proposals for existing school building located in four Mediterranean countries[12], they wanted to convince the stakeholders of potential

Figure 7 Territorial distribution of refurbished schools in Germany in 2017- source: (www.eneff-schule.de)

[11] For further information http://www.zemeds.eu/

[12] Spain(3), Italy(3), France (2) and Greece(2)

Table 5. Schools.in Germany and Austria key parameters- info: (D'Agostino, et al., 2016, p. 70) ; graphics: Author

			
School name		Secondary school in Schrobenhausen (Germany)	Elementary school in Wolfurt (Austria)
Net floor area		7,080 m^2	3367 m^2
Years of Construction | Renovation		1975 | 2010-2012	1974 | 2009
Building envelope	Wall	0.17 W/m^2.K	0.13 W/m^2.K
	Ground slab	0.16 W/m^2.K	0.95 W/m^2.K
	Roof	0.11 W/m^2.K	0.17 W/m^2.K
	Windows	0.96 W/m^2.K	0.85 W/m^2.K
Heating/Cooling system		District heating system, based on renewable energy	
Ventilation		Heat recovery	Central heat recovery system and individual ventilation in classrooms
Shading		-	Blinds incorporated to large window
Renewable energy technologies:		The roof-installed photovoltaic modules for part of electricity demand	80 m^2 PV The roof-installed photovoltaic modules for part of electricity demand and solar thermal plant
Primary energy	Heating	3.0 kWh/m^2.year (auxiliary)	
	DHW	42.3 kWh/m^2.year	
	Ventilation	39.7 kWh/m^2.year	
	Lighting	19.5 kWh/m^2.year	
		104.5 kWh/m^2.year	**120 kWh/m^2.year**
Final energy use for heating	Before renovation	~80 kWh/m^2.year (2009)	
	After renovation	~30 kWh/m^2.year (2013)	15 kWh/m^2.year
Cost		11.1 million € (all costs incl. VAT)	3.8 million € (all costs incl. VAT)

benefits deriving from. Interesting conclusions came out from the possible refurbishment scenarios in terms of final energy consumption and payback period. When undergoing to refurbished interventions aiming nZEB a typical Mediterranean school, built during the 60s-80s, may achieve 110 kWh/square meters/year (final energy). Regarding the payback time there are two possible scenarios: (i) not less than 20 years if deep renovation works are carried out in a unique stage; and (ii) more than 50 years when work performed in different stages. (EURECAT & NKUA, 2016).

Renew School[13] (2014-17), was another important project that supported, promoted and school building renovations aiming the achievement of high-energy performance and its replicability in other similar cases (Knotzer, et al., 2018).

[13] For further information http://www.renew-school.eu/

Table 6 Secondary school in Italy and Germany key parameters- info: (Knotzer, et al., 2018), (Voss & Musall, 2013, pp. 150-151); graphics: the Author

School name		Secondary school "Alessandro Volta" (Italy)	School campus in Detmold (Germany)
Net floor area		3400 m^2	14.300 m^2
Years of Construction | Renovation		1977 | 2016	1954 – 1962 | 2016
Building envelope	Wall	1,64 $W/(m^2K)$ to 0,11 $W/(m^2K)$,	0,11 W/m^2K
	Ground slab	-	
	Roof	-	
	Windows	-	
Heating/Cooling system		Radiators supplied by gas central heating, hot water from a central unit	Heat comes primarily from a cogeneration plant.
Ventilation		Individual. Through Windows	Hybrid ventilation- Decentralised units with heat recovery 85% combined with natural ventilation by window opening
Shading		External movable solar blinds	
Renewable energy technologies:			2.768 m^2 PV panels installed in the roof
Primary energy	Heating	-	21,3 kWh/m^2 GFA.a
	DHW	-	8,5 kWh/m^2 GFA.a (energy demand for electricity, ventilation and auxiliary energy)
	Ventilation	-	
	Lighting	-	
		-	
Final energy use for heating	Before renovation		
	After renovation	45 kWh/m^2.a	35 kWh/m^2 GFA.a (final energy demand including hot water)
Cost		1 million €	6.7 million €

Contrary to ZEMeds, it did not limit in the elaboration of the refurbishment proposals leading to the transformation of existing school buildings into nZEBs, but they included and implemented innovative building system in order to achieve the expected outcomes. The solutions consisted in the use of timber-prefabricated modules, a dry-construction building system allowing the execution of the works also during the ongoing school season by insulating about 3.000 square meters of façade within a week. From the twenty refurbishment proposals leading to the transformation into nZEBs of the school buildings located in 9 countries[14], only two schools underwent to refurbishment intervention until 2017, one in Italy and one in Germany. Among the difficulties to implement this this innovative building system, (Knotzer, et al., 2018) listed the unconsolidated position of the product in the market

[14] Italy, Slovenia, Austria, Germany, Belgium, Denmark, Poland, Norway and Sweden

and low support with incentives to promote the use of this technology. The Eneff[15] schule project, was promoted by the Federal Ministry for Economic Affairs and Energy, within the framework of the funding concept "Energy Optimized Buildings (EnOB[16]). Performed in two stages (2007-2011 and 2012-2017), it aimed to increase of the energy efficiency of the German schools by stimulating their refurbishment through innovative solutions resulting with a reduction of the primary energy requirements for heating, domestic hot water, ventilation, cooling and lighting. There were three possible levels of energy efficiency: (i) the Plus energy school; (ii) the 3-liter home school- very low; and (iii) the Best practice; modernized through a Public Private Partnership PPP between public sector, science and business.

2.4.1. Secondary school in Schrobenhausen (Germany)

This project is considered the pioneer of the nZEB refurbished school buildings in Europe because of achieving important outcomes in terms energy consumption and indoor comfort, too. Its refurbishment started in 2010 and was performed according requirements of DENA[17]'s efficient house pilot project (2009), to undershoot the national energy saving ordinance EnEV by at least 15% of the primary energy use (Erhorn & Erhorn-Kluttig, 2014). Important savings where achieved because of the installation of the heat recovery ventilation system. The building envelope was highly insulated in order to achieve lower U-values (24 centimeters of walls and 40 centimeters cellulose roof) and there were installed triple glazing windows. About 43% of the total final energy (heating energy based on the district heating) and the PV modules to produce electricity. This this intervention was co-financed by the KfW Group and the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMVBS).

2.4.2. Elementary school in Wolfurt (Austria)

The refurbishment intervention of this school building include the merge of the existing school building and gym into a unique volume, followed with the consequent increase of the heating volume and floor area, too. The new compact volume and its highly insulated building envelope, led to a better energetic performance, very

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[15] [GER] Abbreviation for Energieeffiziente Schule – Energy efficient schools
[16] [GER] Abbreviation for Energieoptimiertes Bauen – Energy efficient buildings
[17] [GER] Abbreviation for Deutsche ENergie Agentur – German Energy Agency- https://www.dena.de/en/home/

difficult to reach with the past layout, required just 11 weeks (Voss & Musall, 2013, pp. 150-151). The entire school was provided with mechanic ventilation systems permitting also the heat recovery option at rate of 85 %, whereas the classrooms have a decentralized ventilation system equipped with presence sensors that supplies fresh air directly via the facades or can be performed manually by the users. The required electricity for the operation of the building services is generated by a photovoltaic system on the roof, so that in the annual balance results in a "zero energy building" (Rosskopf, et al., 2015, p. 74).

2.4.3. Secondary school “Alessandro Volta”

The refurbishment of school built in 1977, included in the European program Renew schools and national program “Scuola buona, scuola sicura”. By implementing a very innovative building system as mentioned above, there were achieved the expected outcomes by lowering the heating demand (about 45 kWh/m² year), impact on the environment, and improve indoor air quality (Knotzer, et al., 2018, p. 29). An important attention was given to the seismic security of the school, where because of the advantages that these wood prefabricated system guarantees by absorbing vibrations. Each classrooms is naturally ventilated from the windows.

2.4.4. School campus in Detmold (Germany)

The campus consists of 3 bar-shaped buildings, built between 1954 and 1962. Because of previous poor interventions, it underwent to a deep refurbishment intervention completed in 2016. The existing structure, composed by masonry walls with a U-value of 1.64 W/ $m^{2°}$K that dropped to 0.11 W/ $m^{2°}$K thanks to the installation of wood prefabricated panels. Each classroom was equipped with mechanical ventilation unit with high heat recovery rate (around 85%) but they also could be naturally-ventilated from the windows. The of 2.768 square meters PV panels on the roof reaching 352 kWp guarantee a surplus of energy.

3. School buildings in Albania. Typologies, Research survey and refurbishment approach

In this chapter, will focus on the analysis concerned with the morphological and technological characteristics of and Albanian school building stock and the intervention approach in six recent cases aiming better energy performance and indoor comfort according to the conditions established by the law. For this purpose it will be analyzed the organization and management of the school In the first part, will be discussed the organization and management of the education system and the difficulties encountered by the municipalities in the management and in the funding of the renovation/refurbishment interventions in the school building stock present in their territory. In the second part, will be described the morphological aspects and layouts of the school building typologies spotted as critical cases in collaboration with 14 municipalities that kindly participated to the research. The fourth part is concerned with the technological and capacity problems emerged during the visits and analysis critical of the school buildings in the 14 municipalities as mentioned above. In the fourth part, will analyzed six recent renovation more than refurbishment cases in the three climate zones of the country, to comprehend the approach towards energy efficiency and in the fifth part it will be analyzed the building envelope elements encountered in most of the school buildings included in the research and non.

3.1. School system in Albania. Management and problematics

The number of school buildings in Albania, knew its boom during Socialism (1945-1990) when a large number of public schools were opened in the entire territory of the country. The basic education system (compulsory) including the low cycle and lower secondary cycle (MESY, 2013), has registered various changes through the years: (i) In the period 1950-61, structured as seven-year cycle; (ii) In the period 1962-2012, structured as eight-year cycle; and (iii) since 2013 structured as nine-year cycle. Despite this changes, school buildings built and used in the previous configurations (seven and eight-year cycle system) are being used in the latest configuration (nine-year cycle), although. Fall of the Socialism in early 90s coincided with a drastic change of the demography in the country, resulting with the progressive abandon of the rural centers, because of poor living conditions in comparison with the urban areas. Consequently, schools in the rural areas shut down because of the abandon from the local inhabitants, but on the other hand, school buildings in the main urban areas faced an increase in population and of the number of students in the classrooms, as well. Unfortunately this phenomena is still persistent, because according to (INSTAT, 2018), the number of public school

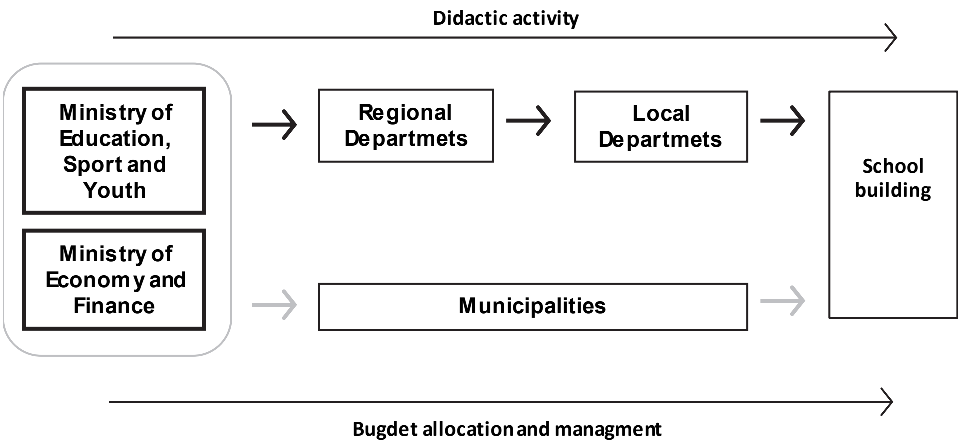


Figure 8 Organization of didactic activity, Funding and school management in the national territory according Law nr.69/2012- graphics: the Author

building in the national territory is constantly decreasing from n=1372 (2014-15) to n=1220 (2017-18), with a rate of nearly 38-school building shutting down every year (see Figure 9). Despite this worrying data, it is still unclear in which municipalities involved the most. The law nr.69 /2012[18], for the pre-university system in Albania specifies two main aspects related with the school buildings: (i) organization of the didactic activity; and (ii) Budget allocation and management.

The organization of the didactic activity, occurs under the directives of the Ministry of Education, Sports and Youth (MESY), and then transmitted to the Regional Education Departments and last to the local ones. According to the article nr.28 of the law, The Municipalities, defined as Local Government Units (LGU), are responsible for: (i) building new schools and renovating the existing ones[19] (iii) safety and maintenance (iii) guarantee hygienic-sanitary and heating conditions in the buildings of public educational institutions. In 2014, the parliament of Albania approved the new territorial reform that reduced the number of municipalities from 312 to 61 units. Referring to the recent data, each municipality manages in average 20 school buildings, regardless of the capacity, more than 30 years old and requiring in some cases urgent renovation interventions. In 2018, 10.4 % of the state budget or 3.1 % of country's GDP, was addressed to public instruction (INSTAT, 2018, p. 43). The reduction of the number of school buildings somehow eases the financial

[18] [ALB] Ligji Nr. 69/2012: "Për Sistemin arsimor parauniversitar në Republikën e Shqipërisë"

[19] … according to standards approved by the Council of Ministers, with State Budget funds or with funds from unconditional transfers or own revenues; (ii) guarantee the inviolability of the building and indoor spaces;

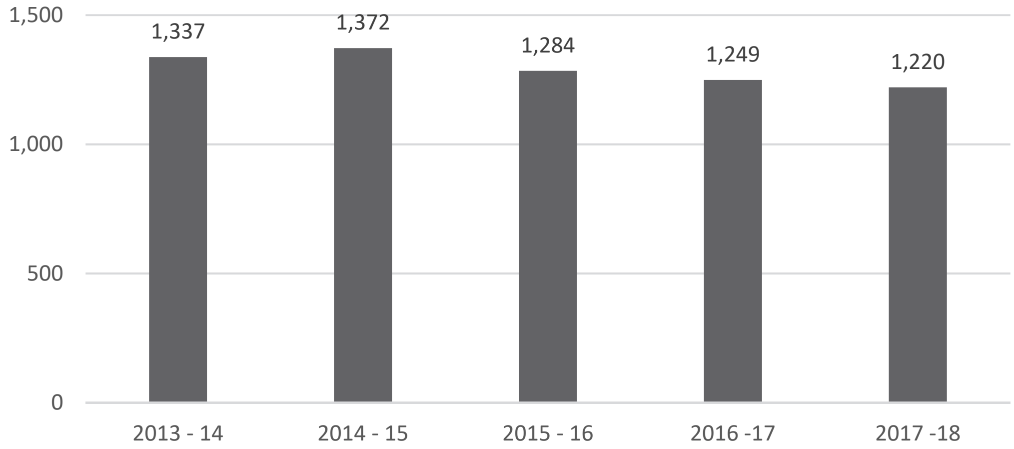


Figure 9. Number of nine-year cycle school buildings in Albania (2013-18) referring to (INSTAT, 2018)- graphics: the Author

efforts in the renovation of the "active" ones but in order to achieve a better quality indoors and energy of performance, the bill for each municipality can be very high. Unfortunately, surveys and studies regarding the perceived level comfort of by students and teachers or even roundtables between architects, planners, public administrations and central government are very rare. In 2017, it was published one of the rarest surveys made on the quality of the school buildings of compulsory school system, by State Supreme Audit entitled "Cilësia e godinave të shkollave parauniversitare[20]". Initially, this audit was programed for the municipalities of Tirana, Shkodra, Korça, Fier, Vlora and later were included the Berat, Dibra, Durrës, Elbasan, Gjirokastra, Kukës and Lezha municipalities (KLSH, 2017). Besides the critical conditions of the school buildings, it also remarked the difficulties encountered by the municipalities in the management and finance of the renovation of the school buildings in their territory. Indeed, most of the municipalities claimed about the impossibility to renovate the existing school building, because of the limited budget available. In the same time, the majority of the municipalities do not have a strategy of how to manage and eventually approach their modernization, (in terms of costs of maintenance and renovation) exception made for the municipality of Tirana. The old and rigid layout is not only distant from the nowadays demands for learning spaces but includes another critic issue, the limited capacity, constraining the split of the didactic activity in two rounds; in the morning from 8.00

[20] [ALB] "Quality of the compulsory system's school buildings"

a.m. to 1.00 p.m.[21] and in the afternoon from 1.30 p.m. up to 5.00 p.m.[22]. This evident limit of the existing school buildings inherited from past, is very unpleasant for the pupils attending classes during fall and winter afternoons with lower

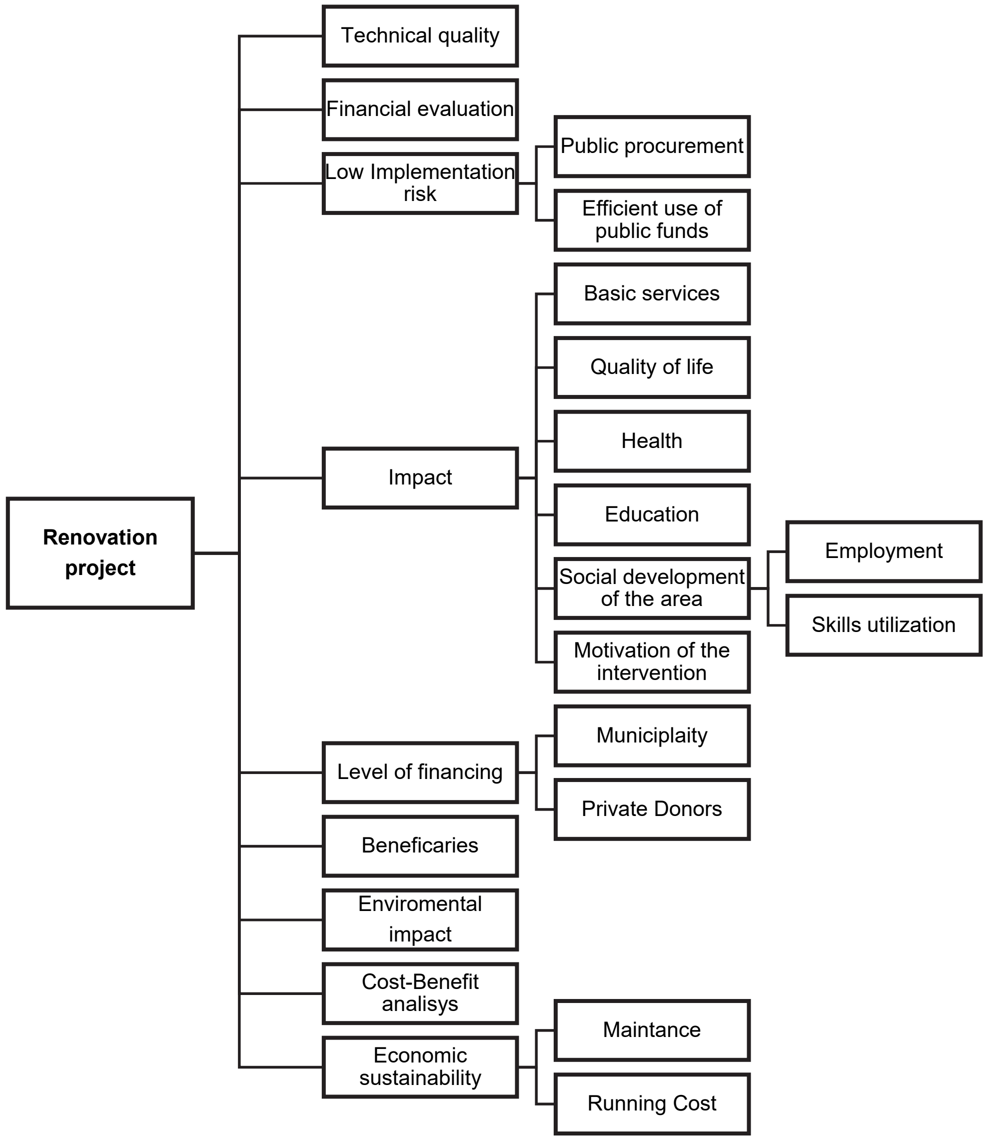


Figure 10 Evaluation of a school renovation project in Albania - source: MESY; graphics: the Author

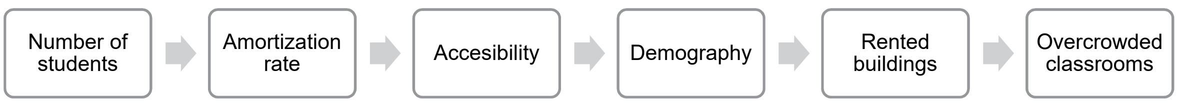


Figure 11 Descending priority factors considered for renovation of school buildings in Albania according to Law nr.69/2012- graphics: the Author

[21] 1st elementary and the 6th , 7th , 8th and 9th grades of the lower secondary education
[22] 2nd, 3rd, 4th and 5th grade elementary.

daylighting. Furthermore, the growth of urban population in early 90s did not coincide with the construction of new school buildings and consequently it led to the increase of the number of pupils in the classrooms. The municipality of Tirana, suffering the most these problems, elaborated a feasibility study concerned with the improvement of the existing school buildings, present in its territory. According to (Bashkia Tiranë , 2016), in the territory of the municipality of Tirana, 49 from 121 school buildings of nine-year cycle were overcrowded whereas in 50 schools the didactic activity was split in two rounds. In order to improve the situation, there were necessary ten new school buildings containing 289 new classrooms (each hosting 30 students).

For (Ministria e Arsimit dhe Sportit , 2014), the improvement of the quality of the existing school buildings and the construction of the new ones are among the main goals of the strategy for the development of the pre-university education system entitled: "Strategy for the development of the pre-university system 2014-2020[23]".

The selection of the school building undergoing to renovation or refurbishment occurs by considering of a series of factors in a descending order. As illustrated in Figure 11, the school buildings likely to be renovated/ refurbished the first are those with: (i) highest number of students; (ii) high amortization rate (risk of collapse, fire, flood, earthquake, etc.); (iii) Location/ Condition of low accessibility and/or by the local transportation system; (iv) Demography; (v) Rented buildings for didactic activity; and (vi) Overcrowded classrooms. In light of this, it emerges that the school buildings with higher capacity "attract" much more attention than the low capacity ones, unless they are in very bad condition or in a difficult situation of accessibility.

Once selected the school building, the renovation project (see Figure 10), is object to technological, economic and sustainability considerations. Technical quality and financial evaluation apart, it should have a low implementation risk and guarantee a successful implementation with efficient use of public funds in the scheduled periods. Very important is also the elaboration of the environmental impact, Cost-Benefit analysis and the economic sustainability of the intervention illustrating the future performance of the renovated school in terms of maintenance and operation costs. In 2017, the Council of Ministers approved the decree nr.319 entitled

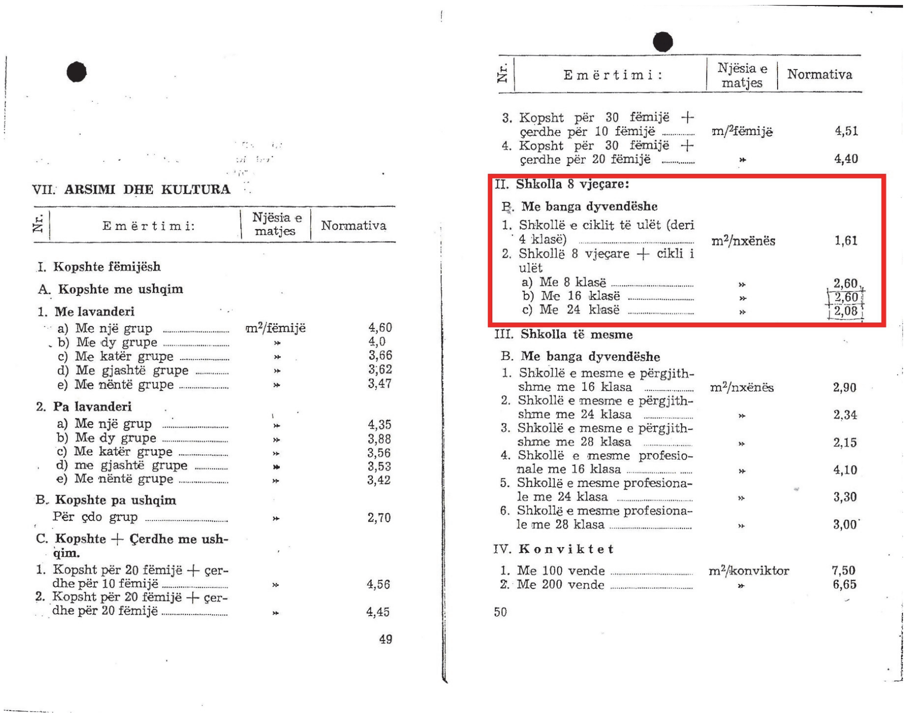
[23] [ALB] "Strategjia e zhvillimit të arsimit parauniversitar 2014-2020"

“Standard for the design of school buildings[24]”, a design manual with the minimum requirements for the design of new school buildings, also valid for the renovations of the existing ones. The indications range from the minimum floor areas of classrooms and spaces within the school other up to the requirements for the heating plant and HVAC system. In terms of attention towards sustainability, there are given useful guidelines for the best orientation, natural ventilation schemes and sun-screening strategies there are not present any guideline in terms of energy efficiency. Unfortunately these guidelines, do not represent useful design advices in terms of energy efficiency because there are not given useful indications for the building envelope U-values or exploit of renewable resources for a better environmental impact. Considering the absence of the national energy label system, the approval of the design manual with this low attention to energy efficiency, widen further the gap between the transposed EU directives in the national legislation (EPBD 2010 recast and EED 2012) and the actions how to achieve the expected outcomes. In light of this, the introduction of the nZEB concept in the refurbishment of the existing school buildings and eventually in the construction of the new ones is very far. But the very alarming, is the low attention to a regulated energy-efficiency framework, because the energy-efficient schools are important for the pupils and students by providing a better IEQ and an important investment for the municipalities that invest on it. Considering the problems with the capacity, very evident in the urban areas, the refurbishment of the school buildings even becomes even more complex.

3.2. School building typologies in Albania

Most of the school buildings in Albania, built during Socialism, reflect the influence of the East-European Socialist countries. Although, being initially designed for seven-year (1950-61) and eight-year cycle (1962-2012), they are still used even now with the nine-year cycle school system (in power since 2013), despite not being suitable in terms of capacity and constraining the split of the didactic activity in two rounds. Conceived as standard typologies from the central design offices, they were implemented all over the country, with some modification because of the climatic context as it was for those located in the climatic zone C, the coldest one. The sizes

[24] [ALB] “Standartet e projektimit për shkollat”



VII. ARSIMI DHE KULTURA

Nr.	Emërtimi:	Njësia e matjes	Normativa
I.	**Kopshte fëmijësh**		
A.	**Kopshte me ushqim**		
1.	**Me lavanderi**		
	a) Me një grup	m²/fëmijë	4,60
	b) Me dy grupe	»	4,0
	c) Me katër grupe	»	3,66
	d) Me gjashtë grupe	»	3;62
	e) Me nëntë grupe	»	3,47
2.	**Pa lavanderi**		
	a) Me një grup	»	4,35
	b) Me dy grupe	»	3,88
	c) Me katër grupe	»	3,56
	d) me gjashtë grupe	»	3,53
	e) Me nëntë grupe	»	3,42
B.	**Kopshte pa ushqim**		
	Për çdo grup	»	2,70
C.	**Kopshte + Çerdhe me ushqim.**		
1.	Kopsht për 20 fëmijë + çerdhe për 10 fëmijë	»	4,56
2.	Kopsht për 20 fëmijë + çerdhe për 20 fëmijë	»	4,45

49

Nr.	Emërtimi:	Njësia e matjes	Normativa
3.	Kopsht për 30 fëmijë + çerdhe për 10 fëmijë	m/²fëmijë	4,51
4.	Kopsht për 30 fëmijë + çerdhe për 20 fëmijë	»	4,40
II.	**Shkolla 8 vjeçare:**		
B.	**Me banga dyvendëshe**		
1.	Shkollë e ciklit të ulët (deri 4 klasë)	m²/nxënës	1,61
2.	Shkollë 8 vjeçare + cikli i ulët		
	a) Me 8 klasë	»	2,60
	b) Me 16 klasë	»	2,60
	c) Me 24 klasë	»	2,08
III.	**Shkolla të mesme**		
B.	**Me banga dyvendëshe**		
1.	Shkollë e mesme e përgjithshme me 16 klasa	m²/nxënës	2,90
2.	Shkollë e mesme e përgjithshme me 24 klasa	»	2,34
3.	Shkollë e mesme e përgjithshme me 28 klasa	»	2,15
4.	Shkollë e mesme profesionale me 16 klasa	»	4,10
5.	Shkollë e mesme profesionale me 24 klasa	»	3,30
6.	Shkollë e mesme profesionale me 28 klasa	»	3,00
IV.	**Konviktet**		
1.	Me 100 vende	m²/konviktor	7,50
2.	Me 200 vende	»	6,65

50

Figure 12 Design standard eight-year school buildings expressed in students per square meters- source: (Këshilli i Ministrave, 1977)

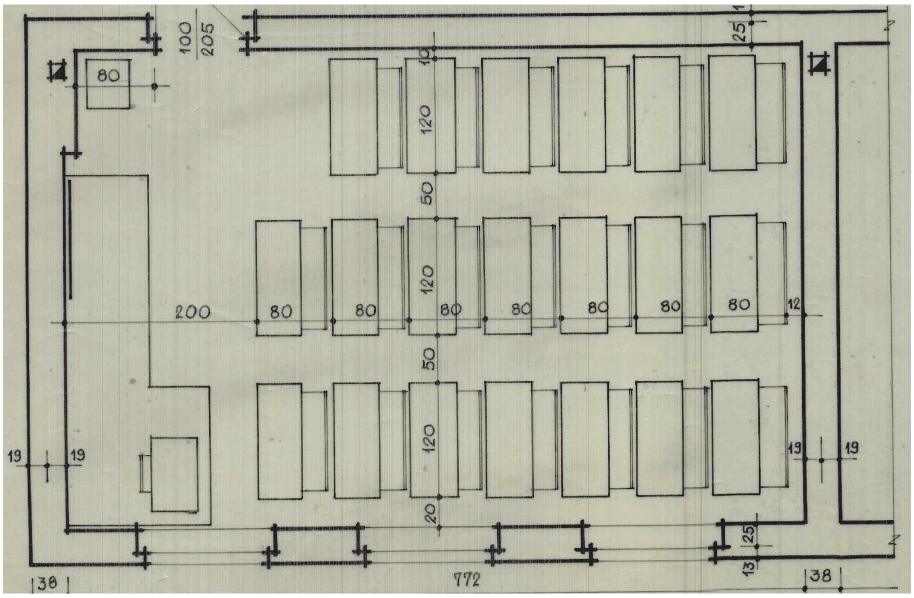


Figure 13 Layout of classroom in a standard school building typology - source: NTA

of schools ranged from a minimum of four up to twenty-four classrooms. Obviously the urban centres contained the biggest ones (18 and 24 classrooms) whereas in the rural centres the smallest ones (4 up to 12 classrooms). The typologies designed for the eight-year cycle system are also known as *Shkolla tip.* Referring to (Këshilli i Ministrave, 1977, pp. 49-50), they were designed by using the standard student per square meter (see Figure 12). The construction of these school buildings typologies stopped in the early 90s with the end of the socialist system in the country. Also the state design offices (known as ZUP[25]), responsible for their design were shut down, too. Despite the different capacities encountered in the urban and rural areas, they represented evident differences, too. For example schools in the rural areas had the hygienic services located outside me main building, totally not pleasant for students and teachers especially in bad weather conditions, but after the 90s they were incorporated to the main buildings through by addition or by "sacrificing" a room in the main building usually in the ground floor. Gyms were not a design priority until the 80s where they were included in the 18 and 24-classrooms typologies and after 90s; they were built in addition to main building in almost all the urban areas. In cold climates, the thickness the external walls was increased to 38 centimetres and there were expected of two windows per opening (one internal and one external) to limit heat loses. Because of the high cost, a centralised heating plants were not expected. During autumn and winter, classroom were heated by wood stoves located at the entrance and it is not a causality that at the entry of each classroom there was placed chimneys to dispose the smoke (see Figure 13). The classrooms are naturally ventilated from the windows and their size range between 35 to 39 square meters (floor area) and with an internal height of three meters. The next step will consist, in the analysis on the school building typologies by describing their main design aspects and internal distribution. Each typology will be identified with three-digit code **N1-N2-X** where: (i) **N1**-number of classrooms; (ii)**N2**- number of storeys; and (iii) **X**- a letter, to differentiate two or more typologies with the same capacity and number of storeys.

3.2.1. 4-classrooms school buildings

It was designed 1976[26] for remote rural areas of the country hosting 30-40 students per classroom and mostly used for the low-cycle. The access into the classrooms occurs through the central lobby and as common for that time, the bathrooms were outside the building. The internal height is equal to three meters. Nowadays school buildings with this capacity are mostly abandoned. Heating plants not expected, and so there were used wood stoves in each classroom.

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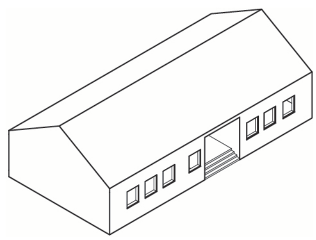
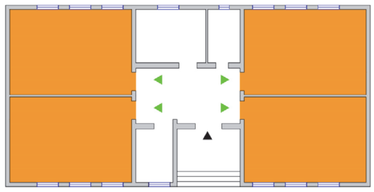
[25] [ALB] abbreviation of "Zyra e Urbanistikës dhe Projektimit" – Design and Planning Office

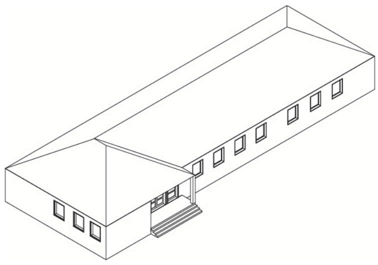
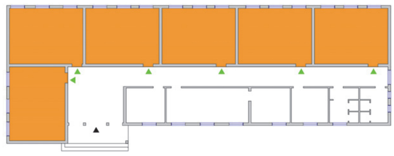
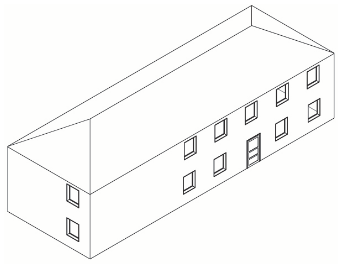
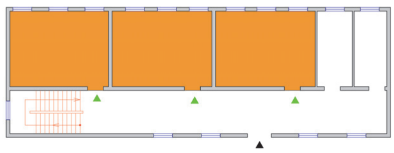
[26] Technical name of the project at the Central National Technical Archive : "Shkollë fshati me 4 klasë për 40 nxënës - 1976" (4- classroom school building for 40 students destinated rural towns)

Table 7 School building typology 4-1- source: NTA; graphics: the Author

4-1			
Classroom area (m^2)	**38**		
Classroom Height (m)	**3,00**		
Total area (m^2)	**200**		
$A_{envelope}$ (m^2)	**742.6**		
V_{heated} (m^3)	**560**		
A/V	**1.33**		

3.2.2. 6-classrooms school buildings

Table 8 School building typology 6-1 and 6-2- source: NTA; graphics: the Author

6-1			
Classroom area (m^2)	**35**		
Classroom Height (m)	**2.9**		
Total area (m^2)	**352.3**		
$A_{envelope}$ (m^2)	**1097**		
V_{heated} (m^3)	**1033**		
A/V	**1.06**		
6-2			
Classroom area (m^2)	**35**		
Classroom Height (m)	**3.1**		
Total area (m^2)	**396.3**		
$A_{envelope}$ (m^2)	**836**		
V_{heated} (m^3)	**1162**		
A/V	**0.72**		

There two typologies with this capacity. The 6-1 typology, one-storey high, is designed was for the low cycle when the eight-year system was in power. Introduced in 1979[27] and developed under the requirements set by the (Këshilli i Ministrave, 1977), its internal height is equal to three meters. Unlike the previous typology, it includes the hygienic services within the building. On the other hand, the 6-2 typology, introduced in 1978[28], expected the hygienic services outside the building. The classrooms (35 square meters) are accessed through the respective L-shaped and linear corridors and ventilated through the windows. Heating plants not expected, and so there were used wood stoves in each classroom.

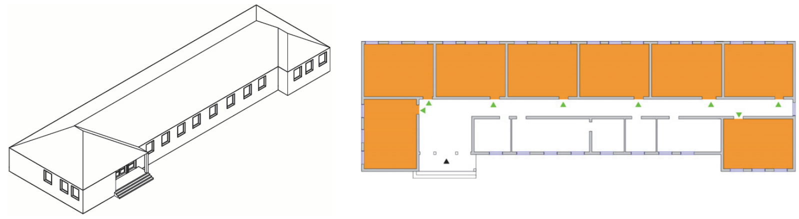
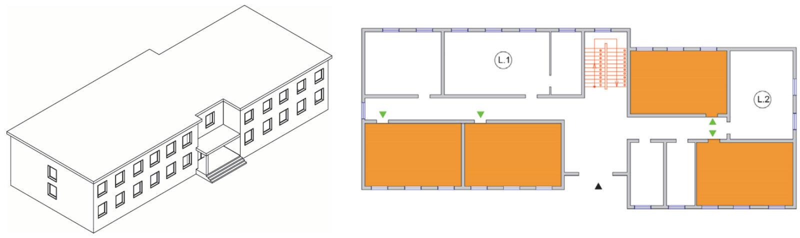
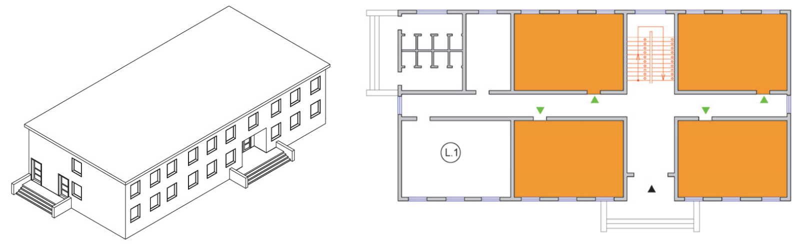
3.2.3. 8-classrooms school buildings

There are three typologies with this capacity. The 8-1 school building, introduced in

[27] Technical name of the project at the Central National Technical Archive : "Shkollë e ciklit të ulët me 6 klasë -Mars 1979" (6- classroom school building for the elementary cycle- March 1979)

[28] Technical name of the project at the Central National Technical Archive : "Shkollë e ciklit të ulët me 6 klasa 78/1" (6-classroom school building for the elementary cycle-78/1)

Table 9 School building typology 8-1, 8-2-A and 8-2-B- source: NTA; graphics: the Author

8-1		
Classroom area (m^2)	**35**	
Classroom Height (m)	**3,1**	
Total area (m^2)	**432,7**	
$A_{envelope}$ (m^2)	**1313**	
V_{heated} (m^3)	**1280**	
A/V	**1,03**	
8-2-A		
Classroom area (m^2)	**37,6**	
Classroom Height (m)	**2,95**	
Total area (m^2)	**743,3**	
$A_{envelope}$ (m^2)	**1454**	
V_{heated} (m^3)	**2095**	
A/V	**0.69**	
8-2-B		
Classroom area (m^2)	**40,2**	
Classroom Height (m)	**2,95**	
Total area (m^2)	**618,4**	
$A_{envelope}$ (m^2)	**1160**	
V_{heated} (m^3)	**1173**	
A/V	**0.65**	

It is similar in terms of internal distribution with 6-1 typology, but it does have the hygienic services inside the building. The 8-2-A building, introduced in 1977[29] is composed by two different staggered volumes. It has also four laboratories. The 8-2-B typology, introduced in the 1967[30], has a regular shape than the 8-2-A and hygienic services inside the building, with classrooms' sizes ranging from 35 to 40.2 square meters. In all three typologies, heating of classroom was expected to occur individually and by using wood stoves. For cold climates the external walls thickness was increased to 38 centimeters.

3.2.4. 12-classrooms school buildings

The school buildings with this capacity were the biggest ones designed for the rural areas. The 12-2-A and 12-2-B introduced respectively in 1973[31] and in the 80s[32].

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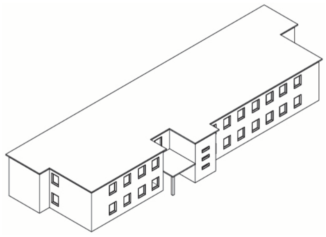
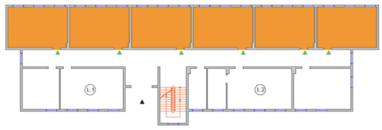
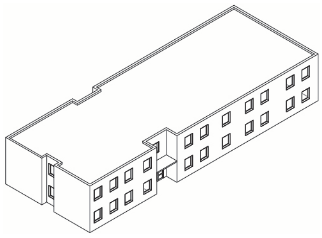
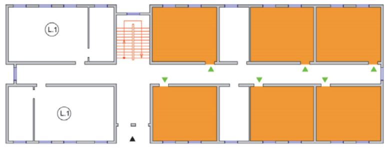
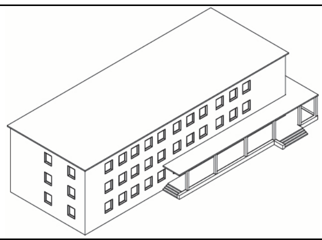
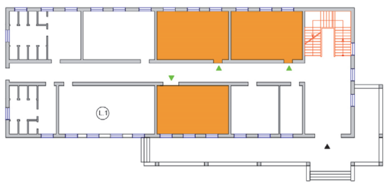
[29] Technical name of the project at the Central National Technical Archive : "Shkollë 8-vjeçare tip 77/2" (8-year cycle 77/2 standard school)

[30] Technical name of the project at the Central National Technical Archive : "Shkollë 8-vjeçare Yrshek-1967" (8-year cycle school in Yrshek-1967)

[31] Technical name of the project at the Central National Technical Archive : "Shkollë 8-vjeçare me 12 dhe 8 klasa 73.6" (8-year cycle school with 12 and 8 classrooms 73.6)

[32] Technical name of the project at the Central National Technical Archive : "Shkollë e mesme bujqësore Darshen-1986" (Agricoultural high school building in Darshen -1986)

Table 10 School building typologies: 12-2-A, 12-2-B and 12-2-C - source: NTA; graphics: the Author

12-2-A		 
Classroom area (m²)	**39**	
Classroom Height (m)	**2.95**	
Total area (m²)	**1041**	
A $_{envelope}$ (m²)	**1912**	
V $_{heated}$ (m³)	**2916**	
A/V	**0.66**	
12-2-B		 
Classroom area (m²)	**35.5**	
Classroom Height (m)	**2.95**	
Total area (m²)	**891**	
A $_{envelope}$ (m²)	**1735**	
V $_{heated}$ (m³)	**2550**	
A/V	**0.68**	
12-3		
Classroom area (m²)	**38**	 
Classroom Height (m)	**2.95**	
Total area (m²)	**1063**	
A $_{envelope}$ (m²)	**2004**	
V $_{heated}$ (m³)	**3334**	
A/V	**0.60**	

Both buildings are very similar in terms of internal distribution and designed to have the hygienic outside the main buildings. The 12-3 typology, introduced for the first time in 1961[33] and designed for the seven-year cycle system, has an asymmetric internal distribution compared with the two-storey typologies and the hygienic services are inside the main building. Unfortunately, spaces for gyms where not among the design goals. In cold climates, external walls' thickness was raised to 38 centimeters.

3.2.5. 16-classrooms school buildings

This typology is an important evidence of the new approach adopted in the design of the school buildings in late 70s, in terms of capacity and facilities compared to the previous ones. Designed in 1978[34], this typology represented a new design approach because of exceeding the thee-storey height (maximum at the time) and furthermore it included the gym. Made by two fragmented blocks positioned at 90 degrees versus each other, the lobby acting as a connector between the two

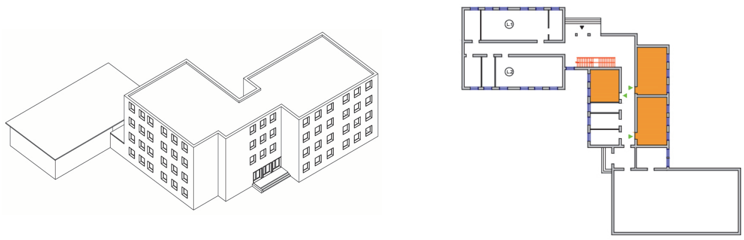
[33] Technical name of the project at the Central National Technical Archive : "Shkollë 7-vjeçare tip Asimetrik-1961 " (Asymetric Standard school building for 7-year cycle)

[34] Technical name of the project at the Central National Technical Archive: "Shkolla të mesme të përgjithshme tip 1978 me 16, 24, 28 klasa- seria I-rë. Për qytete, qëndra koperative të bashkuara dhe qyteza industriale"- (School building for the Secondary cycle type 1978, with 16, 24 and 28 classrooms. For Cities; agricultural and industrial major towns.)

volumes. Even in this case, heating of classrooms is individual and made by wood stoves.

Table 11 School building typologies: 16-4- source: NTA; graphics: the Author

16-4	
Classroom area (m^2)	**24.4** **36.5** **36.8**
Classroom Height (m)	**2.95**
Total area (m^2)	**1561**
$A_{envelope}$ (m^2)	**2825**
V_{heated} (m^3)	**5332**
A/V	**0.53**

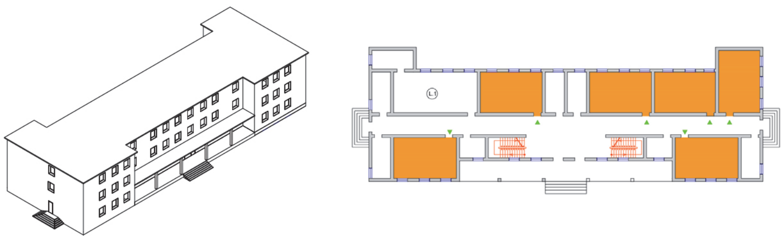


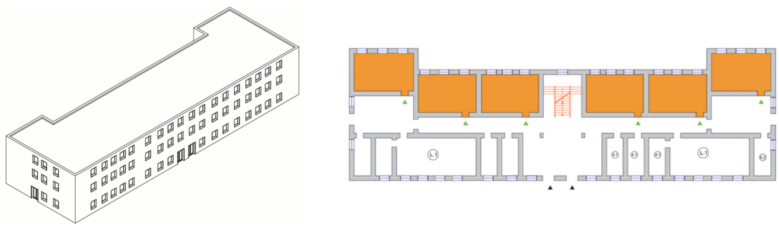
3.2.6. 18-classrooms school buildings

These typologies are common for urban areas and represent a legacy of the 7-year cycle system as well. The 18-3-A typology was designed in 1959[35], has two stair cores guaranteeing the access to the upper floors. A distinguishing element of the building is the canopy at the entry, sustained by concrete columns. On the other hand, the 18-3-B, is also symmetrical but it does a canopy at the main entrance and has only one stairs core. It was also designed for the seven-year system and the same internal distribution as the 18-3-A typology. The structure of the building is load-bearing masonry walls. Even in this case heating of classrooms was designed to be individual and made by wood stoves. Gyms were not included in the original design but integrated years after as additions.

Table 12 School building typologies: 18-3-A and 18-3-B- source: NTA; graphics: the Author

18-3-A	
Classroom area (m^2)	**38.6** **39** **40**
Classroom Height (m)	**2.95**
Total area (m^2)	**1639**
$A_{envelope}$ (m^2)	**2600**
V_{heated} (m^3)	**5051**
A/V	**0.53**
18-3-B	
Classroom area (m^2)	**39**
Classroom Height (m)	**2.95**
Total area (m^2)	**1859**
$A_{envelope}$ (m^2)	**2877**
V_{heated} (m^3)	**5409**
A/V	**0.53**



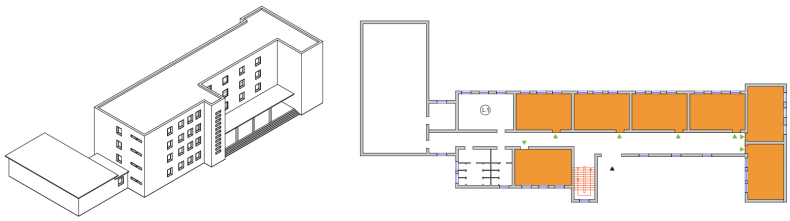


[35] Technical name of the project at the Central National Technical Archive: "Shkollë 7-vjeçare tip-60 për qytete të mëdhenj me 18 klasë"-(18-classrooms school building for main cities-type-60)

3.2.7. 24-classrooms school buildings

Introduced in 1979[36], it represents another outcome of the new approach adopted in the late 70s in the school building design in Albania. Designed for major urban centers, after the change of the political system in early 90s this typology was not implemented anymore. The access to the classrooms is made through the corridors and there is one stair core connecting the four floors of the building. It includes a gym and the hygienic services in every level. The canopy at the entry represents another distinguishing element of the building. Obviously, heating of classrooms was individual and made by wood stoves.

Table 13 School building typologies: 24-4- source: NTA; graphics: the Author

24-4		
Classroom area (m^2)	**36.8** **37.8**	
Classroom Height (m)	**2.95**	
Total area (m^2)	**1890**	
$A_{envelope}$ (m^2)	**3172**	
V_{heated} (m^3)	**5972**	
A/V	**0,53**	

[36] Technical name of the project at the Central National Technical Archive: “Shkollë 8- vjecare me 24 klasë 79/1” (24-classrooms school building for the 8-year cycle 79/1)

3.3. Research's survey: Critical school building in 14 Albanian municipalities

In this part, will be mapped the situation of school buildings in 14 from 61 municipalities of the country (see Figure 14), that have kindly accepted to collaborate for the research. It was requested to: (i) the number of the school buildings they manage (Low cycle; nine-year cycle and 12-year cycle[37]); (ii) the three (or less) school buildings in a critic conditions. The collected data for the each municipality will be briefed in table with the layout of Table 1 illustrating the critical cases (front photo and map) and number of institutions for the nine-year cycle present in the respective territory. These rankings are produced by setting as last deadline January 31st, 2019. Each school building, will be described by an axonometric view where will be highlighted in blue the alterations/additions made to the existing building typology and the map to comprehend the orientation.

Table 14 Layout of the table describe the situation in each municipality - graphics: the Author

<table>
<tr><td colspan="2" rowspan="4">Mapp of the municipality</td><td>Total number of school buildings</td></tr>
<tr><td>number (low- cycle)</td></tr>
<tr><td>number (12-year cycle)</td></tr>
<tr><td>number (9-year cycle)</td></tr>
<tr><td>Cycle
Name of the school</td><td>Cycle
Name of the school</td><td>Cycle
Name of the school</td></tr>
<tr><td>Axonometry of the school

Orthophoto of the school</td><td>Foto of the school

Orthophoto of the school</td><td>Foto of the school

Orthophoto of the school</td></tr>
<tr><td>Orientation: -
Typology: -
Location: -</td><td>Orientation: -
Typology: -
Location: -</td><td>Orientation: -
Typology: -
Location: -</td></tr>
</table>

[37] Common for rural areas when in a unique building there are classes for the 9-year cycle and for upper secondary system (10th,11th and 12th grade)

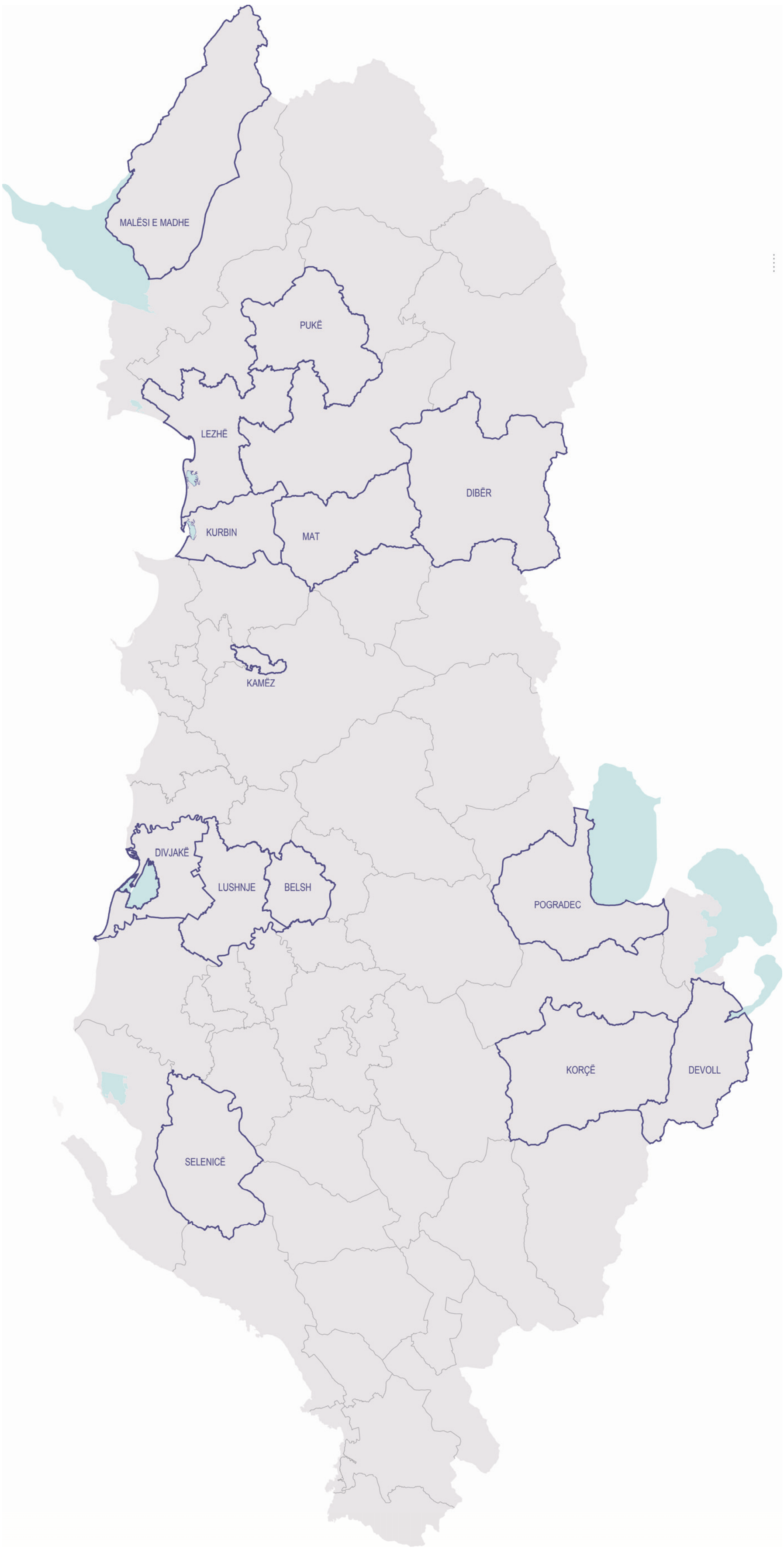
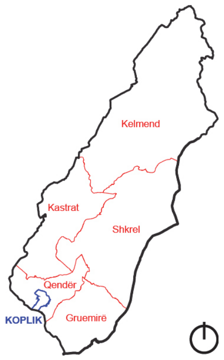
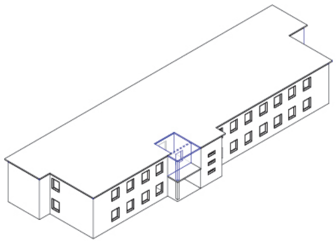
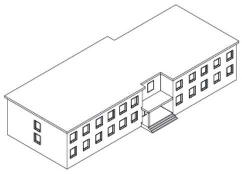
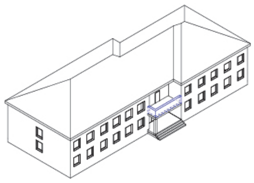


Figure 14 Administrative map of Albania with the 14 municipalities part of the survey- graphics: the Author

3.3.1. Municipality of Malesia e Madhe

Table 15 Situation in Malësia e madhe municipality (Credits: Orthophotos- asig.al; Main map and axonometries: the Author)

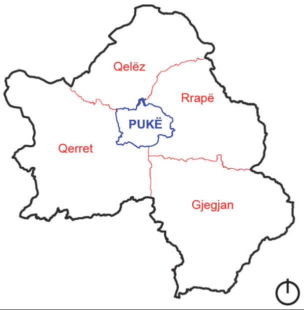
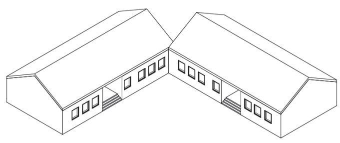
	**24 school buildings**	
	1 (low- cycle)	
	3 (12-year cycle)	
	20 (9-year cycle)	
9-year cycle school "Muhamet Hasmuja"	**9-year cycle school In Vukpalaj**	**12-year cycle school "Kol Martini"**
 	 	 
Orientation: **N-S** Typology: **12-2-A** Location: **Grizhë (Gruemirë)**	Orientation: **NE-SW** Typology: **8-2-A** Location: **Vukpalaj (Kastrat)**	Orientation: **NW-SE** Typology: **8_2_B** Location: **Dedaj, Shkrel**

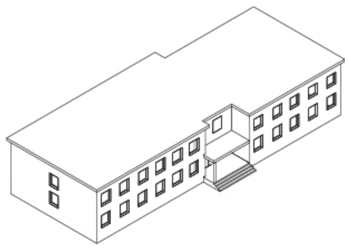
It is the northernmost municipality of the survey, including 24 school buildings where the majority are nine-year cycle schools (n=20). The buildings in critical conditions (see Table 15), are uninsulated and not equipped with heating plants. During, winter the indoor conditions are very poor, because the electric heating units used do not satisfy the demand for heating, and considering that the municipality is located between the climate zone B and C, it is very alarming. Waterproofing problems in the roof are encountered in the schools in Grizhë and Vukplaj and their orientation is not best, as well. Also, these school buildings, in order to place the hygienic services within the building, classrooms at ground floor have been "sacrificed" for this purpose. Despite not being in critic situation of the school in Dedaj, has an evident shortage of classrooms because it used as a 12-year school where it capacity is for 8 classrooms. Referring to the original design, the schools in Grizhë and Dedaj by increasing the volume of the building and by using the canopy as balcony, respectively.

3.3.2. Municipality of Puka

This municipality, located in the climate zone C, manages 12 school buildings the majority of the nine-year cycle (n=11). There are two critical cases identified (see Table 16), all low capacity schools built for rural areas. The school in Rrapë, is made by two 4-1 school building typologies positioned in an L-shaped configuration, but not communicating with each other. The buildings in critical conditions are uninsulated and during cold months there are used electric heating units, unfortunately inappropriate to satisfy the heating demand during winter. The situation of the school in Qerret is more critical because the state of decay of the external walls and roof is very serious. Both do not have problems with capacity, but they have modified them internal layouts to create the necessary space at the ground floor for the hygienic services.

Table 16 Situation in Puka municipality (Credits: Orthophotos- asig.al; Main map and axonometries: the Author)

<table>
<tr><td rowspan="4">
</td><td>12 school buildings</td></tr>
<tr><td>0 (low- cycle)</td></tr>
<tr><td>1 (12-year cycle)</td></tr>
<tr><td>11 (9-year cycle)</td></tr>
<tr><td>9-year cycle school in Rrapë</td><td>9-year cycle school “Ali Bytyçi”</td></tr>
<tr><td>

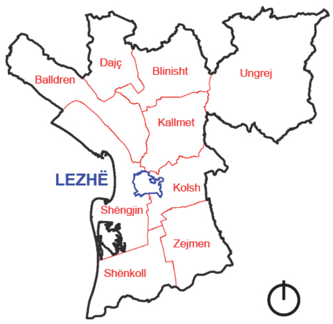
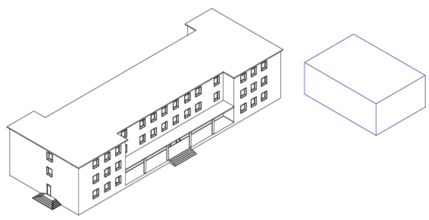
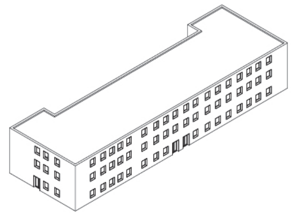
</td><td>

</td></tr>
<tr><td>Orientation: NW-SE
Typology: 4-1
Location: Rrapë</td><td>Orientation: NW-SE
Typology: 8-2-A
Location: Qerret i vogël</td></tr>
</table>

3.3.3. Municipality of Lezha

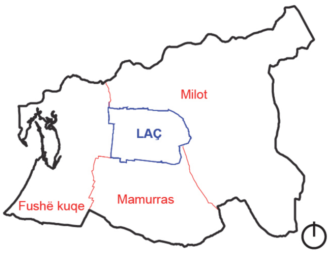
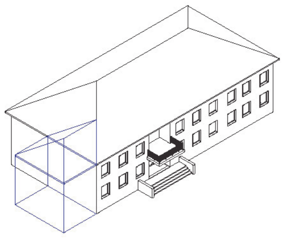
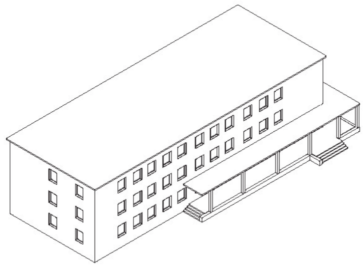
This municipality, divided between the climate zone A and B, counts 37 school buildings the majority of the nine-year cycle (n=21). The school buildings in critical conditions are high capacity ones, 18-3-A (Lezha) and 18-3-B (Shëngjin) respectively. In terms of orientation the "Gjergj Kastrioti" school, oriented E-W, has less fronts exposed North than the school in Shëngjin. In terms of energy performance, both require interventions in the building envelope, also the installation of a decent heating system. During winter, in each classroom, there are plugged electric heating units at the entry of the classrooms, they besides reviling inappropriate for heating contribute to the high consume of power, too. In terms of capacity both schools need twice more classrooms to host the entire didactic activity in the morning. The gym is absent in the school of Shëngjin but built in the other school it was built as addition.

Table 17 Situation in Lezha municipality (Credits: Orthophotos- asig.al; Main map and axonometries: the Author)

<table>
<tr><td rowspan="4">
</td><td>37 school buildings</td></tr>
<tr><td>5 (Low cycle)</td></tr>
<tr><td>11 (12-year cycle)</td></tr>
<tr><td>21 (9-year cycle)</td></tr>
<tr><td>9-year cycle school "Gjergj Kastrioti"</td><td>9-year school in Ishull Lezhë</td></tr>
<tr><td>
</td><td>
</td></tr>
<tr><td>Orientation: E-W
Typology: 18-3-A
Location: Lezhë</td><td>Orientation: NE-SW
Typology: 18-3-B
Location: Ishull Lezhë, Shëngjin</td></tr>
</table>

3.3.4. Municipality of Kurbin

Table 18 Situation in Kurbin municipality (Credits: Orthophotos- asig.al; Main map and axonometries: the Author)

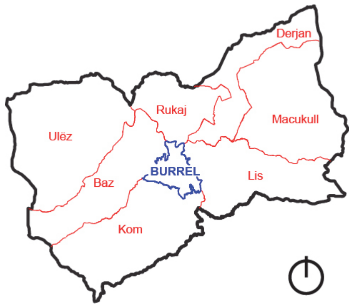
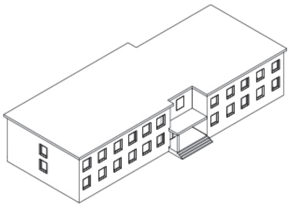
<table>
<tr><td rowspan="4">
</td><td>22 school buildings</td></tr>
<tr><td>0 (Low cycle)</td></tr>
<tr><td>0 (12-year cycle)</td></tr>
<tr><td>22 (9-year cycle)</td></tr>
<tr><td>9-year cycle school "28 Nëntori"</td><td>9-year cycle school "Migjeni"</td></tr>
<tr><td></td><td></td></tr>
<tr><td></td><td></td></tr>
<tr><td>Orientation: E-W
Typology: 8-2-B
Location: Milot</td><td>Orientation: E-W
Typology: 12-3
Location: Mamurras</td></tr>
</table>

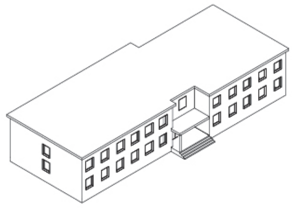
This municipality divided between the climate zone A and B, counts 22 school buildings the majority is composed by the nine-year cycle (n=22). The most critical cases spotted in Milot and Mamurras representing the 8-2-B and the 12-3 typologies respectively. Both require interventions in building envelopes and an efficient heating plant to provide the adequate heating of the classrooms, actually using the same solution as in the critic cases analyzed previously, electric heating units. In terms of orientation, both have most of their fronts avoiding exposition to North. The necessity to increase the capacity is present for both buildings, at least twice the actual ones, also the building of the gym. Referring to the original design, to the 8-2-B typology has been added the hygienic services block.

3.3.5. Municipality of Mat

This municipality divided between the climate zone B and C, counts 22 school buildings the majority is composed by the nine-year cycle (n=12). The most critical cases spotted in Macukull and Bruc, both 8-2-A typologies. Besides the necessity for in building envelopes there is necessary the heating plant as well in both. In terms of orientation, the school in Macukull is not properly oriented. The internal layout of the ground in both cases has been altered to provide space for the hygienic services that according to the original design was not included. Space dedicated for the gym is absent in both buildings.

Table 19 Situation in Mat municipality (Credits: Orthophotos- asig.al; Main map and axonometries: the Author)

<table>
<tr><td rowspan="4">
</td><td>22 school buildings</td></tr>
<tr><td>0 (Low cycle)</td></tr>
<tr><td>4 (12-year cycle)</td></tr>
<tr><td>18 (9-year cycle)</td></tr>
<tr><td>9-year cycle school in Macukull</td><td>9-year cycle school “26 Korriku”</td></tr>
<tr><td>

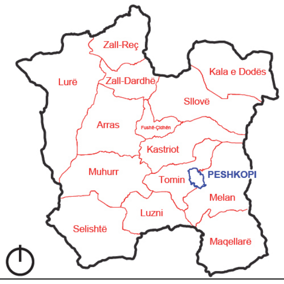
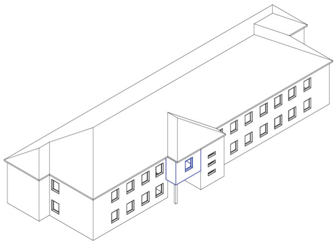
</td><td>

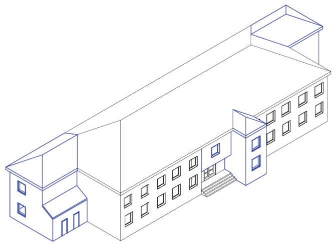
</td></tr>
<tr><td>Orientation: N-S
Typology: 8-2-A
Location: Macukull</td><td>Orientation: E-W
Typology: 8_2_A
Location: Bruc, Rukaj</td></tr>
</table>

3.3.6. Municipality of Dibër

This municipality, part of climate zone C, has the largest number of school buildings, taking part in the research (n= 117). The most critical cases are typologies located in the rural areas. In terms of energy performance, both require interventions in the building envelope, also the installation of a decent heating system. During winter, heating if the classrooms occurs from wood stoves and sometimes by plugging electric heating units at the entry of the classrooms, they besides reviling inappropriate for heating contribute to the high consume of power, too. As seen from the typology analysis above, this typologies expected hygenic services to be located outside the building but years ago there were made extensions to the main

Table 20 Situation in Dibër municipality (Credits: Orthophotos- asig.al; Main map and axonometries: the Author)

<table>
<tr><td rowspan="4">
</td><td>117 school buildings</td></tr>
<tr><td>69 (Low cycle)</td></tr>
<tr><td>7 (12-year cycle)</td></tr>
<tr><td>41 (9-year cycle)</td></tr>
<tr><td>9-year cycle school "Isuf Karasani"</td><td>9-year cycle school "Haxhi Xhika"</td></tr>
<tr><td>

</td><td>

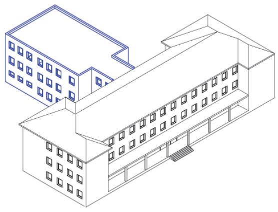
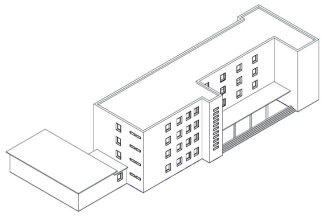
</td></tr>
<tr><td>Orientation: E-W
Typology: 12_2_A
Location: Tomin,Brezhdan</td><td>Orientation: NW- SE
Typology: 8-2-B
Location: Mustafaj, Arras</td></tr>
</table>

building in order to incorporate them. The necesity to intervene in these building is motivated because of roof-leaks, measing of heating plants and building envelope. Both require spaces for gyms. As highlited in blue, the school in Arras has made many additions to the main building.

3.3.7. Municipality of Kamza

This municipality, located in climate zone A is very recent in the national panorama because it was created in 2015 with the new administrative division, after being part of the municipality of Tirana. Actually, there are 18 school building of the nine-year cycle present in this municipality and the school buildings in critical conditions are 18-3-A and 24-4 typologies (see Table 21). Besides being the highest-capacity school buildings built during Socialism, the didactic activity is split two rounds, meaning that the demand for classrooms is higher. The "Hillary Clinton" school building, whose capacity was increased to classrooms (30 in total) with a new addition, requires at least other 15 classrooms to perform the entire didactic activity in the morning. On the other hand, the "Halit Çoka" requires at least 12 new classrooms to perform the entire activity during morning but in terms of capcity but it has also a gym, that it is absent in the other critic case. In terms of energy performance, both require interventions in the building envelope, also the installation of a decent heating system. During winter, heating if the classrooms occurs by plugging electric heating units at the entry of the classrooms, they besides reviling inappropriate for heating contribute to the high consume of power, too.

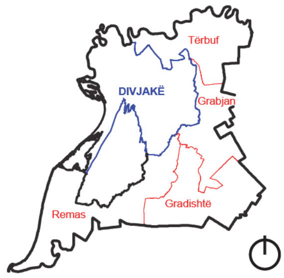
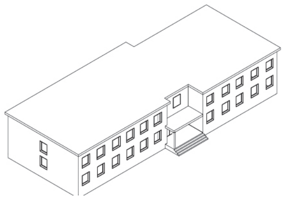
Table 21 Situation in Kamza municipality (Credits: Orthophotos- asig.al; Main map and axonometries: the Author)

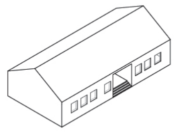
	**18 school buildings** **0 (Low cycle)** **0 (12-year cycle)** **18 (9-year cycle)**
9-year cycle school "Hillary Clinton"	**9-year cycle school "Halit Çoka"**
 	 
Orientation: **NE-SW** Typology: **18-3-A** Location: **Kamëz**	Orientation: **NW-SE** Typology: **24-4** Location: **Kamëz**

3.3.8. Municipality of Divjaka

Located in the climate zone A, it has (n= 10) school building. The most critical cases are typologies of 4 and 8 clasrooms built in the rural areas (see Table 22). In terms of energy performance, both require interventions in the building envelope, also the installation. During winter, heating if the classrooms occurs by plugging electric heating units at the entry of the classrooms, they besides reviling inappropriate for heating contribute to the high consume of power, too. The layout of the ground floor of the school in Kryekuq has been modified to create space for the incorporation of the hygenic services inside the main building, unlike the school in Babunj e Re that has preserved its internal layout, with hygienic services outside

Table 22 Situation in Divjaka municipality (Credits: Orthophotos- asig.al; Main map and axonometries: the Author)

<table>
<tr><td rowspan="4">
</td><td>10 school buildings</td></tr>
<tr><td>1 (Low cycle)</td></tr>
<tr><td>0 (12-year cycle)</td></tr>
<tr><td>(9-year cycle)</td></tr>
<tr><td>9-year cycle school
“Hysni Malko”</td><td>9-year cycle school
in Babunj e Re</td></tr>
<tr><td>

</td><td>

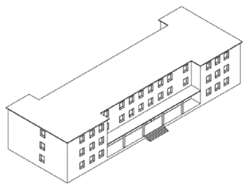
</td></tr>
<tr><td>Orientation: N-S
Typology: 8-2-A
Location: Kryekuq, Divjakë</td><td>Orientation: E-W
Typology: 4-1
Location: Babunj e Re,Remas</td></tr>
</table>

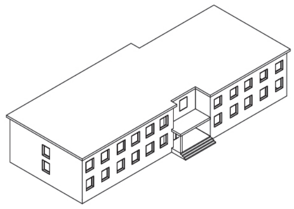
the main building. In terms of capacity, the school in Kryekyq needs at least 10 new classrooms for the activity to occur in the morning and for both a gym.

3.3.9. Municipality of Lushnje

This municipality is located in the climate zone A and has (n=40) school building, all of nine-year cycle (see Table 23). There are two critical cases are 8-2-A and 18-3-A school building typologies located in the city of Lushnja and in town of Dushk. Both schools have an acceptable orientation. In terms of energy performance, both require interventions in the building envelope, also the installation. During winter, heating if the classrooms occurs by plugging electric heating units at the entry of the classrooms, very inappropriate for heating and responsible for increasing the power consume. In terms of capacity, the “Skënder Libohova” school requires twice the actual capacity to perform the didactic activity in the morning, whereas the “Mihal Davidhi” school does not have problems in this perspective but it has modified its internal layout at the ground floor seen to incorporate the higienic services in the main building. Both require spaces for gyms.

Table 23 Situation in Lushnja municipality (Credits: Orthophotos- asig.al; Main map and axonometries: the Author)

<table>
<tr><td rowspan="4">
</td><td>40 school buildings</td></tr>
<tr><td>0 (Low cycle)</td></tr>
<tr><td>0 (12-year cycle)</td></tr>
<tr><td>40 (9-year cycle)</td></tr>
<tr><td>9-year cycle school “Skënder Libohova”</td><td>9-year cycle school “Mihal Davidhi”</td></tr>
<tr><td>

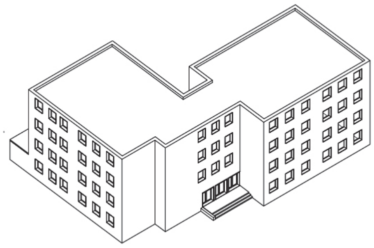
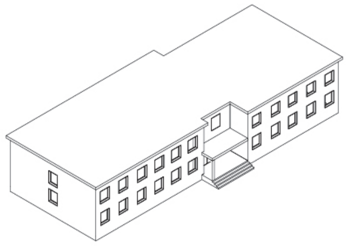
</td><td>

</td></tr>
<tr><td>Orientation: NE-SW
Typology: 18-3-A
Location: Lushnje</td><td>Orientation: NW-SE
Typology: 8-2-A
Location: Dushk</td></tr>
</table>

3.3.10. Municipality of Belsh

This municipaliy, is located in the climate zone A, has (n=16) school building of nine-year cycle. The 8-2-A typology in Shkëndi, has undergone to interventions modifying its internal layout at the ground floor to incorporate the higienic services in the main building. The 16-4 typology in Belsh has several problems related to the indoor comfort of classroom an aspect also critical and overheating problems summer. Both have an acceptable orientation. Interventions in the building envelope are necessary to improve energetic performance of school buildings, using as heating solution the same solution as mentioned in all the analyzed cases, by plugging electric heating units at the entry of the classrooms. Even though it has a gym the school in Belsh requires at least eleven new classrooms to perform the didactic activity in the morning.

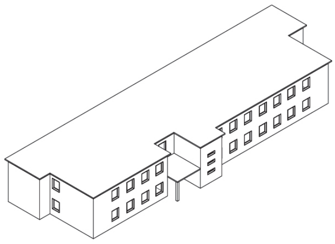
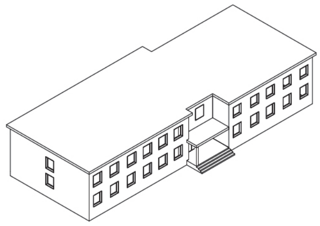
Table 24 Situation in Belsh municipality (Credits: Orthophotos- asig.al; Main map and axonometries: the Author)

<table>
<tr><td rowspan="4"></td><td>16 school buildings</td></tr>
<tr><td>0 (Low cycle)</td></tr>
<tr><td>3(12-year cycle)</td></tr>
<tr><td>13 (9-year cycle)</td></tr>
<tr><td>9-year cycle school
“Ndriçim Shehu”</td><td>9-year cycle school in Shkëndi</td></tr>
<tr><td>
</td><td>
</td></tr>
<tr><td>Orientation: NE-SW
Typology: 16-4
Location: Belsh</td><td>Orientation: NW-SE
Typology: 8-2-A
Location: Shkëndi, Belsh</td></tr>
</table>

3.3.11. Municipality of Selenica

It is the southernmost municipality of the research and located in the climate zone A. It counts (n =21) school building where (n=18) are for the nine-year cycle. The most critical cases are an 8-2-A and a 12-2-A school building typologies. Both have an optimal orientation. Interventions in the building envelope are necessary to improve energetic performance of school buildings and eventually to provide a better indoor comfort. Electric heating units are used in winter to heat the indoors, but even in this municipality the outcomes are the same. Unlike the original design, both have “sacrificed” a classroom or room at the ground floor to incorporate the services within the main building. In terms of capacity both require at least ten and six new classrooms respectively for the didactic activity to occur in the morning. Both do not have gyms.

Table 25 Situation in Selenica municipality (Credits: Orthophotos- asig.al; Main map and axonometries: the Author)

<table>
<tr><td rowspan="4">
</td><td>21school buildings</td></tr>
<tr><td>0 (Low cycle)</td></tr>
<tr><td>3 (12-year cycle)</td></tr>
<tr><td>18 (9-year cycle)</td></tr>
<tr><td>9-year cycle school
“Qani Nuredini”</td><td>9-year cycle school
“Qazim Sinaj”</td></tr>
<tr><td></td><td></td></tr>
<tr><td>
</td><td></td></tr>
<tr><td>Orientation: NW-SE
Typology: 12_2_A
Location: Sevastër</td><td>Orientation: E-W
Typology: 8-2-A
Location: Kocul, Vllahinë</td></tr>
</table>

3.3.12. Municipality of Pogradec

Divided betwen the climatic zone B and C, this municipality counts (n=47) schools buildings, the majority for the nine-year cycle. The most critical cases are a 6-2, 8-2 and a 12-2-A school building typologies. Unlike the original design, these school buildings have seen “sacrificing” a classroom at the ground floor to incorporate the hygienic services within the main building. In terms of capacity, the schools in Çërravë and Gështenjas need at least four and three new classrooms repsecitvely to reach a total capacity of nine classrooms, whereas the school in Lin at least seven. As usual, none of them has a space dedicated for gym. Considering, the severe weather conditions in winter, the improvment of the energy performance of these school building is also fundamental for the performance of teachers and pupils, too. In terms of orientation they avoid exposition to North.

Table 26 Situation in Pogradec municipality (Credits: Orthophotos- asig.al; Main map and axonometries: the Author)

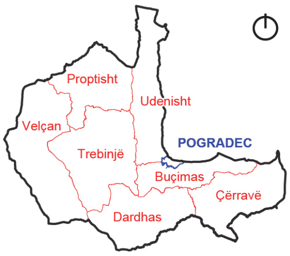
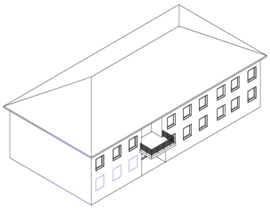
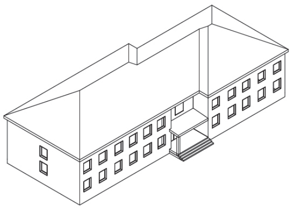
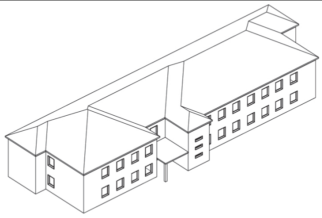
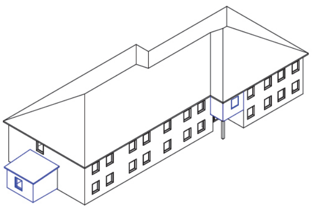
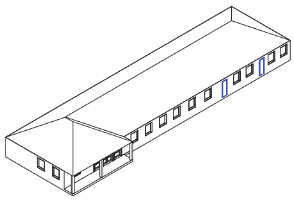
		47 school buildings 8 (Low cycle) 3 (12-year cycle) 36 (9-year cycle)
9-year cycle school "Islam Ibi"	**9-year cycle school "Kajo Karafili"**	**9-year cycle school "Myredin Bashalli"**
 	 	 
Orientation: **NW-SE** Typology: **6-2** Location: **Çërravë**	Orientation: **NE-SW** Typology: **8-2-A** Location: **Gështenjas, Buçimas**	Orientation: **E-W** Typology: **12-2-A** Location: **Lin, Udenisht**

Table 27 Situation in Devoll municipality (Credits: Orthophotos- asig.al; Main map and axonometries: the Author)

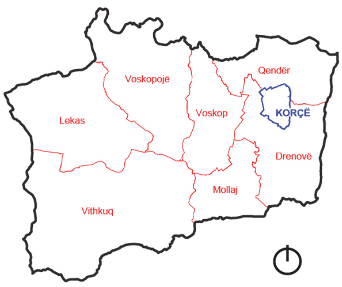
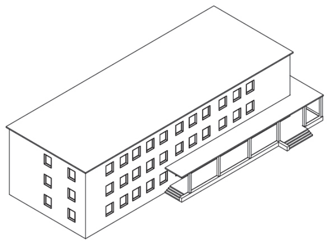
	21 school buildings 0 (Low cycle) 3 (12-year cycle) 18 (9-year cycle)
9-year cycle school "Nevruz Gjoza"	**9-year cycle school "Shefki Mane"**
 	 
Orientation: **NW-SE** Typology: **12-2-B** Location:**Poloskë, Bilisht Qendër**	Orientation: **NE-SW** Typology: **8-1** Location: **Progër**

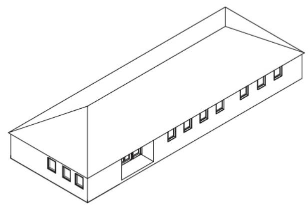
3.3.13. Municipality of Devoll

Located in the climate zone C, this municipality counts (n=21) school buildings where the majority (n=18) are of the nine-year cycle. The most critical cases are 8-1 and 12-2-B school building classrooms. Referring to the original design, they implied the position of the hygienic services outside the main building. Their incorporation to main building has occurred by addition (Poloskë) and by "sacrificing" the teachers' room in Progër. In terms of capacity, both need six and two classrooms to perform the didactic activity in the morning and a gym, too. The poor indoor conditions during winter represent a disadvantage for the teachers and pupils, even worse considering the use of inefficient wood stoves and electric heating units. Regarding the orientation, it is not the best.

3.3.14. Municipality of Korçë

Table 28 Situation in Korça municipality (Credits: Orthophotos- asig.al; Main map and axonometries: the Author)

<table>
<tr><td rowspan="4">
</td><td>47 school buildings</td></tr>
<tr><td>8 (Low cycle)</td></tr>
<tr><td>3 (12-year cycle)</td></tr>
<tr><td>36 (9-year cycle)</td></tr>
<tr><td>9-year cycle school
"Naim Frashëri"</td><td>9-year cycle in Gjonomadh</td></tr>
<tr><td>

</td><td>

</td></tr>
<tr><td>Orientation: NE-SW
Typology: 12-3
Location: Korçë</td><td>Orientation: N-S
Typology: 6-1
Location:Gjonomadh, Voskopojë</td></tr>
</table>

The last municipality included in the research, located in the climate zone C, counts (n=47) where the majority is composed by the nine-year cycle. The most critical cases are a 6-1 and of 12-3 school building typologies. Besides lacking of gym, The "Naim Frasheri" should triplicate its capacity to perform the didactic activity in the morning. On the hand, the school in Gjonomadh requires at least three new classrooms (and a gym) but not as urgent as the nececisity to improve the indoor comfort during of the indoors and consequently the energy performance of the buildings. Both do not represent an expection of the heating appliances used in comparison with the other cases analysed above. Regarding the orientation, it is critic for "Naim Frasheri" school and accepatable for the Gjonomadh.

3.3.15. Survey Results

After illustrating the (n=31) critical school buildings reported in collaboration with the municipalities important considerations emerge in terms of territorial distribution and orientation. Most of the school buildings are located in the climate zone A (n=14), (n=9) in climate zone B and (n=8) in climate zone C. The eight and twelve-classrooms typologies are the most diffused which means that situation in the rural areas is more critic in rural areas, as long as this typologies "embody" different design goals in comparison with those designed for the urban areas. Referring to the original design, in (n=21) cases it has occurred the: (i) change the internal layout in the ground floor to incorporate the hygienic services in the ground floor; (ii) addition of new volumes to existing buildings (hygienic services, closet or gym); and (iii) building a new volume onto the canopy at the main entry and including it to the main building. Regarding the orientation, the majority of the analyzed cases have acceptable orientation (n=15) and optimal one (n=7), referring to the schemes in Figure 15. Considering the orientation advices in the technical reports, only in (n=9) cases the orientation is critic meaning that some classrooms suffer cold during winter because facing North and the others experience overheating in Spring and Summer because facing South. In climatic Zone A, it is present a larger variety of school building typologies and orientation, except the N-S orientation (n=2. In the climate zone B the most encountered typologies are the 8-2-A (n=4) and 12-2-A (n=2), and in terms of orientation there are (n=2) critic cases for each orientation. And last, the climate zone C, the critic cases are school buildings not exceeding the twelve-classroom typologies, but in term of orientation there (n=3) critic cases.

In terms of classrooms shortage, it is a critic issue for all the school buildings but more urgent in the urban centers where the school buildings require twice more

Table 29 Classification based on Typology and Orientation according to the climate zone- source: the Author

		Climate Zone A	Climate Zone B	Climate Zone C	Total
Typologies	4-1	1		2	3
	6-1			1	1
	6-2		1		1
	8-1			1	1
	8-2-A	4	4	1	9
	8-2-B	1	1	1	3
	12-2-A	1	2	1	4
	12-2-B			1	1
	12-3	1		1	2
	16-4	1			1
	18-3-A	3			3
	18-3-B	1			1
	24-4	1			1
	Total	**14**	**8**	**9**	**31**
Orientation	N-S	2	2	1	5
	NE-SW	4	2	3	9
	E-W	4	2	1	7
	NW-SE	4	2	4	10
	Total	**14**	**8**	**9**	**31**

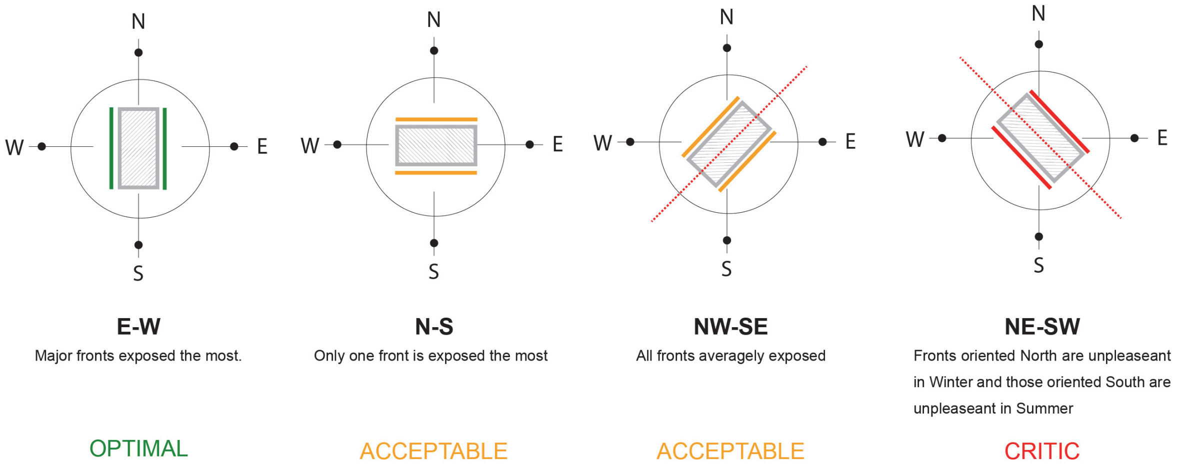


Figure 15 Building orientation scheme- graphics: the Author

classrooms than their current capacity. The indoor gym is present only in three cases, because of not being design a priority in the past, but nowadays it is mandatory for the new schools and eventually be incorporated to existing ones as an addition. The poor indoor comfort during winter is more worrying than the shortage of classrooms because it directly affects the performance of students and teachers. The use of wood stoves and electric heating units, usually positioned at the entry of the classrooms are not efficient in this perspective because consuming a lot of power without providing a uniform heating within the classrooms. In terms of environmental impact, wood stoves are not the best solution but as long it was the original solution launched when these school typologies were designed they represent an outdated solution in comparison to the solutions available nowadays and goals in terms of energy efficiency and environmental goals, too.

3.4. School buildings renovation approach in Albania. Examples

The number of interventions aiming a better energetic performance and indoor comfort of the existing school buildings is constantly growing in the country. The selection of the school building to be refurbished occurs according to the consideration of a six factors in a descending order as illustrated in Figure 11, by means the high-capacity schools will prevail towards the low-capacity ones. Unfortunately, the renovations of the existing schools in Albania occur in a situation of: (i) undefined energy certification system; (ii) undefined annual refurbishment rate; (iii) technical values for the building envelope; and (iv) undefined policy for the use of renewable sources.

The first aspect, is important to measure the consistency and the improvement deriving from a renovation (or refurbishment) intervention based on the specific requirements of the certification system. The absence of legally-approved energy consumption levels, known as energy classes (usually from G to A or even A+) leads to incorrect interpretations of these kind of interventions. As analyzed in the previous chapters, the EED 2012 set the annual refurbishment rate for the member 3% of the total floor area of heated and/or cooled buildings owned and occupied by its central government each year to meet at least the minimum energy performance, starting from 01/01/2014. Despite having transposed in the national legislation two important EU directives: (i) the Energy Efficiency directive EED 2012 (2012/27/EU) in the respective Law Nr.124/2015[38]; and (ii) the EPBD recast (2010/31/EU) in the Law Nr.116/2016[39]; the annual refurbishment threshold values have not been set yet.

The third issue, related with the absence of minimum transmittance U values for the building envelope elements such as walls, ground slabs, roof and openings (doors and windows), increases further the uncertainty of renovation or refurbishment intervention. Indeed, in recent renovation cases (as will be analyzed in the selected examples), there has not occurred a total insulation of building envelope in its whole rather than partial insulation of the walls, roofs (sometimes) and replacement of windows and doors. Furthermore, the insulation and the new layers do not reflect

[38] [ALB] Ligji Nr. 124/2015 “Për efiçencën e energjisë”

[39] [ALB] Ligji Nr. 116/2016 “Për performancën e energjisë së ndërtesave”

the intention to achieve a certain level or percentage of energy savings based on technic and technologic considerations.

Regardless of the climate zone the school is located, the thickness of the insulation in the wall and in the roof ranges usually between five or ten centimeters. The ground slab is subject to finish and waterproofing works, and never insulated. Regarding the openings (windows in particular), the decree nr.319 the Council of Ministers approved in 2017 entitled "Standartet e projektimit për shkollat[40]", advices designers to propose new double-glazed ones whose U-value is equal to 1.2 W/m^2K, and eventually lowered to 0.8 with triple-glazed windows when renovating in cold climates.

The fourth aspect, concerned with the environmental impact of the power plants. Indeed the analyzed renovation cases, the installation of the centralized heating system with radiators as terminals are becoming very frequent, representing a turning point compared to the design solution during Socialism and the widespread use of electric heating units in schools in critic or normal conditions. Quite often the power plants are run by fossil fuels, totally in contrast of the aim of the refurbishment intervention. Considered pillars of the EU energy efficiency policies, the 2020, 2030 and 2050 climate & energy frameworks, pose important goals in terms of reducing emissions and generating clean energy from renewable sources (such as sun, wind, geothermal and tidal energy), highlighting the importance of environmental issue in within the policy.

In light of this considerations, the interventions made on the existing buildings that are not evaluated in terms of energy consumption class, as long as there is nothing similar legally defined, may have as main finality the improvement of the indoor comfort rather than reaching a higher level of energy efficiency. But providing heating through plants running with fossil fuels does not increase the benefits expected in environmental quality perspective. In a survey that involved seventeen school buildings performed by (Novikova, et al., 2016) in various climates zones of the country emerged that even half of them used centralized heating systems using an oil boiler and radiators (zone A and B) whereas in the coldest climate zone C bio-mass stoves were common.

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[40] [ALB] "Standard for the design of school buildings"

They also highlighted that the higher attention toward classrooms heating, is higher compared to domestic hot water DHW, ventilation or cooling systems. In order to comprehend the measures taken in the renovation projects, there were chosen 6 interventions made on existing school buildings (2 in each climate zones) where were also interviewed the design studios about the strategies adopted in the energy refurbishment of the school buildings.

3.4.1. Interventions in the climatic zone A

Table 30 Recent school renovations in climatic zone A- design info: MESY; graphics: the Author

(source: the Author)

(source: ata.gov.al)

School name		9-year cycle school “Nenë Tereza Laknas”	9-year cycle school Jakov Xoxa in Fier
Renovation Project		Office of Planning, Control and Development of Territory in the Municipality of Kamza	Office of Planning, Control and Development of Territory in the Municipality of Fier
Typology		12-2-A	18-3-A
Climatic Zone		A	A
Years of Construction | Renovation		- | 2019	-| 2019
Building envelope	**Wall**	5 centimeters thermal insulation in EPS	5 centimeters thermal insulation in EPS
	Ground slab	-	-
	Roof	-	-
	Windows	Double-glazed windows in aluminium	Double-glazed windows in aluminium
Heating/Cooling system		3 radiators per classroom. Pellet heating plant 80 kW	-
Ventilation		Natural. Through the windows	Natural. Through the windows
Shading		-	-
Renewable energy :		Pellets heating plant	-

The examples illustrated and detailed in Table 30, are partial renovation. Before the recent intervention, the school in the municipality of Kamza (a 12-2-A typology), saw the addition of a hygienic service block, as long in the original design it was expected outside the main building. Regarding the envelope, only the external walls were the only to be insulated (including finishes works) whereas the roofs and ground slabs were mostly subject to waterproofing and finishes works. The old windows were replaced with new double-glazed ones with air-gap in between. Unlike the school in Fier, in the “Nenë Tereza” it was installed an 80 kilowatt heating plant run by pellet and 3 radiators in each classroom in proximity of the windows. The classroom are naturally-ventilated through the windows, the same as before the intervention.

Unlike the school in Fier, the school in the municipality of Kamza has evident shortage of classrooms and a gym, meaning that the didactic activity continues to be divided between morning and afternoon. Despite being located in climate zone A, the hottest of the country, sun-screening strategies were not applied in these cases

3.4.2. Interventions in the climatic zone B

Table 31 Recent school renovations in climatic zone B- design info: MESY; graphics: the Author

(source: RTSH.al)

(source: 9-year cycle school "Abdyl Bajraktari")

School name		**9-year cycle school "Rifat Keli", Poliçan**	**9-year cycle school "Abdyl Bajraktari", Malesi e madhe**
Renovation Design Project		**NG Structures sh.p.k**	**Novatech studio sh.p.k**
Typology		**12-3**	**24-Clasrooms**
Climatic Zone		**B**	**B**
Years of Construction | Renovation		**-| 2017**	**-| 2019**
Building envelope	Wall	**5 centimeters thermal insulation in EPS**	**5 centimeters thermal insulation in EPS**
	Ground slab	**-**	**-**
	Roof	**5 centimeters thermal insulation in EPS**	**5 centimeters thermal insulation in EPS**
	Windows	**Double-glazed windows in aluminium**	**Double-glazed windows in aluminium**
Heating/Cooling system		**x3 Radiators per classroom. Fuel heating plant 190 kW**	**X2 Radiators per classroom. Fuel heating plant 80 kW**
Ventilation		**Natural. Through the windows**	**Natural. Through the windows**
Shading		**-**	**-**
Renewable energy technologies:		**Building Envelope**	**Pellets heating plant**

These two interventions, made in 2017 and 2019 and have many similarities among each other. Compared to the interventions made in the two cases in climate zone A, the interventions on the building envelope include the insulation of the roofs. In light of the absence of regulated transmittance U-values for the building envelope elements, it was applied the same insulation material and thickness in the external walls and roof. Also, the old windows were replaced with new double-glazed ones with air-gap in between with horizontal openings allowing the one-sided natural ventilation of the classrooms as well. The only difference between them, is the type of heat plant installed to fulfil the heating demand. Although being different in terms of capacity, the school in Poliçan has power plant three times bigger than the school in Malësi e Madhe that is twice bigger in terms of capacity. The attention toward the enviromental impact of the heat plant is diffrent as well, with the a heating plant run by fuel in Poliçan and the pellet-running heat plant in Malësi e Madhe. In terms of capacity both are ok in terms of classrooms and indoor gym.

3.4.3. Interventions in the climatic zone C

These two interventions, made in 2019 and have many similarities among each other. Located in the climate zone C, these school are exposed to severe weather conditions in winter. Surprisingly, only the external walls where insulated and the existing windows replaced with double-glazed windows with air gap in between whereas the roofs and ground floors were subject to waterproofing and finishing works. Another encouraging fact is the installation of heating plants running in pellet and even here the school building with the biggest capacity has a down-sized heat plant compared to the other school with six classroom less. In light of this brief analysis it is hard to affirm which intervention is the best in terms of energy performance but considering that in foreign countries with a defined energy-efficiency framework, in cold climate zones the insulation is thicker than in the other ones. In terms of capacity both are ok in terms of classrooms and indoor gym.

Table 32 Interventions in the climatic zone C- design info: MESY; graphics: the Author

(source: the Author)

(source: HMK-consulting sh.p.k)

School name		**9-year cycle school in Bulqizë**	**9-year cycle school "Ditero Agolli, in Devoll**
Renovation Design Project		**ERALD-G sh.p.k**	**HMK-consulting sh.p.k ,ERALD-G sh.p.k, HP-Studio**
Typology		**24-4**	**18 classrooms**
Climatic Zone		**C**	**C**
Years of Construction | Renovation		**- | 2019**	**-| 2019**
Building envelope	Wall	5 centimeters thermal insulation in EPS	5 centimeters thermal insulation in EPS
	Ground slab	-	-
	Roof	-	-
	Windows	Double-glazed windows in aluminium	Double-glazed windows in aluminium
Heating/Cooling system		x3 Radiators per classroom. Pellet heating plant 95 kW	x3 Radiators per classroom. Pellet heating plant 200 kW
Ventilation		Natural. Through the windows	Natural. Through the windows
Shading		-	-
Renewable energy technologies:		Pellets heating plant	Pellets heating plant

3.5. Conclusions

After a careful examination of the critical cases in the fourteen municipalities, starting from their typological analysis based on the original design and the six recent interventions made on existing school buildings aiming a better indoor comfort and energy performance, many useful indications emerged. Dealing with an outdated building stock that resembles indoor comfort, energy efficiency, facilities and capacity problems is not that easy. During Socialism, there was a different design approach for the school of urban and rural areas, in terms of capacity and other services. Only in the 80s the elaboration of school building typologies exceeding with higher capacity and indoor gym, represented a turning point but unfortunately interrupted in the early.

Nowadays the refurbishment of the school building has two major challenges: (i) improvement and of the energy efficiency and consequently indoor comfort and (ii) increase the capacity to the needs of the actual configuration the nine-year cycle. Based on the six analyzed cases and the national energy efficiency framework, the interventions performed in the existing school buildings are not made according to final energy performance level to achieve. The absence of the energy certification system and requirements for the building envelope components has led into a situation where the partial intervention in the building envelope are performed without distinguishing the climatic differences. The most common interventions concerned with insulation of the external walls, occasionally the roofs and replacement of the windows without being regulated by building codes put in serious question the effectiveness of these interventions. Moreover the installation of the centralized heating systems sometimes run by pellet or fossil fuels represent another evidence regarding the environmental goals to pursue in these kind of intervention. In a context of clear energy-efficiency framework, they might be probably downsized and use renewable resources would be exploited.

Not less important is also the capacity shortage of the school buildings present in the rural and urban areas. The actual nine-year cycle system has inherited buildings designed in large part for the eight-year cycle and in a smaller part for the seven-year one. Besides the differences in the internal layouts, and presence/ absence in some important facilities (hygienic services and gym), most of the school building have been undergoing to extension interventions and modification of the interior layout resulting with reduction of didactic space or augmentation of their volume. But the addition of this facilities, does not solve the main problem that is adverted in most of the school building in the country, which is the split of the didactic activity in two rounds, which is not very pleasant for students of the lower cycle in particular that of the 2nd, 3rd, 4th and 5th grades.

So the renovation school building in Albania, has to accomplish two important missions that have to contemplate each other: the increase of capacity and improve energy performance and indoor quality. The school buildings in Albania have to adapt in terms of capacity (intended as number of classrooms) and required facilities to the current configuration of the nine-year cycle system. Obviously the increase of capacity cannot be generalized because of depending on the availability of free space but it should be included as goal because the split of the didactic activity morning and afternoon should not persist any longer. The second mission, consists in the transformation of the school buildings into energy efficient with good IEQ by performing complete and well-structured interventions rather than partial ones. As main condition to approach their renovation should be the definition of a series of intervention that will also permit the transformation into nearly Zero Energy nZEB school buildings.

4. nZEB strategy for the refurbishment of the existing school. A two-scenario approach

In this chapter there will be illustrated the approach and strategy to adopt for the renovation of the existing school building into nZEB according two possible scenarios, by refurbishing the existing building (first scenario) and increasing the capacity (second scenario). The first part will discuss about the differences among the Albanian an EU context in order to set an appropriate pillars for the refurbishment of the school buildings in an nZEB perspective. The second part will be proposed methodology to calculate the Energy performance index (EPi). The third part, will focus in the interventions to be made in existing buildings by setting the transmittance values and possible solutions to achieve them. The fourth part will deal with the heating, cooling and ventilation strategies to be adopted in relation to the climatic context, valid for the existing buildings and new additions. The fifth part will include the recommendations for the first scenario based on the capacity of the school buildings and climate context they are located. In the sixth part, will be described the approach to increase the capacity of the existing buildings in relation to the nine-year cycle system, describing the building system to adopt and aggregation schemes.

4.1. Approaching nZEB in Albania. Differences with the EU

The refurbishment of non-residential public buildings in an nZEB perspective prompted continuously from various EU directives, has two main specific goals: (i) increase the energy efficiency of the building stock; and (ii) reduce the dependence from the grid. From the analysis of the four recent cases regarding the refurbishment of the school building into nZEB perspective, it emerged that this policy is more diffused in the Northern European countries rather than the Southern ones even though potentials to transform them into nZEB are higher as stated in the conclusions and recommendations of the program ZeMEDs.

Indeed, differences in climate conditions between Northern Europe and EU Mediterranean countries (such as Italy, Greece), imply different insulation thickness in the buildings envelope and transmittance U-values to reduce heat loses, too. The second reason, strongly related with the environmental aspect, aims to identify of new alternatives to produce clean energy from renewable sources guiding towards the abandon of the grid. In 2017, (Eurostat, 2019) highlighted that 69 % of electricity consumed in the EU was produced from non-renewable sources (44 % from fossil fuels plants and 25 % from nuclear plants) a remaining 31 % from renewable sources. In same proportions was the production of energy, 71.1 % from non-renewable sources (27.8 % nuclear energy; 19.0 % solid fuels; 13.6 % natural gas and 9.7 % crude oil) and 28.9 % from renewable sources. Although the nonrenewable sources are still dominant, the growing attention toward renewables has decreased the emissions by 22 % compared with the levels registered in 1990, representing an absolute reduction of 1,240 million tons of CO2 equivalents, putting the EU on track to surpass its 2020 target, to reduce GHG emissions by 20 % in 2020. In light of the 2030 and 2050 climate & energy frameworks (see Table 3) aiming the reduction of GHG by 40% and 95 % respectively and increasing the share of renewables and energy efficiency across the union, the diffusion of nZEBs (new construction or refurbished) are considered fundamental in the achievement of these goals as soon as possible. Despite not being a member of the EU, Albania has showed the will to transpose into its legislation the two important directives: (i) the Energy Efficiency directive EED 2012 (2012/27/EU) in the respective Law Nr.124/2015; and the EPBD recast (2010/31/EU) in the Law Nr.116/2016 but has not proceed yet toward the further steps to make these laws fully operative. In absence of a national energy certification system, transmittance requirements for building envelope elements and a policy for renewable sources, meanwhile the Law Nr.116/2016[41] in the Article 3, coma 15 explicitly defines a building whose performance is close to zero: "As a buildings with a high energy performance as defined in the national calculation methodology. Their energy demand is very low, close to zero, and be covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby." Since 2016, the nZEB are included in the national legislation but not regulated. The six recent renovation cases analyzed previously highlight the inefficiency of the current legislation because of the missing acts. The risk for these interventions to be considered inappropriate in an energetic point of view will be very high when these missing acts will be approved, meaning that they should undergo again into refurbishment to obtain a decent energy class or eventually the nZEB label. The decree nr.38 /16.01.2013 of the Council of ministers "Approval of the norms, rules and design and construction requirements, for the production and conservation of heat in buildings[42]", guiding the calculation of heat loses for transmission and ventilation was used in the size of the heat plants. In comparison with foreign calculation methods it is outdated and incomplete because nowadays domestic heating DHW, power for illumination and cooling demand are included in the calculation.

The introduction and implementation of the nZEB concept in the refurbishment of the existing school buildings should consider the differences between Albania and the EU context. Indeed most of energy supply is covered by crude oil (53.3%) and

[41] [ALB] "Ndërtesë me performancë "afër zero energji"" janë ndërtesat që kanë një performancë shumë të lartë të energjisë, siç përcaktohet në Metodologjinë Kombëtare të Llogaritjes. Kërkesa për konsum energjie shumë të ulët ose pothuajse zero duhet të mbulohet kryesisht nga burimet e rinovueshme të energjisë, duke përfshirë energjinë e prodhuar nga burimet e rinovueshme në ndërtesë, në njësinë e ndërtesës ose pranë tyre.

[42] [ALB] - vendim Nr. 38, datë 16.1.2003: "Për miratimin e normave, të rregullave dhe kushteve të projektimit dhe të ndertimit, të prodhimit dhe ruajtjes së nxehtësisë në ndërtesa."

Table 33 Comparison between requirements for nZEB in northern EU and Albania- graphics: the Author

	EU	Albania
Reference context	Northern European countries	South-Eastern Europe. Mediterranean basin
Power production	69 % non-renewable sources	>90 % from hydropower
Energy production	71,1 % non-renewable sources	53,6 % non-renewable sources
Main nZEB goal (for existing buildings)	Produce energy by exploiting renewable sources to rely less possible from the grid	The grid transmits clean energy and eventual production of clean energy by buildings
2030 and 2050 climate and energy frameworks goals	Possible to achieve in the established deadlines	Can be achieved even soone
Renewable sources for nZEB: Solar Energy	Average low.	Very High
Refurbishment main goals	Thicker insulation. Limit heat loses Heat recovery-	Adequate Insulation Prevent overheating. Sun-screening and cooling strategies

renewables (46.7%) whereas the production of electricity derives for more than 90% from hydropower (Eurostat, 2018). Furthermore, being a Mediterranean country is very advantageous because of large potentials of sun energy and especially geothermal energy to be exploited (AEA, 2012). From these considerations, emerge that the nZEB goal is not impossible to reach in a renewable resources point of view and considering the favorable climate when refurbishing the building envelope, the U-values should not be as lower as in the Norther EU countries (Germany, Denmark etc.). By implementing the nZEB approach in the refurbishment of the existing school buildings important goal, Albania can contribute enormously to the achievement of the important goals included 2030 and 2050 climate and energy framework.

4.2. Strategy

Considering the problematics, the strategy for the refurbishment of the existing school buildings in order to transform them into nearly Zero Energy buildings (nZEBs) will occur by considering two main scenarios: (i) Refurbishment of the existing building - preserving its capacity independently the absence of facilities such as gyms; (ii) Refurbishment of the existing building and increase of capacity- to comprehend the consume of the building in the adequate capacity with the didactic activity entirely in the morning. The first step will consist in the definition of a calculation methodology of the buildings demand that will include: (i) heat loses for transmission; (ii) heat loses for ventilation; (iii) domestic hot water (DHW) demand; and (iv) power for illumination. From the sum of these four components it will be defined the energy performance index (EPi) of the building expressed in (kwh/m^2/year). Besides, being very simple compared to certification protocols in the EU, it is the evidence that the strategy aims a deep intervention, the opposite of what has been performed so far in the country. It will not be set an energy label system because it is not the aim of the research to achieve at any cost a hypothetic nZEB label by applying the proposed interventions in the selected case study that will discussed in the next chapters. Referring to title of the thesis, the use of the word "towards" indicates the path towards the refurbishment of the existing school buildings in the future by illustrating the impact of the proposed measures, that in a near future may be even more efficient. The second step, will consist in the definition of the building envelope parameters for the refurbishment and the new constructions in this case the additions, by referring to the Greek and Italian normative because of the similarities in the climate context. Step three and four are valid for both and aim the improvement and control of the IEQ in the classrooms and stimulate the use of renewable sources given the potentials of the country. Finally, the fourth step, is dedicated to the recommendations for the refurbishment of the existing buildings based on the typology and climate, and regarding the additions by giving the aggregation schemes and gradual increase of the capacity of analyzed school building typologies into a new system and updated school building typologies suitable for the nine-year cycle system, in power since 2013.

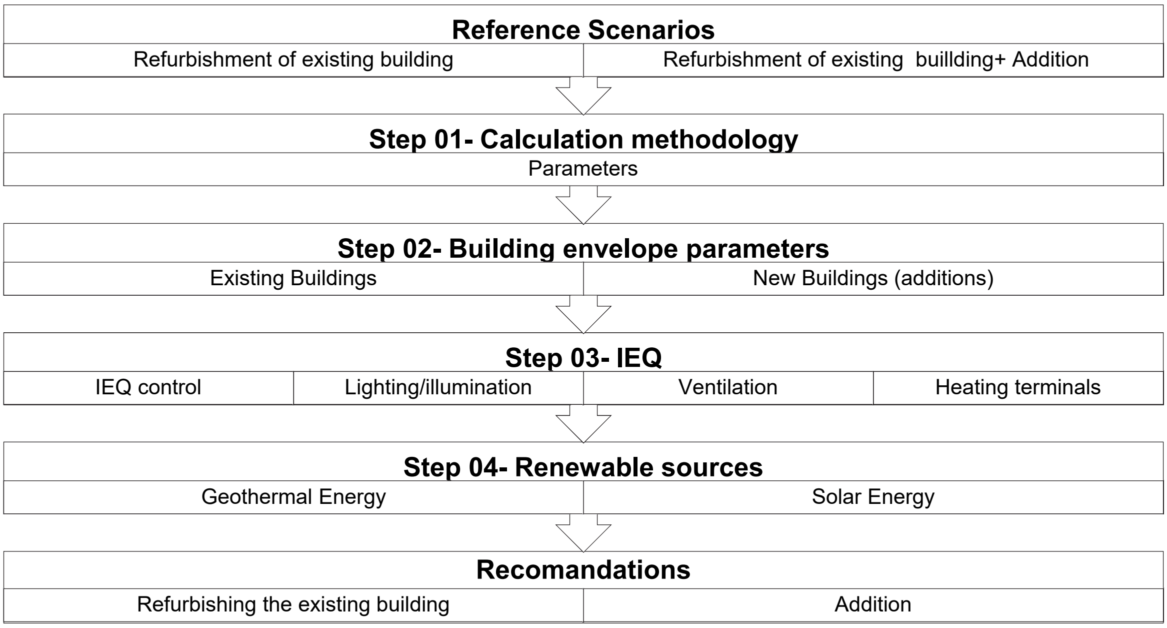


Figure 16 Strategy graphics: the Author

4.3. Refurbishment. Building envelope parameters

Table 34 Building envelope U values for existing buildings- graphics: the Author

	Italy **Decreto Ministeriale 26.06.2015:** *"Applicazione delle metodologie di calcolo delle prestazioni energetiche e definizione delle prescrizioni e dei requisiti minimi degli edifici"*						Greece **Law nr.2367 of 12.07.2017:** *"Έγκριση Κανονισμού Ενεργειακής Απόδοσης Κτι- ρίων". Οι υπουργοι οικονομικων - περιβαλλοντοσ και ενεργειασ*				Albania		
Climate Zone	A	B	C	D	E	F	A	B	C	D	A	B	C
HDD	**<600**	**601-900**	**901-1400**	**1401-2100**	**2100-3000**	**>3000**	**<1000**	**1000-1500**	**1500-2000**	**>2000**	**<1500**	**1501-2500**	**> 2500**
Building envelope U values (W/m² K)													
Roof	0.32	0.32	0.32	0.26	0.24	0.22	0.50	0.45	0.4	0.35	**0.45**	**0.4**	**0.35**
Floor in contact with the ground	0.42	0.42	0.38	0.32	0.29	0.28	1.2	0.9	0.75	0.70	**0.75**	**0.7**	**0.65**
Walls	0.40	0.40	0.36	0.32	0.28	0.26	0.60	0.50	0.45	0.40	**0.50**	**0.45**	**0.4**
Windows Doors	3.00	3.00	2.00	1.8	1.4	1.0	3.20	3.00	2.80	2.60	**3.00**	**2.80**	**2.60**

Before approaching the interventions in the building envelope with the values present in Table 34, with the new materials and finishes it is important to investigate the building technology of the existing school buildings. In light of the partial interventions made in the six recent cases the analysis of the building envelope will reveal the difficulties encountered in the renovation of the existing school buildings in Albania. Independently from the typology, the approach adopted in past in the construction of the Albanian school building, took on consideration the local climatic parameters. For the schools built in the cold climate areas walls where thicker and usually there were expected double windows in each opening (but rarely happened) in order to limit heat loses and the inclined roof, too.

Built with loadbearing walls (see Table 35) their transmittance ranges between 1.34 and 1.77 W/m²°K. The ground floor of the school building usually elevated from the ground (45 to 100 centimeters), is mostly subject to waterproofing and finishing works. Due to the impossibility to comprehend the layer composition directly in the critic cases, there were used the materials of the National Technic Archive. As illustrated in Table 36, its composition is very simple with the bottom layer that in most of cases was made of large stones or eventually gravel (when locally not available) guaranteeing the stability. This solution highlights the accurate considerations made by the designers to contain costs that could have been unsustainable if reinforced concrete would have been used. The gap with the ground, was leveled by the compact earth mass underneath it (varying from 13 to

70 centimeters) and free of humus. It can be affirmed that one of the main reasons, it was never subject to insulation in the analyzed cases is because it is impossible to intervene in the substrate layers that would require time and costs, too. In terms of transmittance it is very problematic because its U-value is equal to 3.09 W/m²°K. Regarding the roofs (inclined and flat), although being easy to insulate compared to ground floors, they are usually subject to waterproofing (and tiles-replacement) and when insulated it occurs with just a standard thickness of five centimeters. As illustrated in Table 37, typical flat roof have a U-value equal to 1,04 W/m²°K, have a waterproof barrier on top and the second layer with varying slope (max 28 centimeters) to facilitate water disposal. Inclined non-ventilated roofs have a higher a U-value compared to flat ones and furthermore the height of the classrooms is increased too. To avoid this problem the designers, elaborated a very innovative solution that consisted in the placement of a false ceiling roof made of reed-reinforced plaster (see Figure 17) that are still maintained in many schools with this type of roof. In the original design concepts, the windows were expected to have three horizontal divisions (the middle/ the upper part openable) made with single glazed and wood frames.

Equation 1 Calculation of the transmittance of walls, ground floor and roofs

$$U = \frac{1}{R_{tot}} = \frac{1}{\frac{1}{\alpha_{in}} + \sum_{i=0}^{n} \frac{\delta_n}{\lambda_n} + \frac{1}{\alpha_{out}}}$$

α_{in} - Interior air resistance (m²°K/W)

α_{out}- Exterior air resistance (m²°K/W)

δ_n- material thickness (m)

λ_n- material conductance (W/m°K)

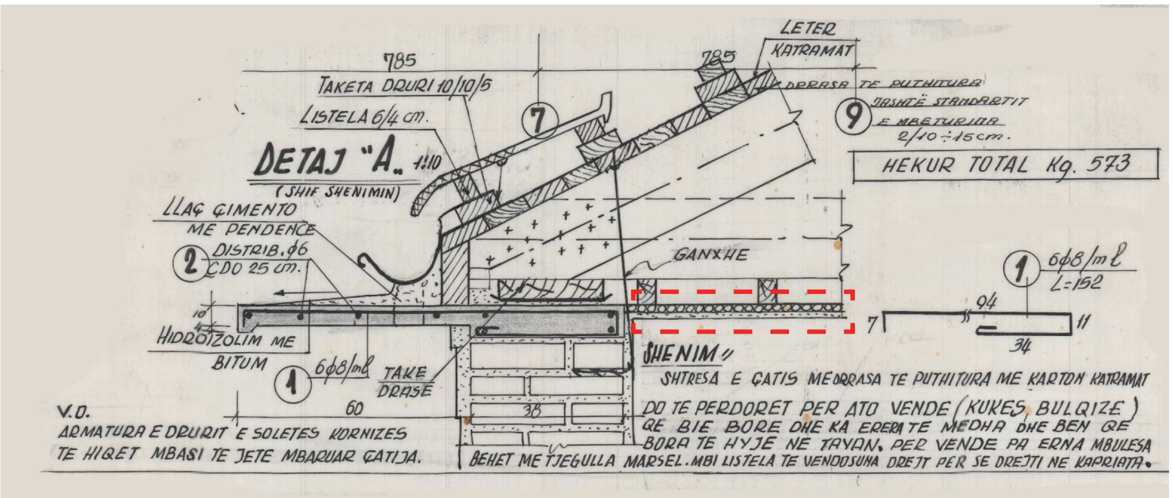


Figure 17 Detail of false ceiling roof for 8-year cycle school for cold areas- source: NTA

Table 35 Walls. Layers and U-value calculation- graphics: the Author

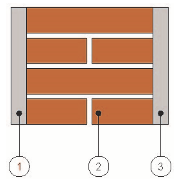
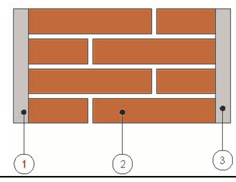
		δ	λ	ρ	c	R	
		m	W/m°K	kg/m³	kJ/kg°K	m²°K/W	
	Exterior air (α_{out}=23)					0,043	
1	External plaster	0,035	1,40	2000	0.67	**0,025**	
2	Brick wall	0,250	0,72	1800	0.79	**0,347**	
3	Internal plaster	0,035	1,40	2000	0.67	**0,025**	
	Interior air (α_{in}=8)					0,125	
	Total	**0,320**				**0,567**	**U= 1,77 W/m2°K**
	Exterior air (α_{out}=23)					**0,043**	
1	External plaster	0,035	1,40	2000	0.67	**0,025**	
2	Brick wall	0,380	0,72	1800	0.79	**0,528**	
3	Internal plaster	0,035	1,40	2000	0.67	**0,025**	
	Interior air (α_{in}=8)					**0,125**	
	Total	**0,450**				**0,746**	**U= 1,34 W/m2°K**

Table 36 Ground floor. Layers and U-value calculation- graphics: the Author

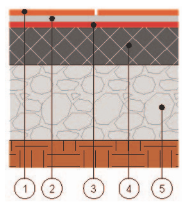
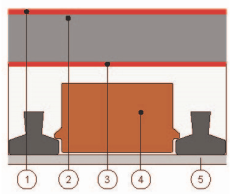
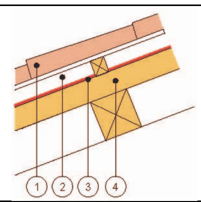
		δ	λ	ρ	c	R	
		m	W/m°K	kg/m³	kJ/kg°K	m²°K/W	
	Interior air (αin=8)					**0,125**	
1	Tiles ceramic tiles	0,02	1,00	2000		**0,020**	
2	Concrete substrate	0,02	0,90	1800	0,91	**0,022**	
3	Waterproof	0,01	0,35	950	2,21	**0,029**	
4	Reinforced Concrete	0,08	2,00	2400	1000	**0,040**	
5	Gravel/Stone	0,15	1,70	2200	1000	**0,088**	
	Total	**0,280**				**0,324**	**U= 3,09 W/m2°K**

Table 37 Roofs. Layers and U-value calculation- graphics: the Author

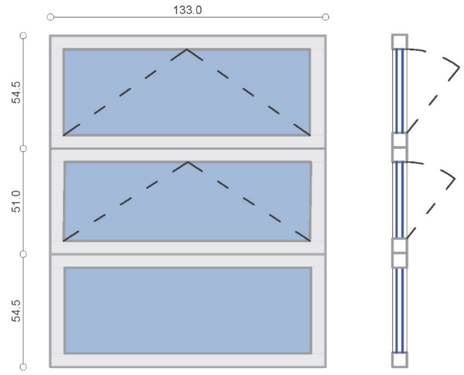
		δ	λ	ρ	c	R	
		m	W/m°K	kg/m³	kJ/kg°K	m²°K/W	
	Exterior air (α_{out}=23)					**0,043**	
1	Wateproof barrier	0,01	0,35	950	2,21	**0,029**	
2	Concrete substrate	0,14	0,90	1800	0,91	**0,156**	
3	Waterproof barrier	0,01	0,35	950	2,21	**0,029**	
4	Slab in concrete and masonry	0,25				**0,34**	
5	Plaster	0,02	1,40	2000	0.67	**0,025**	
	Interior air (α_{in}=8)					**0,125**	
	Total	**0,31**				**0,735**	**U= 1,36 W/m2°K**
	Exterior air (α_{out}=23)					**0,043**	
1	Clay Tiles	0,015	1,00	2000	800	**0,015**	
2	Air Gap (non-ventilated)	0,05				**0,16**	
3	Wateproof barrier	0,010	0,350	950	2,210	**0,029**	
4	wood deck	0,050	0,180	700	1600	**0,278**	
	Interior air (α_{in}=8)					**0,125**	
	Total	**0,105**				**0,669**	**U= 1,49 W/m²°K**

Equation 2 Calculation of the transmittance of windows and doors

$$Uw=\frac{Ag\times Ug+Af\times Uf+Ig\times \Psi g}{Ag+Af} \qquad [W/m^2{}^\circ K]$$

A_g- Glass area (m²)
A_f- Frame area (m²)
U_g- Transmittance glass (W/m²°K)
U_f- Transmittance frame (W/m²°K)
I_g - Perimeter of glass (m)
Ψ_g- linear heat transfer coefficient (W/m°K)

Table 38 Standard type of window in existing school buildings and U-value calculation- graphics: the Author

When single-glazed with aluminum frame		
		
	Glass	**Frame**
A_g and A_f (m^2)	1,42	0.76
U_g and U_f ($W/m^2°K$)	5.7	7.00
l_g (m)	9.56	
Ψ_g (W/m°K)	0.02	
U_w ($W/m^2°K$)	**6.24**	
When double-glazed (**$U_{g=}$ 3,3** $W/m^2°K$) with aluminum frame		
U_w ($W/m^2°K$)	**4.68**	

After the 90s, the windows in almost all the school building have been replaced by preserving the original layout or even by introducing new ones, usually single-glazed with aluminum frame. Another issue that is critical in the renovation interventions, related with a morphology of the Albanian school buildings are the thermal bridges, encountered in the canopies at the entry of the buildings. They represent a serious issue especially in the twelve, eighteen and 24-classrooms typologies, where they are extended in a large part of the central façade. In order to improve the energy performance of the building envelope important considerations should be made in relation to the properties and thickness of the insulation materials.

Equation 3 Calculation of the thermal insulation thickness

$$s_i = \Delta R_i * \lambda \quad [m]$$

where:

$$\Delta R_i = \frac{1}{U_n} - \frac{1}{U_n^{'}} \qquad \left[\frac{m^2°K}{W}\right]$$

Δ_{Ri}- Resistance of the insulation material ($m^2°K/W$)

n – Reference climate Zone: A, B, or C

U_n - Transmittance of building envelope element for the reference climate zone ($W/m^2°K$)

U'_n - Transmittance of building envelope element for the reference climate zone without insulation ($W/m^2°K$)

λ- material conductance (W/m°K)

s_i – thermal insulation thickness (m)

Table 39 Thermal insulation materials properties - source: (Deplazes, 2005); graphics: the Author

Insulating material	μ*	λ [W/mK]	Φ***	Price	Remarks	Application
Mineral fibre glass wool [A]	1	0,030 – 0,045	1,5-2 h	inexpen sive	The smallest fibers can be inhaled	● ● ● ● ●
Mineral fiber rockwool [A]	1–2	0,040 – 0,050	8-9 h	inexpen sive	The smallest fibers can be inhaled	● ● ● ● ●
Cellular glass [A]	∞		4-6 h	expensiv e	Can be reused as road sub-base, raw material: scrap glass	● ● ● ● ●
Expanded clay [B]	2	0,010 – 0,030			Incombustible insulating material	Loose fill
Expanded polystyrene (EPS) [C]	40-100	0,039 – 0,045	1-2 h	inexpen sive	Does not rot, ultraviolet radiation causes embrittlement, can be worked mechanically	● ● ● ● ● ●
Extruded polystyrene (XPS) [C]	80–250	0,034 – 0,041	2-3 h	moderat e- exp.	Does not rot, ultraviolet radiation causes embrittlement, can be worked mechanically	● ●
Rigid polyurethane foam [C]	60–80	0,025 – 0,032	1-2 h	moderat e- exp.	Dust must not be inhaled, not resistant to ultraviolet radiation	● ● ● ● ●
Wood fibers [D]	5	0,038 – 0,040	8-10 h	moderat e	Fine dust during sawing, sheets can be reused	● ● ● ● ● ●
Cement-bonded wood-wool [D]	2–7	0		moderat e	Fixed with nails, wall anchors, tile adhesive, suitable as substrate for plaster/render, ceramic products, plasterboard	● ● ● ●
Cellulose fibers [D]	1–2	0,038 – 0,042	6-8 h	inexpen sive	Loose fill (tipped or blown)	● ●
Sheep's wool [D]	1–2	0.04	2-4 h	moderat e exp.	Formaldehyde catalyst, hence recommended for air hygiene aspects, easily reused	● ● ●
Flax, hemp [D]	1		3-5 h	inexpen sive exp.	Easily reused (except facade panels), facade insulation panels readily available	● ● ●
Cork [D]	2–8	0,038 – 0,050	4-7 h	inexpen sive exp.	Smell of material must be considered when used indoors	● ● ● ●

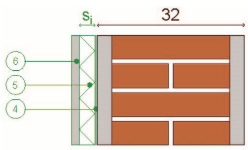
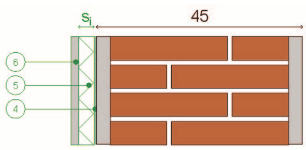
* Diffusion resistance index ** Thermal conductance *** Thermal Phase shift [A] Inorganic,synthetic raw materials [B] Inorganic, natural raw materials [C] Organic,synthetic raw materials [D] Organic, natural raw materials	● Not subject to compression, e.g. for walls, floors and ventilated roofs ● Not subject to compression, e.g. for insulation between rafters and joists ● Subject to compression, e.g. for casting against concrete as permanent formwork, for general use in floors and roofs ● Beneath floors distributing compression loads, e.g. industrial floors ● Beneath floors distributing compression loads, e.g. parking decks for heavy goods vehicles ● Able to withstand bending moments, e.g. for cladding timber-frame constructions subject to wind loads ● Thermal insulation material able to withstand pull-off loads, e.g. for facades with mineral render ● Impact sound insulation material ● Impact sound insulation material also suitable for use with defined low compressibility

For this purpose, there will be made several combinations to determine by calculating the thickness a thermal insulation material with the minimum and maximum conductibility value λ (W/m°K), to reach the specified U-values for the walls, ground floors and roofs.

4.3.1. Walls

The solution proposed for the external walls is the typical insulation coating but with the only difference that the possible combinations are made by considering the best insulation materials for this element of the building envelope. The choice of this solution does not exclude the use of other solutions such as the ventilated façade, but it aims to show how to identify the best solution with the adequate insulation thickness using Equation 3 in order to achieve the minimum U-values established in Table 34. Besides the insulation, they include a new external plaster finish. The insulation material where chosen because guaranteeing good properties in terms of thermal phase shift and vapor diffusion. The seven insulation materials chosen (referring to Table 39) have different performances when considering these two main aspects regardless the necessary thickness to permit the achievement of the desired U-value. The materials with high resistance to vapor (EPS, XPS and Polyurethane foam) do not guarantee an elevated performance in terms of thermal

Table 40 External walls insulation. Possible solutions- graphics: the Author

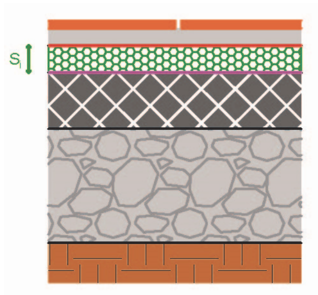
							
		Zone A	**Zone B**	**Zone C**	**Zone A**	**Zone B**	**Zone C**
U'n(W/m^2°K)		**1,71**			**1,31**		
Un(W/m^2°K)		**0,50**	**0,45**	**0,40**	**0,50**	**0,45**	**0,40**
ΔRi (m^2°K/W)		**1,415**	**1,637**	**1,915**	**1,237**	**1,459**	**1,737**
Mineral fibre glass wool	0,030	0,042	0,049	0,057	0,037	0,044	0,052
	0,045	0,064	0,074	0,086	0,056	0,066	0,078
Mineral fiber rockwool	0,040	0,057	0,065	0,077	0,049	0,058	0,069
	0,050	0,071	0,082	0,096	0,062	0,073	0,087
Expanded polystyrene (EPS)	0,039	0,055	0,064	0,075	0,048	0,057	0,068
	0,045	0,064	0,074	0,086	0,056	0,066	0,078
Extruded polystyrene (XPS)	0,034	0,048	0,056	0,065	0,042	0,050	0,059
	0,041	0,058	0,067	0,079	0,051	0,060	0,071
Rigid polyurethane foam	0,048	0,068	0,079	0,092	0,059	0,070	0,083
	0,055	0,078	0,090	0,105	0,068	0,080	0,096
Wood fibers	0,038	0,054	0,062	0,073	0,047	0,055	0,066
	0,040	0,057	0,065	0,077	0,049	0,058	0,069
Cork	0,038	0,054	0,062	0,073	0,047	0,055	0,066
	0,050	0,071	0,082	0,096	0,062	0,073	0,087
Insulation material	**λ [W/mK]**	**Si (m)**			**Si (m)**		
New added layers (included in the calculation of the U'n)		4. Vapor barrier 5. Insulation 6. Plaster					

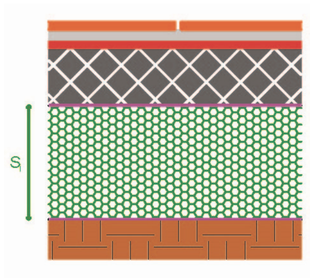
shift but they do not require an elevated thickness to achieve the established U-values. As analyzed in the previous interventions, the EPS was the most used insulation material in the renovation of the existing school building in the thickness of Si= 5 centimeters, can be considered acceptable even though slightly below the established value for the climatic zone A, whereas for the B and C climate zone it is not suitable. The four materials chosen because of their elevated phase shift (Mineral Fiber glass wool, Mineral Fiber Rockwool, wood fibers and cork) should be taken into consideration even though not being resistant to vapor. Except Rockwool fiber which is present in the Albanian market the other insulation material are not very present, but one of the potential ones is undoubtedly the Wood fibers that have a phase shift from 8-10 hours.

4.3.2. Ground floor slab

Table 41 Ground Floor insulation. Possible solutions-- graphics: the Author

		Zone A	**Zone B**	**Zone C**
	U'n(W/m^2°K)		**3,09**	
	Un(W/m^2°K)	**0,75**	**0,70**	**0,65**
	ΔRi (m^2°K/W)	**1,010**	**1,105**	**1,215**
Cellular glass	0,040	0,040	0,044	0,049
	0,050	0,050	0,055	0,061
XPS	0,034	0,034	0,038	0,041
	0,041	0,041	0,045	0,050
EPS	0,039	0,039	0,043	0,047
	0,045	0,045	0,050	0,055
	U'n(W/m^2°K)		**4,24**	
	Un(W/m^2°K)	**0,75**	**0,70**	**0,65**
	ΔRi (m^2°K/W)	**1,097**	**1,193**	**1,431**
Cellular glass (granulated)	0,040	0,044	0,048	0,057
	0,050	0,055	0,060	0,072
Expanded clay (granulated)	0,010	0,011	0,012	0,014
	0,030	0,033	0,036	0,043
XPS	0,034	0,037	0,041	0,049
	0,041	0,045	0,049	0,059
	U'n(W/m^2°K)		**4,24**	
	Un(W/m^2°K)	**0,35**	**0,3**	**0,25**
	ΔRi (m^2°K/W)	**2,621**	**3,097**	**3,764**
Cellular glass (granulated)	0,040	0,105	0,124	0,151
	0,050	0,131	0,155	0,188
Expanded clay (granulated)	0,010	0,026	0,031	0,038
	0,030	0,079	0,093	0,113
XPS	0,034	0,089	0,105	0,128
	0,041	0,107	0,127	0,154
Insulation material	**λ [W/mK]**		**Si (m)**	





As seen from the layer composition analysis and the on the existing school buildings in the three climate zones of the country, the ground floor remains very critic and delicate part to intervene. Considering the stratigraphy, there the possibilities to improve its energy performance are by: (i) reduce floor-ceiling height (ii) deep renovation. In order to meet the minimum values established in Table 34. The first option implies also a new finishing works by removing the existing ones.

Considering that the ground floor is subject to compression the materials guaranteeing the proper insulation and resistance to compression are: Cellular glass (panel), EPS and XPS. Contrary to the last two that have a higher resistance to vapor, the cellular glass offers more advantages in terms of vapor diffusion (∞) and phase shift (4-6 hours). Furthermore, there is not necessary waterproof and vapor barriers which means that the finish substrate can be directly applied to the cellular glass panel. In order to reach the established U-values, the height of the classrooms at the ground floor is expected to be reduced by at least 8 centimeters.

The other insulation materials guarantee lower thickness but imply waterproof works as well, and do not provide the phase shift and strength to compression as the cellular glass does. On the other hand, the second option implying a deep intervention should be performed only when encountered serious problems such as structural instability or serious damages of the layers.

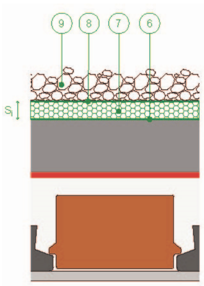
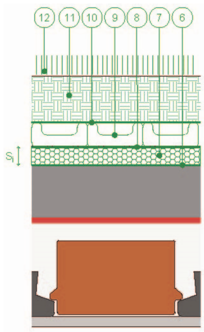
To achieve the established U-values, besides the high quantities to be demolished, it expects the total replacement of the stones (last layer) with the insulation that can be in granules (cellular glass and expanded clay) or in XPS panels, resulting with a thinner layer in comparison with the 15-centimeters of the stone layer. It means that in order to compensate the 8- 11 centimeters, there should be added more soil or by increasing the insulation thickness that will result with a lower U-values of the ground floor.

For this reason the deep intervention is not convenient at the initial established values in Table 34 and for the large waste it creates. Because of the building technology even an innovative system largely used nowadays such as the igloo that are very suitable to deal with humidity and so the reduction of the height remains the one and only solution to improve the energetic performance of the floor in the existing school buildings.

4.3.3. Roofs

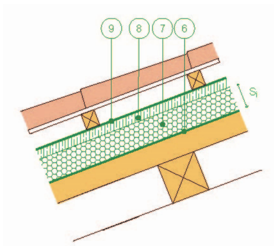
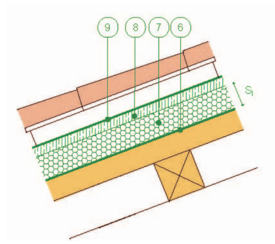
For the flat roofs there is expected a scenario with: (i) insulation with gravel layer as finish; and (ii) insulation and green extensive roof. Both solutions are proposed to improve the energetic performance of the building envelope and indoor comfort of the classroom located in the upper floors. A gravel roof is a very cheap solution providing excellent protection against UV rays and an excellent fire retardant. Generally, it lasts around 20 years but it can last even more if properly installed and constantly maintained, too. The second solution, is not very diffused in the country, but should be taken in consideration in the refurbishment in of the schools located in the climate zone A and B at least. It is not excluded its implementation in the climate zone C but the flat roofs are very rare in this zone but it is included in well in

Table 42 Flat roof insulation. Possible solutions- graphics: the Author

							
		Zone A	Zone B	Zone C	Zone A	Zone B	Zone C
U'n(W/m^2°K)		**1,25**			**1,59**		
Un(W/m^2°K)		**0,45**	**0,40**	**0,35**	**0,45**	**0,40**	**0,35**
ΔRi (m^2°K/W)		**1,422**	**1,700**	**2,057**	**1,593**	**1,871**	**2,228**
Mineral fibre glass wool	0,030	0,043	0,051	0,062	0,048	0,056	0,067
	0,045	0,064	0,077	0,093	0,072	0,084	0,100
Mineral fiber rockwool	0,040	0,057	0,068	0,082	0,064	0,075	0,089
	0,050	0,071	0,085	0,103	0,080	0,094	0,111
Expanded polystyrene (EPS)	0,039	0,055	0,066	0,080	0,062	0,073	0,087
	0,045	0,064	0,077	0,093	0,072	0,084	0,100
Extruded polystyrene (XPS)	0,034	0,048	0,058	0,070	0,054	0,064	0,076
	0,041	0,058	0,070	0,084	0,065	0,077	0,091
Rigid polyurethane foam	0,048	0,068	0,082	0,099	0,076	0,090	0,107
	0,055	0,078	0,094	0,113	0,088	0,103	0,123
Wood fibers	0,038	0,054	0,065	0,078	0,061	0,071	0,085
	0,040	0,057	0,068	0,082	0,064	0,075	0,089
Cork	0,038	0,054	0,065	0,078	0,061	0,071	0,085
	0,050	0,071	0,085	0,103	0,080	0,094	0,111
Cellular glass	0,040				0,064	0,075	0,089
	0,050				0,080	0,094	0,111
Insulation material	**λ [W/mK]**	**Si (m)**			**Si (m)**		
New added layers		6. Vapor barrier 7. Insulation 8. Waterproof barrier 9. Gravel			6. Vapor barrier 7. Insulation 8. Waterproof + Anti-root barrier 9. Drain		10. Filter barrier 11. Soil (10 centimeters) 12. Vegetation

the calculations. This solution should be seriously taken into consideration because their benefits go beyond the energetic improvements. Besides reducing the temperature indoors, it purifies the air, delays the rainwater disposal and increases the efficiency of solar panels in the roof. To achieve the established U-values there were selected the 8 insulation materials (referring to Table 39) in the calculation because of being resistant to vapor and guaranteeing a high thermal phase shift. The materials with high resistance to vapor (EPS, XPS and Polyurethane foam) do not guarantee an elevatedperformance in terms of thermal shift but they can provide the adequate insulation within 5 to 10 centimeters (gravel roof) and 6 to 12 centimeters (green roofs). Regarding the materials with high thermal phase shift they can provide the adequate insulation within 4 to 10 centimeters (gravel roof) and 5 to 11 centimeters (green roofs). The pitched roofs, very diffused in the climate zone C but present as well in the climate zones A and B are not only subject to

Table 43 Pitched roof insulation. Possible solutions- graphics: the Author

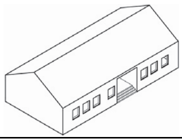
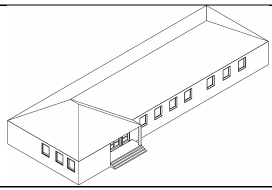
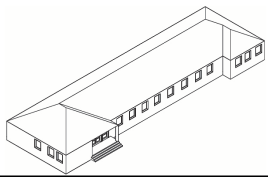
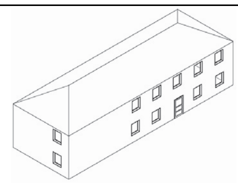
							
		Zone A	Zone B	Zone C	Zone A	Zone B	Zone C
	U'n (W/m^2°K)	**1.21**			**1.43**		
	Un (W/m^2°K)	**0,45**	**0,4**	**0,35**	**0,45**	**0,4**	**0,35**
	ΔRi (m^2°K/W)	**1,396**	**1,674**	**2,031**	**1,525**	**1,803**	**2,160**
Mineral fibre glass wool	0,030	0,042	0,050	0,061	0,046	0,054	0,065
	0,045	0,063	0,075	0,091	0,069	0,081	0,097
Mineral fiber rockwool	0,040	0,056	0,067	0,081	0,061	0,072	0,086
	0,050	0,070	0,084	0,102	0,076	0,090	0,108
Expanded polystyrene (EPS)	0,039	0,054	0,065	0,079	0,059	0,070	0,084
	0,045	0,063	0,075	0,091	0,069	0,081	0,097
Extruded polystyrene (XPS)	0,034	0,047	0,057	0,069	0,052	0,061	0,073
	0,041	0,057	0,069	0,083	0,063	0,074	0,089
Rigid polyurethane foam	0,048	0,067	0,080	0,097	0,073	0,087	0,104
	0,055	0,077	0,092	0,112	0,084	0,099	0,119
Wood fibers	0,038	0,053	0,064	0,077	0,058	0,068	0,082
	0,040	0,056	0,067	0,081	0,061	0,072	0,086
Cork	0,038	0,053	0,064	0,077	0,058	0,068	0,082
	0,050	0,070	0,084	0,102	0,076	0,090	0,108
Cellular glass	0,040	0,056	0,067	0,081	0,061	0,072	0,086
	0,050	0,070	0,084	0,102	0,076	0,090	0,108
Insulation material	**λ [W/mK]**	**Si (m)**			**Si (m)**		
New added layers		6. Vapor barrier 7. Insulation 8. Wood deck 9. Waterproof barrier			6. Vapor barrier 7. Insulation 8. Wood deck 9. Waterproof barrier 10. Air Gap ventilated		R_{in}= R_{out} = 0,1 m^2°K/W

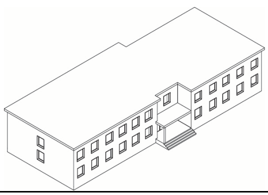
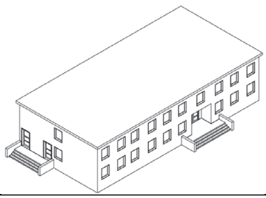
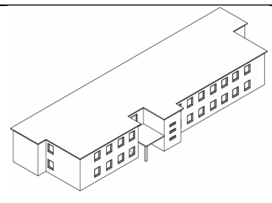
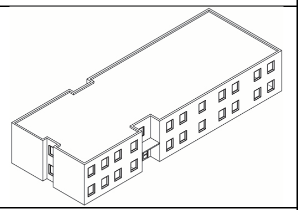
measures to improve the energetic performance. Considering that the classroom have false ceiling made in plastered-reed as previously analyzed, in both proposals it will be removed and in the lighting and ventilation strategies it will be illustrated further. To meet the established U-values there are two possible solutions: (i) insulated non-ventilated and (ii) insulated and ventilated roof. The first option preserves most of the layers that compose and obviously includes the addition of the wood deck, insulation layer and vapor and waterproof barriers, too. Like in the flat roof's proposal, also there have been spotted the same eight insulation materials because of having the best performance in vapor diffusion/thermal shift phase. The materials with high resistance to vapor (EPS, XPS and Polyurethane foam) do not guarantee an elevated performance in terms of thermal shift but they can provide the adequate insulation within 4 to 11 centimeters (non-ventilated roofs) and 5 to 12 centimeters (ventilated roofs). In case of use of materials with high thermal phase shift they can provide the adequate insulation within 4 to 9 centimeters (non-ventilated roofs) and 5 to 11 centimeters (ventilated roofs).

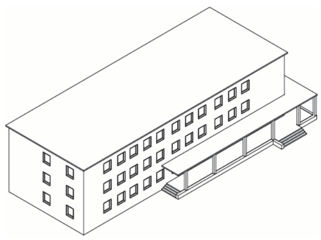
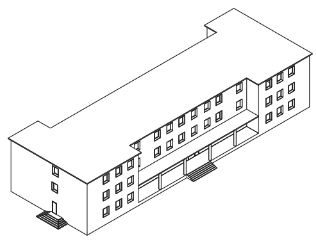
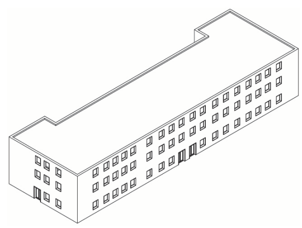
4.3.4. Thermal bridges

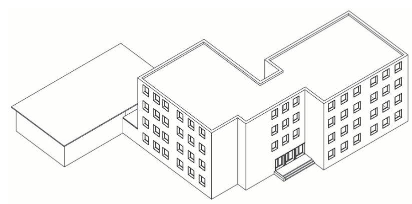
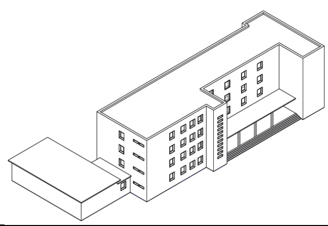
The thermal bridges in the existing school buildings represent a critic point to their refurbishment. The roof represents one of the most critical point because of its extensions to facilitate the disposal of the rainwater and when including the main entry of the schools. The flat roofs were designed to dispose the rainwater without using gutters and drain tubes to reduce cost or because of the difficulties to provide them. Consequently, it was made an offset by 50-60 centimeters of the roof's footprint. The second most critical issue are the canopies at the main entrance that have different composition and extension in the façade as well. In the eight and twelve classroom building typologies their extension is limited whereas in sixteen, eighteen and twenty-four classrooms school buildings they are extended in more than half of the façade's length. To reduce the thermal bridges the following actions are necessary: (i) insulation; (ii) demolish and insulation (iii) addition as a new volume and (iv) total replacement. The insulation of thermal bridges is referred mainly to the canopies at the main entrance less than five meters long, including waterproofing and a new finish, too. In this case, the thickness of the insulation can be limited (3-5 centimeters) or even more when in case it defines the slope to facilitate the water disposal.

Table 44 Thermal bridges in existing school buildings in Albania- graphics: the Author

4-1	6-1	8-1	6-2
			
Entrance: Roof -Stair	Entrance: Roof	Entrance: Roof	Probable presence of canopy at the entrance

8-2-A	8-2-B	12-2-A	12-2-B
			
Canopy at the entrance Roof offsett	Canopy at the entrance Roof offsett	Canopy at the entrance Roof offsett	Canopy at the entrance Roof offsett

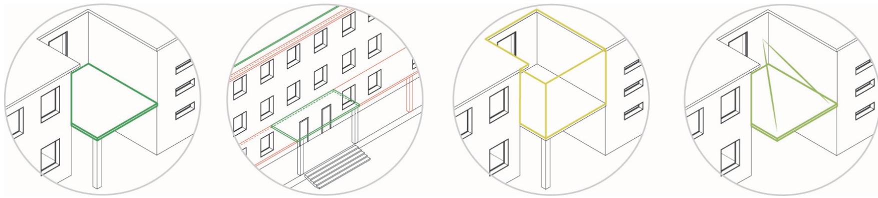
12-3	18-3-A	18-3-B
		
Canopy at the entrance Roof offsett	Canopy at the entrance Roof offsett	Probable presence of canopy at the entrance Roof offsett

16-4	24-4
	
Probable presence of canopy at the entrance	Canopy at the entrance

The demolish and insulation is recommended when the thermal bridge covers more than 40% of the façade length, referring in particular to the 12-3, 18-3-a and 24-4 school building typologies. When approaching the refurbishment part of the canopy can be demolished and preserving only the part at the entrance. The benefits will include the reduction of the thermal bridge and increase of natural lighting for the classrooms at the ground floor but there also occurs an alteration of the buildings design. Another useful method to reduce the thermal bridges is by adding volume to the existing building. By inscribing the upper part of the canopies into the building, the reduction of thermal bridges will be easier. Even in this case there is altered the building composition and there are required extra costs to make the new volume part of the building. The last solution, referred to canopies, involves their total demolish and installation of new one to integrate with insulated building envelope without creating new-thermal buildings. It is implies demolition and transportation costs.

Table 45 Possible solutions to reduce the thermal bridges in Albanian school buildings- graphics: the Author

Thermal bridge solutions



	Insulation	**Demolish and Insulation**	**Addition**	**Total replacement**
Advantages	Roof extension: – Eliminate thermal bridges with external walls. Continuity of thermal insulation contour Canopies: – Improve energetic performance of building	Roof extension: – Eliminate thermal bridges with external walls. – Continuity of thermal insulation contour Canopies: – Reduce thermal bridges with external walls – More natural lighting to classrooms	Canopies: – Reduce thermal bridges with external walls – New volume crated – Less insulation of external walls	Canopies: – Reduce thermal bridges with external walls – If in wood thermal bridges lowered and short construction time –
Disadvantages	Canopies: – Demand for waterproof and finish works	Roofs: – Eliminate thermal bridges with external walls. – Continuity of thermal insulation contour	Canopies: – Roof works-needed – Possible problems with the integration with the existing building.	Canopies: – Reduce thermal bridges with external walls – If in wood thermal bridges lowered and short construction time
Recommendations	– Only incases when it does not exceed 5 meter of length –		– Only incases when it does not involve structural complications – Possible for he two-strorey school typologies	– An wooden canopy can be built In places where there is not one

4.3.5. Windows

The openings, in particular the windows, represent an important issue to deal with in every school building refurbishment. Reminding the importance of natural lighting and ventilation for the didactic activities their properties go beyond the normal U_w value to fulfil when replaced. In the six-examples of the refurbished school buildings highlighted that the double-glazed PVC windows are becoming very frequent, even though not regulated by any law in the energetic point of view. Regarding the windows, the decree nr.319 the Council of Ministers approved in 2017 entitled

Sun screening and Ventilation strategy

Ventilation	Natural		Mecanic	
Sun Blinds position	External	Internal	External	Internal
Considerations	**Possible** Depending on the orientation, sun blinds can be fixed or mobile. They must avoid shade.	**Critic** Sun blinds should be set at a height to not to ostacle, air flow and windows' opening from inside. Adequate ventilation and suncreening is difficult. Sun blinds must avoid shade.	**Difficult** Acepptable if mecanic ventilation system includes heat recovery. Depending on the orientation, sun blinds can be fixed or mobile. Sun blinds must avoid shade	**Difficult** Acepptable if mecanic ventilation includes heat recovery. Depending on the orientation, sun blinds can be fixed or mobile. Sun blinds must avoid shade
Climate zone A	Heat loses in winter. Optimal for cooling in during spring and summer	Difficult to have simultaneously adequate ventlation and sun-screen natulal lighting during summer	Optimal indoor enviroment with lowered heat looses if heat recovery included	Optimal indoor enviroment with lowered heat looses if heat recovery included
Climate zone B	Heat loses in winter. Optimal for cooling in during spring and summer	Difficult to have simultaneously adequate ventlation and sun-screen natulal lighting during summer	Optimal indoor enviroment with lowered heat looses if heat recovery included	Optimal indoor enviroment with lowered heat looses if heat recovery included
Climate zone C	Heat loses in winter. Optimal for cooling in during spring and summer	Difficult to have simultaneously adequate ventlation and sun-screen natulal lighting during summer	Optimal indoor enviroment with lowered heat looses if heat recovery included	Optimal indoor enviroment with lowered heat looses if heat recovery included

Figure 18 Considerations sun-screening strategies and ventilation type scenarios- graphics: the Author

“Standartet e projektimit për shkollat[43]”, advices designers to replace them with new double-glazed ones whose Ug is equal to 1.2 W/m^2°K, eventually lowered to 0.8 with triple glazed windows when renovating in cold climates. The term “advice” is not followed by detailed technical specifications concerning the glass and frame requirements. Nowadays the requirements of the windows go beyond energy efficiency by including two important parameters such as the solar gain and solar shadow factor, both important because guaranteeing the indoor quality and visual comfort. In the Italian and Greek normative taken as reference, approach this two parameters differently this two factors, In Italy the ministerial decree D.M 26.06.2015

[43] [ALB] “Standard for the design of school buildings”

Figure 19. External Roller blinds (source: Ripo international)

sets the total gain value as the sum of glass and shade gain (g_{gl+sh}) for the windows in the Eastern and Western fronts passing South, whereas the Greek normative has separate values glass and the shade. When dealing with school buildings the visual comfort deriving from a good balance between natural lighting and illumination is extremely important, but the high amount of natural lighting means better environment and low power consume although there might be installed efficient lighting terminals. Recalling the typology analysis, each classroom has three windows that provide the natural lighting and ventilation so limiting to the energetic requirement may not lead to better learning environments in terms of lighting and air quality. As a first step, there will be set two possible layouts for the windows, guaranteeing better natural ventilation in relation to the best sun-screening option determined by the orientation. The layouts described in Table 46, include the Type1, frequent in the refurbishment interventions and Type2, the most diffused one. Regardless of the orientation, they perform the ventilation of the classrooms from the top in order not to create discomfort to the pupils seating nearby especially during winter, and eventual disturb the windows opening. In particular the Type 2, can also have the middle part openable without creating disturb, resulting with more air flow in hotter month of the year. The sun- screening elements are very important in “filtering” the natural light and consequently preventing the overheating of the classrooms. If the windows oriented south can be easily protected by cantilevered elements, sun-screening in the East, West and intermediate orientations is very

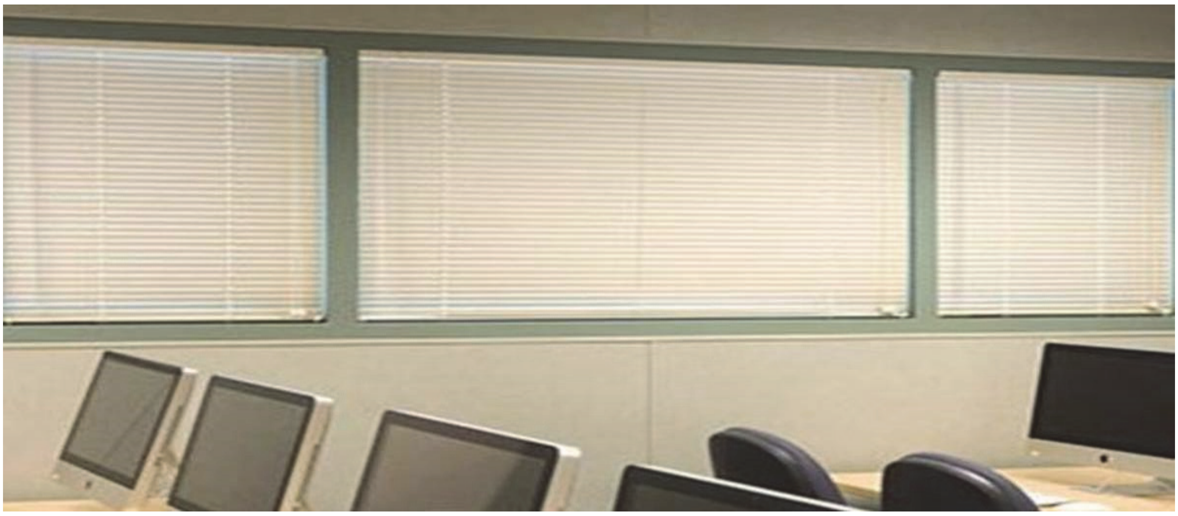
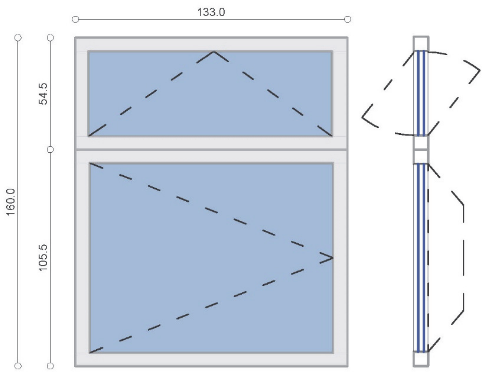
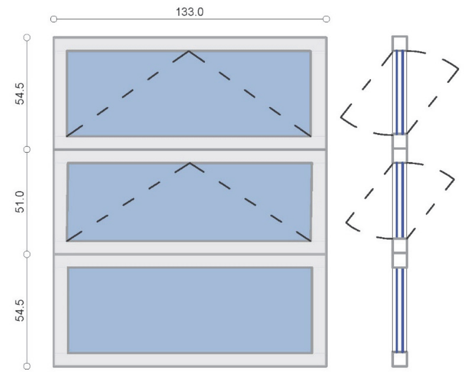
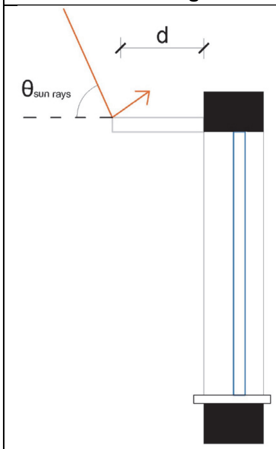
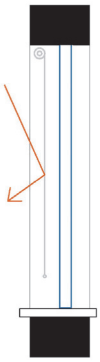
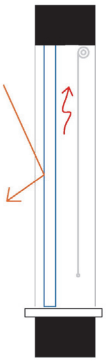
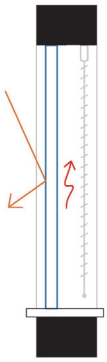


Figure 20 Internal shutters Roller blinds (source: www.zebrablinds.com)

Figure 21. Internal Roller blinds known as roman shades (source: Insolrooll)

Table 46 Window layout and sun-scrrening strategies- graphics: the author

Window layouts			
			
Type 1: **133 x160 centimeters**	**2 partitions**	**Type 2:** **133 x160 centimeters**	**3 partitions**
A_W = 2.08 m^2			
Glass	**Frame**	**Glass**	**Frame**
A_g = 1.57 m^2	**A_f =** 0.51 m^2	**A_g =** 1.42 m^2	**A_f =** 0.66 m^2
(75.5 %)	(24.5 %)	(68.2 %)	(31.8 %)
l_g = 7.34 m		**l_g** = 9.40 m	
Note: The upper part performs the ventilation, is horizontally-openable from inside or outside during didactic activity. The lower part could be openable by rotation laterally. The frame/glass ratio is low which means more natural light into the classroom.		**Note:** The upper part performs the ventilation, is horizontally-openable from inside or outside during didactic activity. For more air flow The middle partition can be openable but not during didactic activity during winter because may create discomfort to pupil sitting nearby.	
Overhang	**Roller blind (Internal)**	**Roller blind (External)**	**Shutters**
			
Material: No preference. The cantilevered element should not create thermal bridge.	**Material:** Transparent white blinds Should screen but also filter light	**Material:** Transparent white Should screen but also filter light	**Material:** Transparent white Should screen but also filter light
g_{sh} =0.9	**g_{sh} =0.3**	**g_{sh} =0.3**	**g_{sh} =0.2**
All the three types can work with this configuration	Blind distanced from window to let air flow. All the types can work in this configuration but the upper opening's angle should be at 90° to let more air flow in. The blinds may need frequent maintenance because exposed to climate agents.	The blind represents a barrier, so horizontal opening should haven an rotation angle equal to: i) 180° if opened internally ii) 90° if opened externally to let more air flow in	The blind represents a barrier, so horizontal opening should haven an rotation angle equal to: i) 180° if opened internally ii) 90° if opened externally to let more air flow in
South	**East, West and intermediate positions**		
Sun blinds position and material recommendations			

critical because shade should be avoided. So there is recommended the use of elements such as transparent roller blinds and light aluminum shutters that offer a better performance. The opening of the windows should not obstruct the operation of the blinds and vice versa. For this purpose there are four possible scenarios as specified in . For the windows oriented East, West and in intermediate orientations, the roller blinds remain a valid options even though there may emerge the necessity of frequent maintenance (externally) or necessity to open windows from the outside in case located in the Interior, valid also for the aluminum shutters. This considerations are very important because there is avoided the installation expensive of mechanic ventilation units.

After spending this part with considerations related with layout, and incorporation of sun-screening elements and heat recovery/ventilation ones, now it is time to approach the materials and their energetic properties in order to obtain the Uw values set for the climate zones of the country. The proposals will be based on double-glazed and triple-glazed windows with PVC frame and by altering the size of the gap between the two glass sheets and the glass and the properties of the glass that should fulfil the solar gain values equal to 0.75 or less. The windows in PVC are known for their properties Impermeability, lightness, low U_f values, durability, high thermal insulation and acoustic comfort and low cost but with low mechanic resistance. After spending this part with considerations related with layout, and incorporation of sun-screening elements and heat recovery/ventilation ones, now it is time to approach the materials and their energetic properties in order to obtain the Uw values set for the climate zones of the country. The proposals will be based on double-glazed and triple-glazed windows with PVC frame and by altering the size of the gap between the two glass sheets and the glass and the properties of the glass that should fulfil the solar gain values equal to 0.75 or less. The windows in PVC are known for their properties Impermeability, lightness, low U_f values, durability, high thermal insulation and acoustic comfort and low cost but with low mechanic resistance. So there will be made two proposals concerning with this frame material: (i) double-glazed; and for the triple glazed one with gap fill in Air, Argon and Krypton thermal insulation and acoustic comfort and low cost but with low mechanic resistance. After spending this part with considerations related with layout, and incorporation of sun-screening elements and heat recovery/ventilation ones, now it is time to approach the materials and their energetic properties in order to obtain the Uw values set for the climate zones of the country. The proposals will be based on double-glazed and triple-glazed windows with PVC frame and by altering the size of the gap between the two glass sheets and the glass and the properties of the glass that should fulfil the solar gain values equal to 0.75 or less.

Table 47 Double-glazed PVC-graphics: the Author

Glass type	Combination	Ug (W/m²°K)	Uw Type 1 (W/m²°K)	Uw Type 2 (W/m²°K)
No surface treatment	4-6-4 (Air)	3,30	3,21	3,13
	4-6-4 (Argon)	3,00	2,99	2,93
	4-6-4 (Krypton)	2,80	2,84	2,79
	4-9-4 (Air)	3,00	2,99	2,93
	4-9-4 (Argon)	2,80	2,84	2,79
	4-9-4 (Krypton)	2,60	2,68	2,66
	4-12-4 (Air)	2,90	2,91	2,86
	4-12-4 (Argon)	2,70	2,76	2,72
	4-12-4 (Krypton)	2,60	2,68	2,66
	4-15-4 (Air)	2,70	2,76	2,72
	4-15-4 (Argon)	2,60	2,68	2,66
	4-15-4 (Krypton)	2,60	2,68	2,66
	4-20-4 (Air)	2,70	2,76	2,72
	4-20-4 (Argon)	2,60	2,68	2,66
	4-20-4 (Krypton)	2,60	2,68	2,66
Glass with surface treatment (low-emissivity)	4-6-4 (Air)	2,70	2,85	2,81
	4-6-4 (Argon)	2,30	2,55	2,54
	4-6-4 (Krypton)	1,90	2,25	2,27
	4-9-4 (Air)	2,30	2,55	2,54
	4-9-4 (Argon)	2,00	2,32	2,34
	4-9-4 (Krypton)	1,60	2,02	2,06
	4-12-4 (Air)	1,90	2,25	2,27
	4-12-4 (Argon)	1,70	2,10	2,13
	4-12-4 (Krypton)	1,50	1,95	2,00
	4-15-4 (Air)	1,80	2,17	2,20
	4-15-4 (Argon)	1,60	2,02	2,06
	4-15-4 (Krypton)	1,60	2,02	2,06
	4-20-4 (Air)	1,80	2,17	2,20
	4-20-4 (Argon)	1,70	2,10	2,13
	4-20-4 (Krypton)	1,60	2,02	2,06
Glass with surface treatment (emissivity ≤ 0.05)	4-6-4 (Air)	2,50	2,70	2,68
	4-6-4 (Argon)	2,10	2,40	2,41
	4-6-4 (Krypton)	1,50	1,95	2,00
	4-9-4 (Air)	2,00	2,32	2,34
	4-9-4 (Argon)	1,60	2,02	2,06
	4-9-4 (Krypton)	1,30	1,79	1,86
	4-12-4 (Air)	1,70	2,10	2,13
	4-12-4 (Argon)	1,30	1,79	1,86
	4-12-4 (Krypton)	1,10	1,64	1,72
	4-15-4 (Air)	1,50	1,95	2,00
	4-15-4 (Argon)	1,20	1,72	1,79
	4-15-4 (Krypton)	1,10	1,64	1,72
	4-20-4 (Air)	1,50	1,95	2,00
	4-20-4 (Argon)	1,20	1,72	1,79
	4-20-4 (Krypton)	1,20	1,72	1,79

Note:
Ψg = 0.04 (W/m°K) for glass with no surface treatment and with surface treatment low emissivity
Ψg = 0.06 (W/m°K) for Glass with surface treatment (emissivity ≤ 0.05)

Table 48 Triple-glazed PVC-graphics: the Author

Glass type	Combination	Ug (W/m²°K)	Uw Type 1 (W/m²°K)	Uw Type 2 (W/m²°K)
No surface treatment	4-6-4-6-4 (Air)	2,30	2,46	2,45
	4-6-4-6-4 (Argon)	2,10	2,31	2,31
	4-6-4-6-4 (Krypton)	1,80	2,08	2,11
	4-9-4-9-4 (Air)	2,00	2,23	2,25
	4-9-4-9-4 (Argon)	1,90	2,16	2,18
	4-9-4-9-4 (Krypton)	1,80	2,08	2,11
	4-12-4-12-4 (Air)	1,90	2,16	2,18
	4-12-4-12-4 (Argon)	1,80	2,08	2,11
	4-12-4-12-4 (Krypton)	1,60	1,93	1,97
Glass with surface treatment (low-emissivity)	4-6-4-6-4 (Air)	1,80	2,17	2,20
	4-6-4-6-4 (Argon)	1,50	1,95	2,00
	4-6-4-6-4 (Krypton)	1,10	1,64	1,72
	4-9-4-9-4 (Air)	1,40	1,87	1,93
	4-9-4-9-4 (Argon)	1,20	1,72	1,79
	4-9-4-9-4 (Krypton)	0,90	1,49	1,59
	4-12-4-12-4 (Air)	1,20	1,72	1,79
	4-12-4-12-4 (Argon)	1,00	1,57	1,65
	4-12-4-12-4 (Krypton)	0,80	1,42	1,52
Glass with surface treatment (emissivity ≤ 0.05)	4-6-4-6-4 (Air)	1,60	2,02	2,06
	4-6-4-6-4 (Argon)	1,30	1,79	1,86
	4-6-4-6-4 (Krypton)	0,90	1,49	1,59
	4-9-4-9-4 (Air)	1,20	1,72	1,79
	4-9-4-9-4 (Argon)	0,90	1,49	1,59
	4-9-4-9-4 (Krypton)	0,70	1,34	1,45
	4-12-4-12-4 (Air)	1,00	1,57	1,65
	4-12-4-12-4 (Argon)	0,80	1,42	1,52
	4-12-4-12-4 (Krypton)	0,50	1,19	1,31

Note:
Ψg = 0.04 (W/m°K) for glass with no surface treatment and with surface treatment low emissivity
Ψg = 0.06 (W/m°K) for Glass with surface treatment (emissivity ≤ 0.05)

The windows in PVC are known for their properties Impermeability, lightness, low U_f values, durability, high thermal insulation and acoustic comfort and low cost but with low mechanic resistance. So there will be made two proposals concerning with this frame material: (i) double-glazed; and for the triple glazed one with gap fill in Air, Argon and Krypton. The calculations of the U_w value for each possible combination will be done according on Equation 2 and listed in resistance. So there will be made two proposals concerning with this frame material: (i) double-glazed; and for the triple glazed one with gap fill in Air, Argon and Krypton thermal insulation and acoustic comfort and low cost but with low mechanic resistance. After spending this part with considerations related with layout, and incorporation of sun-screening elements and heat recovery/ventilation ones, now it is time to approach the materials and their energetic properties in order to obtain the Uw values set for the climate zones of the country. The aim of these several calculation is to comprehend how to achieve the established U-values in Table 34 through several options and by giving technical specifications, too. Referring to resistance. So there will be made two proposals concerning with this frame material: (i) double-glazed; and for the triple glazed one with gap fill in Air, Argon and Krypton thermal insulation and acoustic comfort and low cost but with low mechanic resistance. After spending this part with considerations related with layout, and incorporation of sun-screening elements and heat recovery/ventilation ones, now it is time to approach the materials and their energetic properties in order to obtain the Uw values set for the climate zones of the country., there emerges very interesting scenarios. In case of glass with no surface treatment with air gap equal to 6 mm and filled argon and krypton there can be archived good values for the climatic zone A and B. With a gap thickness of 9, 12 and 15 there can be obtained the desired values for the three zones. Obviously, when the glass quality is high (low emissivity) there is no necessity to have Argon and Krypton filling the gap because the established values can be obtained even with the Air fill in between the glass sheets. Although being not very diffused in the market those will gap thickness equal to 20 mm, they were posed as a probable solution in case there should be taken as a possible solution in any future refurbishment intervention. Referring to the decree nr.319 the Council of Ministers, the "proposed" value of Ug equal to 1.2 ($W/m^2°K$) can be achieved with glass with very low emissivity, likely with Argon and Krypton gas fill.

The second proposal for the new types of windows, the triple glazed ones was also taken into account even though they are not very present in the country. Aware that this technology will hardly be implemented, even though their performance is very high compared to double glazed ones it was elaborated to comprehend the possible combination and hot to obtain the other "proposed" value of Ug equal to 0.8 ($W/m^2°K$) with triple glazed ones. As can be seen from the final values are clearly lower than the established values for the climate zone C. Considering that the cost for this windows is higher than the double-glazed ones, they may reveal in school buildings typologies from 4 to 8 classrooms but hardly in the bigger ones unless there will be approved a strict building code.

4.4. Indoor Environmental quality

Approaching school building renovation in an energy efficiency perspective rather than an opportunity to create healthy learning spaces is not worthy for the cause. An nZEB school building, relies on intelligent devices to control illumination and air quality at the adequate levels also for a matter of energy consumption. The aspects that will be discussed in this part are concerned with the control of such parameters such as lighting (natural and artificial), ventilation (cooling), heating (terminals to be used and recovery).

4.4.1. IEQ Control

The normative in power for the design of the new school buildings has established the air change rates that should be fulfilled when activities occur in classrooms and in other facilities within the school building as described in Table 49. The indoor quality in the majority of the cases is related to the air quality that must be constantly monitored in order to avoid the high concentration of CO_2 and other polluting substances, affecting negatively the productivity and attention of the pupils. As illustrated in Figure 22, this kind of instruments are necessary to alert the teacher/pupils when the air inside the classrooms is not the best. In case of

Table 49 Indoor parameters recommended values in the Albanian normative, decree nr.319/2017

	Indoor termperature T_{in} (°C)		Relative humidity (%)	Fresh Air Supply	Air change rate (h^{-1})	Noise level dB(A)	Air speed m/s
	Winter	Summer					
Classrooms	22	26	35-60%	8 (L/s*person)	6	35-40	0.15
Auditorium	22	26	35-60%	8-10 (L/s*person)	12	30-35	0.15
Laboratory	22	26	-	10 (L/s*person)	10	40	0.13-0.15
Reading Room	20	25	55% +/-5%	8 (L/s*person)	-	45	0.07-0.15
Office	22	26	55% +/- 10%	8 (L/s*person)	6	45	0.07-0.15
Library	22	26	45-50%	8 (L/s*person)	-	40	0.13
Locker room	24	-	-	2.5 (L/s*m2)	10	55	0.15
Corridor, stairs	20	27	-	0.5 (L/s*m2)	4	50)	0.15
Stockroom	18	-	-	-	4	55	0.15
Technical rooms	16	-	-	-	-	55	0.15
Bar, restaurants	21-23	23-26	20-30% / 55-60%	10 (L/s*person)	12	50	0.13-0.15
Gym	20-22	25-26	30-70%	8 (L/s*person)	6	45	0.12-0.15
Pools	26	30	50-60%	-	4-6	45	0.13
Dormitory	20	25	50%	15 l/s/ dhome	4	30	0.15
WC, Shower	24	-	-	2.5 (L/s*m2)	6-10	55	0.15
Shops	22	26	50%	1-1.5 (L/s*m2)	-	47-56	0.015-0.2
Museums	20	25	55% +/-5%	10 (L/s*person)	-	40-50	0.13
Kitchens	20-23	28-30	-	508-762 l/s/m2	12	55	0.15-0.25

presence of mechanic ventilation units they can easily be integrated to them in order to immediately perform the air change in the classroom but when the air change is expected to occur by natural ventilation the windows should be opened immediately.

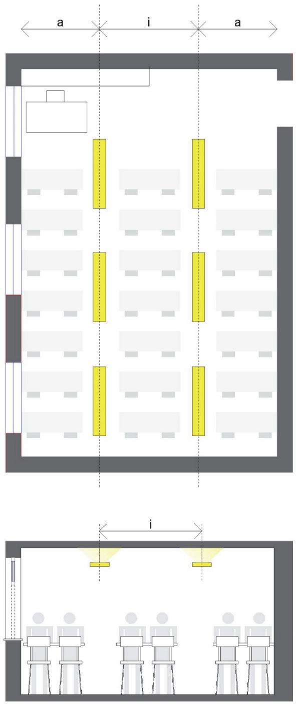
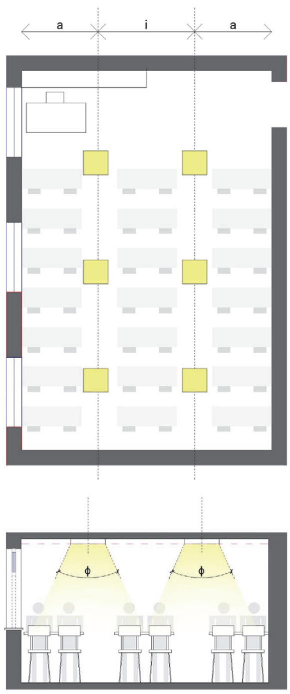
Figure 22. Example of IEQ meter - source: https://graywolfsensing.com/iaq/

4.4.2. Illumination

In the Albanian context, as long as didactic activity is split in two rounds (morning and afternoon), the illumination of the classrooms is extremely important. Indeed in the critic cases analyzed, the illumination of the classrooms was far from being decent in terms of efficiency of the lighting fixtures and uniform distribution of the illumination in the classrooms. Despite the installation of LED lamps, well-known for the energy savings, not that high attention was registered in order to guarantee the appropriate LUX that according to the normative in power should be equal to 500. The reduction of the power consumes cannot prevail towards the adequate illumination because it also affects the performance of the users. As illustrated in Figure 23, the illumination of the classrooms is not treated with the adequate attention. The strategy to improve the illumination in the classrooms will occur by considering: (i) fixture type; (ii) Configuration; (iii) luminance; and (iv) energy consume. Considering the dimensions of the classrooms, the most suitable illuminations schemes (see Table 50) are the linear and punctual fixtures. The linear fixtures are very advantageous for the classrooms for the low cycle because they

Figure 23. Illumination in a classroom and corridor in the municipality of Kamza- source: the Author

Table 50 Possible illumination configurations: Linear (left) and punctual (right) - graphics: the Author

	
Linear indirect Optimal in classroom of the low-cycle because it provides a diffused light in the classroom. It should not lowered more than 50 centimeters from the ceiling. Can be used in the corridors but not in storey limited with pitched roof	**Square-based direct** The most suitable if taken into consideration for the class height and also possible to integrate in gypsum ceiling (1-storey or upper floors) in school building with pitched roof.

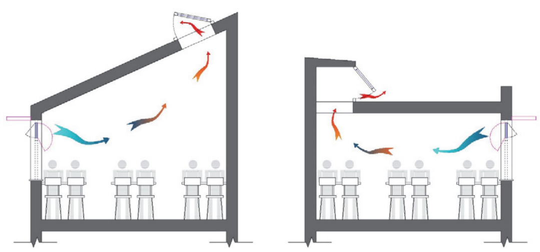
do not emit the light directly to classroom but a diffused one after being reflected in the ceiling. The punctual configuration, includes the use of square-shaped fixtures that include a semi-transparent glass in order filter the light flux into the classrooms.

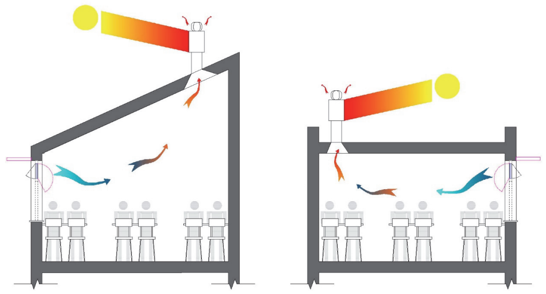
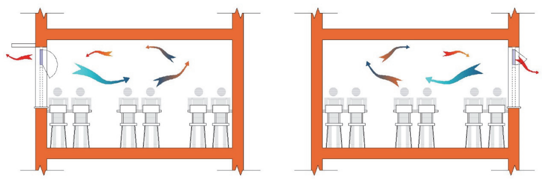
Both configurations imply an alignment in two parallel lines where the size of the lighting fixtures should be proportioned in order to reach the value of 500 lux classrooms and laboratories). In terms of energy consume the lamps must be all LED 3000 K (white) and 20 W. and with an illuminance expressed in Lux per square meter over 100.

4.4.3. Ventilation

The layout of the school buildings expects the natural ventilation of classrooms to occur from the windows, a one-sided one. Considering the morphology, in the existing school buildings there are possible other types of natural ventilation and the integration of mechanic ventilation units, too. The natural ventilation is largely implemented in nZEB refurbished schools because it provides air-change without requiring additional consume of energy. Considering the country's climate, the natural ventilation is recommended because heating is not the main problem. The possible integration of mechanic ventilation units, besides resulting with an increase the consume of energy, is more advantageous when including the heat recovery option suitable for cold climates and resulting with the reduction of heat loses. In order to provide a wide range of solutions by listing the respective advantages and disadvantages, in

Table 51 Natural ventilation schemes during didactic activity- graphics: the Author

Type of natural ventilation	Scheme	Type of natural ventilation
Cross-ventilation pitched roofs Window Types 1, 2 or 3 can be used but the fresh entering in the upper part. If the opening is from inside there should be provided protection from rain even if the window is oriented East, West and intermediate orientations with sun-screening elements placed outside **Advantage:** Natural lighting – ventilation **Disadvantage:** Impossible during rain and snow. **Suitable for:** Climate zone A and zone B		**Cross-ventilation flat roofs** Window Types 1, 2 or 3 can be used but the fresh entering in the upper part. If the opening is from inside there should be provided protection from rain even if the window is oriented East, West and intermediate orientations with sun-screening elements placed outside **Advantage:** Natural lighting – ventilation **Disadvantage:** Increase of costs in the roof. **Suitable for:** Climate zone A and zone B

Cross-ventilation pitched roofs- Solar chimney Window Types 1, 2 or 3 can be used but the fresh entering in the upper part. Provides constant ventilation of the classrooms by consuming zero energy. **Advantage:** Constant ventilation Zero energy consumed **Disadvantage:** Only when sunny **Suitable for:** Climate zone A, B and C		**Cross-ventilation flat roofs- Solar chimney** Window Types 1, 2 or 3 can be used but the fresh entering in the upper part. Provides constant ventilation of the classrooms by consuming zero energy. **Advantage:** Constant ventilation Zero energy consumed **Disadvantage:** Only when sunny **Suitable for:** Climate zone A, B and C
One-sided ventilation-Opening from inside Window Types 1, 2 or 3 can be used but the fresh entering in the upper part. Suitable in every season, but If the angle of the opening is from inside is > 90°very there should be provided protection from rain even if the window is oriented East, West and intermediate orientations with sun-screening elements placed outside **Advantage:** Constant ventilation Zero energy consumed **Disadvantage:** Problem with the position of sun-screening elements **Suitable for:** Climate zone A, B and C		**One-sided ventilation-Opening from outside** Window Types 1, 2 or 3 can be used but the fresh entering in the upper part. Suitable in every season, but If the opening angle inside is equal to 90°very **Advantage:** Constant ventilation Zero energy consumed **Disadvantage:** Problem with the position of sun-screening elements **Suitable for:** Climate zone A, B and C
		
Implementation		

and Table 52, there are illustrated all the possible configurations related to the implementation of natural and mechanic ventilation schemes. Starting with the cross-ventilation, not performed in any of the critical cases and renovated ones, is technically possible but for the 1-storey high school buildings and the upper floors of the 2, 3 and 4-storey high ones, regardless of the capacity. This type of ventilation can be performed by positioning in the roof: (i) sky domes and (ii) solar chimneys. Each option has it benefits and limitations but they

Equation 4. Airflow calculation

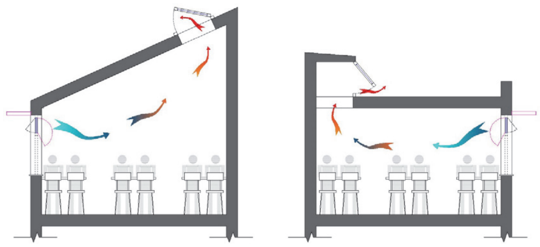
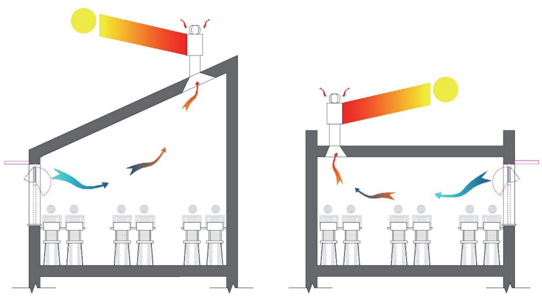
$$\dot{V} = A \times \bar{v} \quad \left[\frac{m^3}{s}\right]$$

$\dot{V}$ – Air flow rate [m^3/s]
$\bar{v}$ – Air flow speed = 0.15 [m/s]
A – Opening area [m^2]

n – Number of air changes volume per hour [h^{-1}]

$$A=\frac{n \times V}{\bar{v}} \quad [m^2] \quad \rightarrow \quad A=\frac{6\ h^{-1} \times 120\ m^3}{0.15\ \frac{m}{s}}=1.33\ m^2$$

Table 51 Natural ventilation schemes during didactic activity- graphics: the Author

Type of natural ventilation	Scheme	Type of natural ventilation
Cross-ventilation pitched roofs Window Types 1, 2 or 3 can be used but the fresh entering in the upper part. If the opening is from inside there should be provided protection from rain even if the window is oriented East, West and intermediate orientations with sun-screening elements placed outside **Advantage:** Natural lighting – ventilation **Disadvantage:** Impossible during rain and snow. **Suitable for:** Climate zone A and zone B		**Cross-ventilation flat roofs** Window Types 1, 2 or 3 can be used but the fresh entering in the upper part. If the opening is from inside there should be provided protection from rain even if the window is oriented East, West and intermediate orientations with sun-screening elements placed outside **Advantage:** Natural lighting – ventilation **Disadvantage:** Increase of costs in the roof. **Suitable for:** Climate zone A and zone B
Cross-ventilation pitched roofs- Solar chimney Window Types 1, 2 or 3 can be used but the fresh entering in the upper part. Provides constant ventilation of the classrooms by consuming zero energy. **Advantage:** Constant ventilation Zero energy consumed **Disadvantage:** Only when sunny **Suitable for:** Climate zone A, B and C		**Cross-ventilation flat roofs- Solar chimney** Window Types 1, 2 or 3 can be used but the fresh entering in the upper part. Provides constant ventilation of the classrooms by consuming zero energy. **Advantage:** Constant ventilation Zero energy consumed **Disadvantage:** Only when sunny **Suitable for:** Climate zone A, B and C

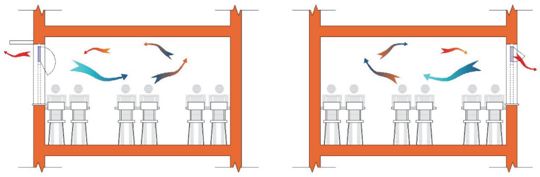
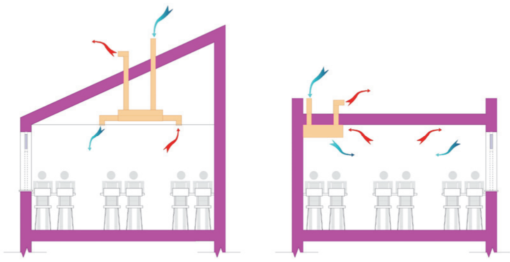
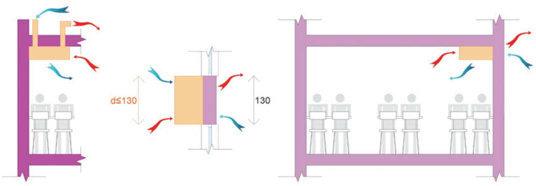
One-sided ventilation- Opening from inside Window Types 1, 2 or 3 can be used but the fresh entering in the upper part. Suitable in every season, but If the angle of the opening is from inside is > 90°very there should be provided protection from rain even if the window is oriented East, West and intermediate orientations with sun-screening elements placed outside **Advantage:** Constant ventilation Zero energy consumed **Disadvantage:** Problem with the position of sun-screening elements **Suitable for:** Climate zone A, B and C		**One-sided ventilation- Opening from outside** Window Types 1, 2 or 3 can be used but the fresh entering in the upper part. Suitable in every season, but If the opening angle inside is equal to 90°very **Advantage:** Constant ventilation Zero energy consumed **Disadvantage:** Problem with the position of sun-screening elements **Suitable for:** Climate zone A, B and C
		
Implementation		

Table 52 Mechanic ventilation schemes during didactic activity- graphics: the Author

	Scheme	
Pitched roofs - Buildings/ upper floors The height is a big advantage to be exploited for the ceiling ventilation unit. There can eventually integrated with a gypsum ceiling and with the lighting system. Can be used for heating and cooling. **Advantage:** Ventilation, heating cooling **Disadvantage:** Increase of the energy consume **Suitable for:** All climate zones but very advantageous in climate zone C for height recovery		**Flat roofs - Buildings/ upper floors** Unlike pitched roofs, it can be placed at the bottom of the class. It can represent a problem because its dimensions may hurdle the lighting of the desks near it **Advantage:** Ventilation **Disadvantage:** Increase of costs in the roof. **Suitable for:** Climate zone A and zone B

Flat roofs - Buildings/ upper floors		Intermediate floors
It should be of limited dimensions because the wall between the windows does not exceed the 130 centimeters. It can represent a problem because its dimensions may hurdle the lighting of the desks near it. **Advantage:** Ventilation **Disadvantage:** Increase of costs in the roof. **Suitable for:** Climate zone A and zone B		It should be of limited dimensions because the wall between the windows does not exceed the 130 centimeters. It can represent a problem because its dimensions may hurdle the lighting of the desks near it. **Advantage:** Constant ventilation Zero energy consumed **Disadvantage:** Only when sunny **Suitable for:** All climate zones but very advantageous in climate zone C for height recovery
		
Implementation		

for all the climatic zones because during spring and summer they are constantly operative because being constantly hit by the sun that activates the motion to remove the exhausted air from the classrooms. Their only limit is that they do not work under bad weather conditions but as an alternative the one-sided ventilation can be easily performed. Referring to the decree nr.319 the Council of Ministers, when the natural ventilation is performed from the windows, the openings should be 5 % of total area, which is about two square meters (maximum area of classroom is 40 square meters). Indeed, the two layouts proposed in , fulfil perfectly this condition because referring results of Equation 4, the total area of the upper openings exceed this result[44]. This result highlights that the ventilation from windows can easily occur from the windows but in the energy balance of energy-efficient building (also NZEBs) ventilation loses should be limited as much as possible as much as possible. During winter heat recovery can be very positive for a certain typology and in particular cold climate context. The school building located in the climate zone C and with big capacity may benefit from the air change and heat recovery, done by apposite units placed on the top edges of the classrooms. Basically, mechanic

[44] Upper Openings Type 1 and 2 = 1.33 x 0.545 = 0.725 m^2 x 3 → the total area 2.13 m^2 >1.33

ventilation includes this benefit but in the same time it requires energy that eventually can be supplied by and by PV panels. The position of these units on the top corners should be careful because it may create problems to the illumination of the classrooms because by disturbing the light emitted from the lighting fixtures. One storey high school buildings and top floor with pitched roof can achieve a better integration of these units with the lighting fixtures because of the internal height. Anyways it not meant that this kind of ventilation can be used fulltime over a year or not considered at all. Considering the climate it can be used in the cold moths and turned off during spring and summer when natural ventilation can aerate the classroom without consuming power.

4.4.4. Heating terminals

As analyzed previously, the heating scheme of the classrooms was decentralized by using individual wood stoves placed in the entry of the classroom, connected to the chimney in order to exhale the smoke. Although in most of the critic cases electric heating units are used during cold months, in remote rural areas wood stoves are still used. In the recent renovation cases, there were installed heating plants with radiators used as terminals, representing a total shift in comparison with the past approach, but followed with a uniform and efficient heating of the classrooms. Considering that heating is becoming mandatory in new and refurbished buildings interventions, other possible solutions should be considered.

Table 53 considerations for the heating plant- graphics: the Author

	Type of heating therminal	
	Water	**Air**
		
Unit	Radiator	Ceiling based unit
Position	Floor	Ceiling
	Near windows	In pitched
Renewable energy	• Ground-based heat-pump • Pellet	• Solar panels • Air-air heat pump (for each classroom)
Advantages	• Does not obstacolate window opening • Does not obstacolate interior lighting • Reduced Thickness	• Can provide cooling • Can provide heat recovery

Disadvantages	• Only for winter	• High energy demand unless it is covered from renewables • Continuous maintenance • Indvidual heat pumps per classroom • Limited position option.

Figure 24 Radiators in the renovated school "Nene Tereza" in Laknas, Kamza Municipality- source the Author

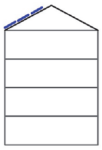
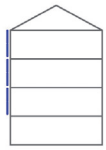
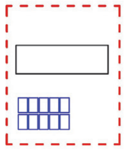
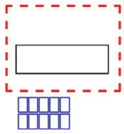
In Table 53, there is made a comparison between this two possible solutions highlights that the heating system, using radiators as terminals can reveal with more benefits than the air-unit based system. The dimension of the classroom and in particular their height drives us more convicted to this solution even though it can be exploited only in winter. If renewable sources such ground-based heat-pumps will be used the process will be more environmentally friendly and efficient than other energetic resources.

4.5. Renewable resources exploit for energy and power production

As common for a refurbished nZEB school building, the exploit of renewable resources is important to produce (fulfil) its energy and power demand because it should rely the least possible from the grid. Recalling that in Albania, the national grid transmits power generated by 93 % from renewable sources (hydropower), means that the starting point is different and more promising to reach an important goal that the EU aims to reach in 2050 which is the decarbonization of the building stock.

Table 54 Consideration for possible exploit of solar panels- graphics: the Author

Possible integration/location

Roof		Façade	In relation with Site	
			Inside	Outside
				
Type PV panels and collectors **Best Orientation:** The longest front South. **Location:** Optimal location to exploit the energy even in cold months. In urban areas: Not convenivent if nearby buildings shade them. **Convient for :** Installed to fulfil power demand from mechanic ventilation in high capacity school buildings. Power demand for illumination Domestic hot water	**Type** PV panels and collectors **Best Orientation:** The longest front South. **Location:** Optimal location to exploit the energy even in cold months. In urban areas: Not convenivent if nearby buildings shade them. **Convient for :** Installed to fulfil power demand from mechanic ventilation in high capacity school buildings. Power demand for illumination Domestic hot water	**Type** PV panels **Best Orientation:** The longest front South, East or West **Location:** Optimal location to exploit the energy even in cold months. In urban areas: Not convenivent if nearby buildings shade them. **Convient for :** Installed to fulfil power demand from mechanic ventilation in high capacity school buildings. Power demand for illumination	**Type** PV panels **Best Orientation:** South, the more area the more energy. **Location:** Optimal for rural areas Set proper distance between pannels **Convient for :** Installed to fulfil power demand from mechanic ventilation in high capacity school buildings. Power demand for illumination	**Type** PV panels **Best Orientation:** South, the more area the more energy. **Location:** Optimal for rural areas Set proper distance between pannels **Convient for :** Installed to fulfil power demand from mechanic ventilation in high capacity school buildings. Power demand for illumination

4.5.1. Solar energy: recommendations

The solar energy can be exploited to produce electricity and hot domestic water. Referring to , where it illustrated the annual solar exposure values and sunshine's hours in the national territory, there are very promising values that can be integrated in the refurbished school buildings. In most of the territory, the annual solar exposure ranges between 1.185 to 1.690 kilowatt-hours per square meters, with an average of 1.500 kilowatt-hours per square meters (AEA, 2012, pp. 6-8). Solar energy is not very exploited nowadays but its potential is very high in case of eventual integration of mechanic ventilation units and to supply the power demand for illumination although there might be used efficient fixtures. Before deciding to install solar panels or collectors, although there might be a large potential to exploit it is necessary to perform simulations during the design phase. Referring to Table 54, it illustrates a series of scenarios where the installation of solar panels and collectors can occur without making consideration in relation to building orientation and context is located. As emerged in the survey results, the North-South orientation has been spotted in about 25 percent of the critic cases, meaning that the panels can hardly be installed and exposed south in the roof or facade.

4.5.1. Geothermal energy

This resource has a high potential to reduce cost for heating and domestic hot water DHW. Referring to Figure 28, in the country there are present two tectonic fractures that represent the important potentials to exploit this resource. By using this resource in two possible options vertical probes or horizontal serpentine there is provided heating without performing without emitting CO_2 emissions and constantly available without being affected by weather conditions.

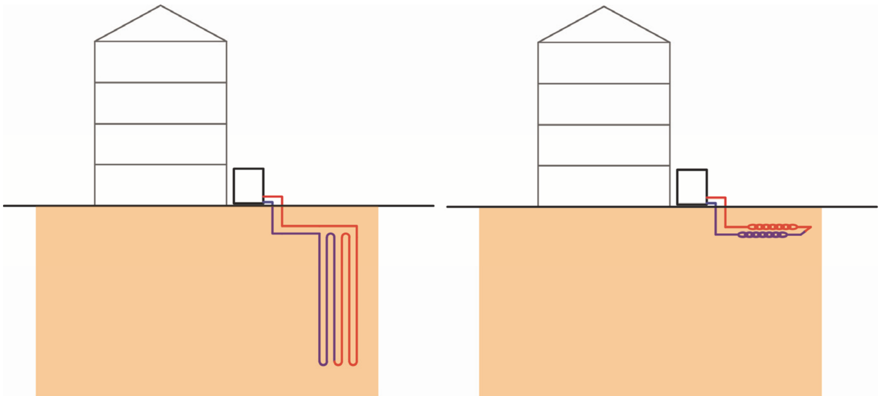


Figure 25. Ground based heat pump: vertical probes and serpentine- graphics: the Author

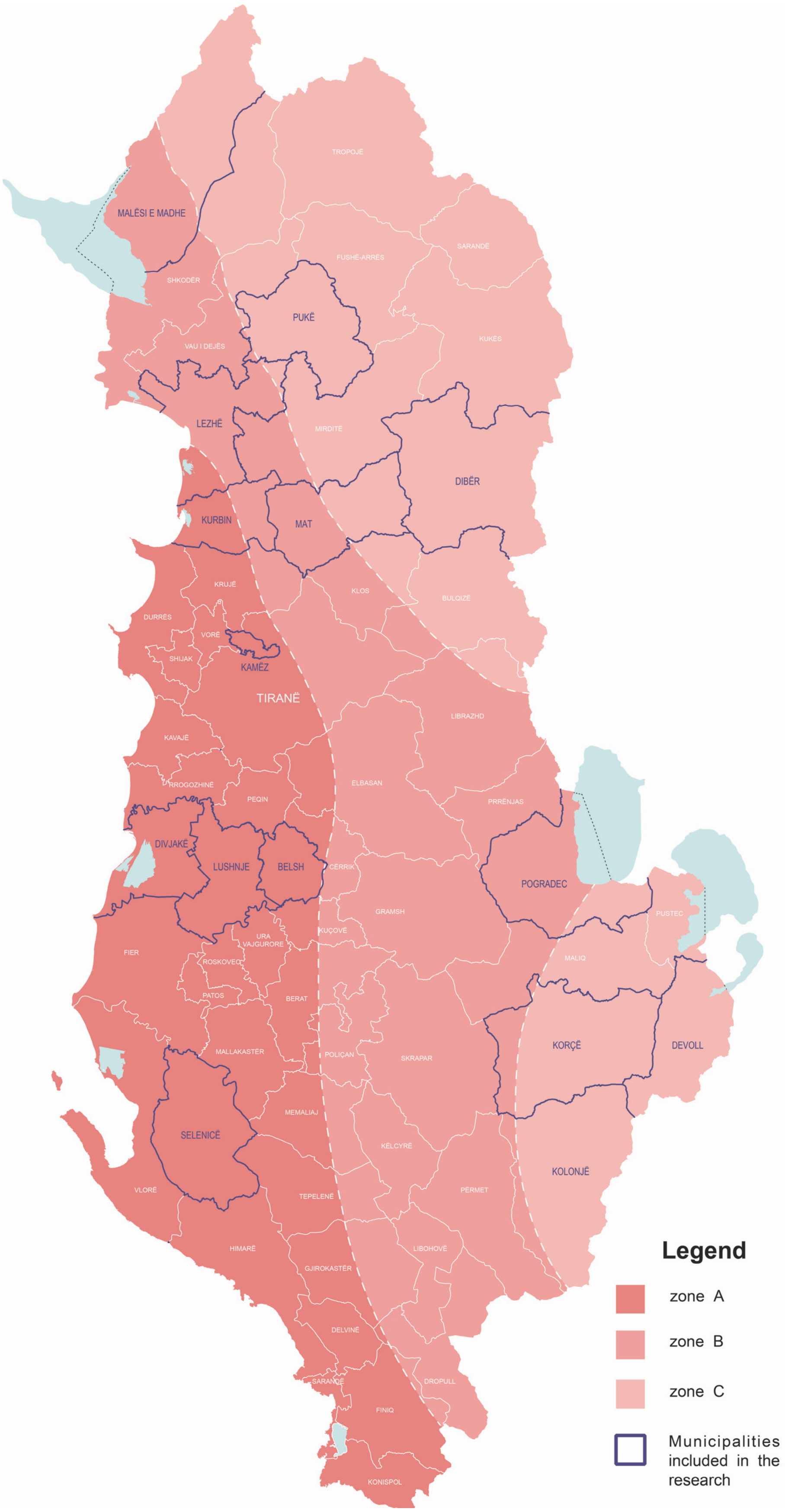


Figure 26 . Climatic map zone of the country with the 15 municipalities included in the research- source map (Novikova, et al., 2016)-graphics: the Author

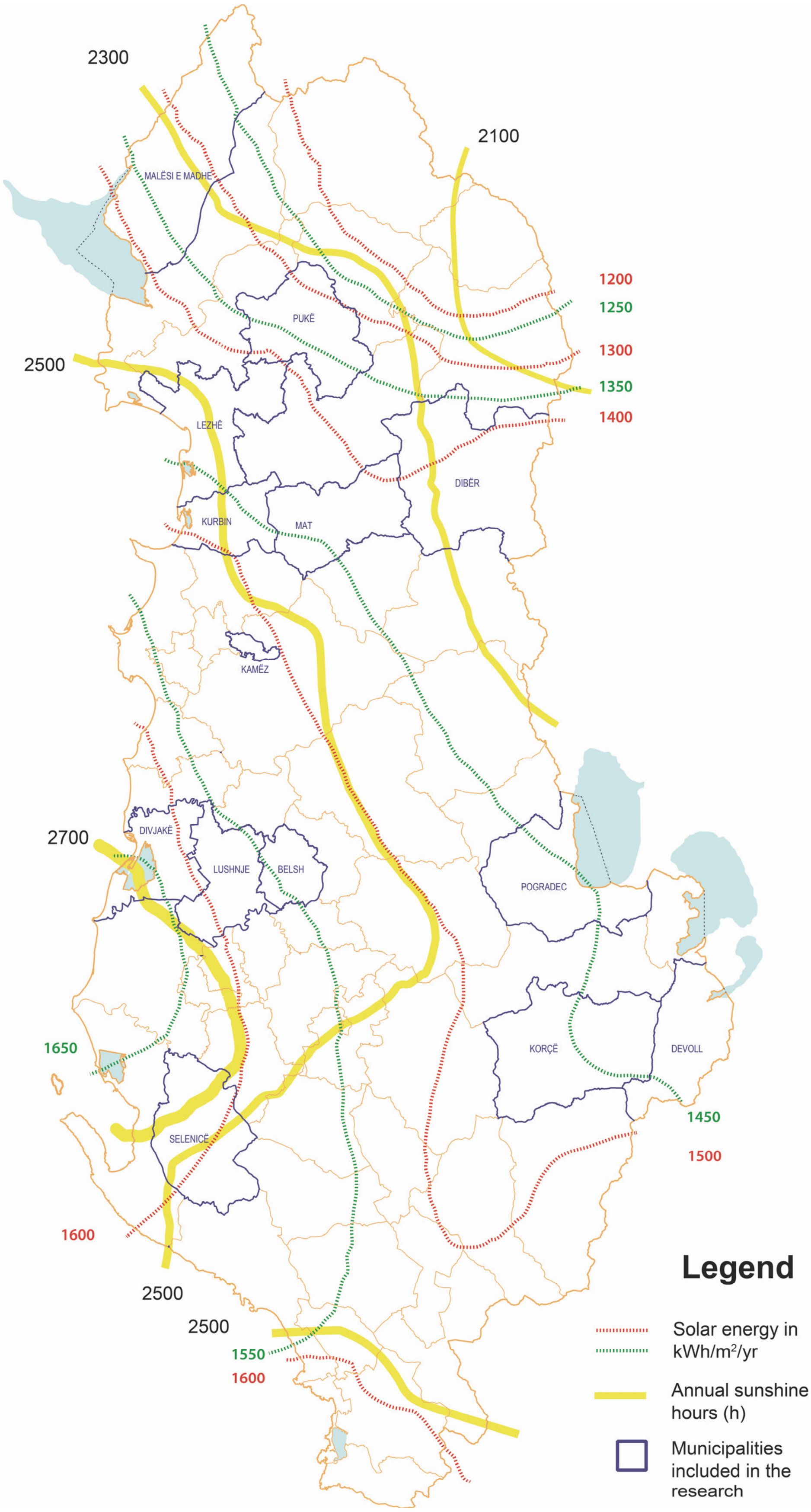


Figure 27. Solar energy potential in the 15 municipalities included in the research - source map (AEA, 2012); graphics: the Author

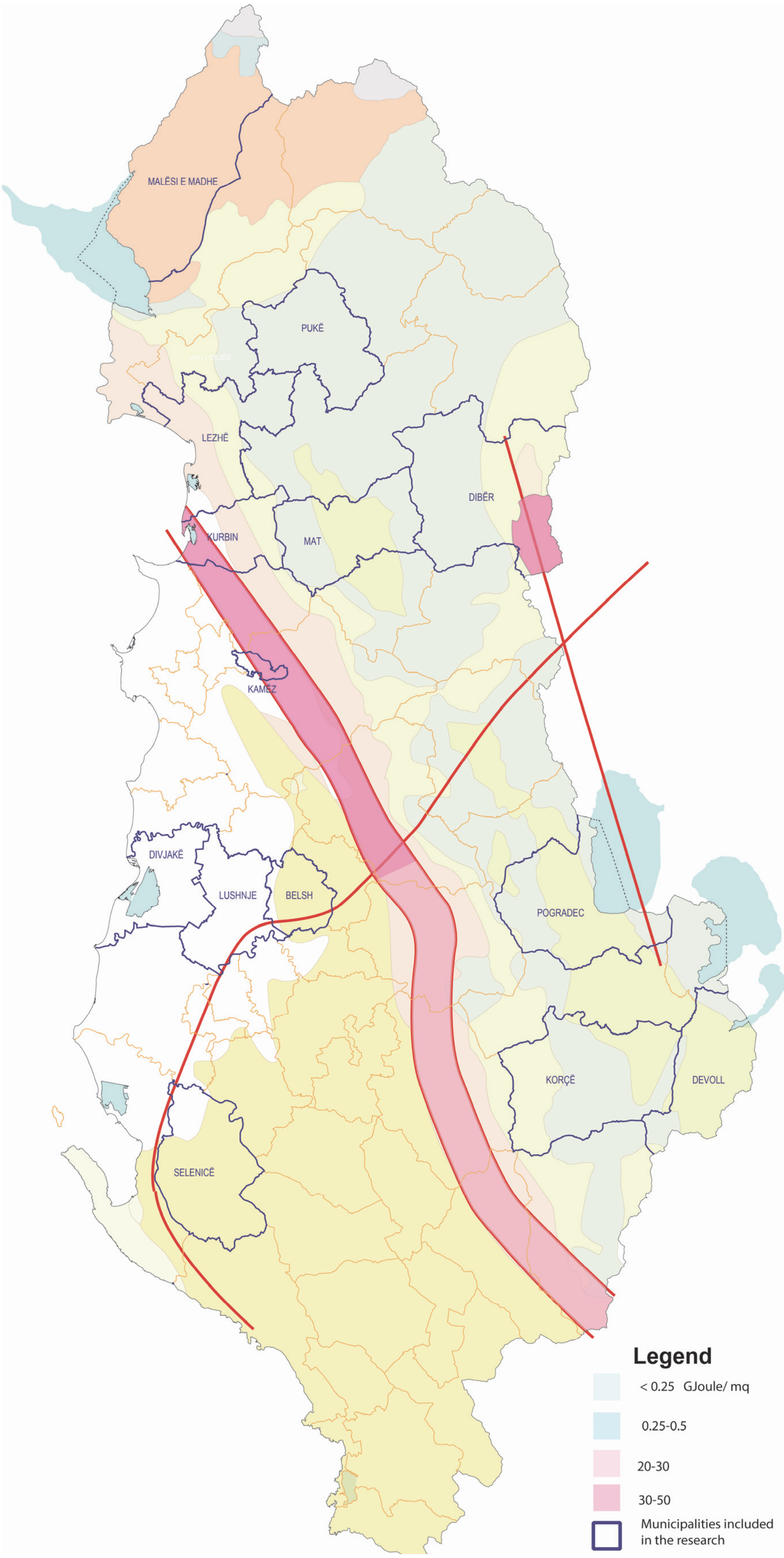


Figure 28 Geothermal potential in the 15 municipalities included in the research - source map (AEA, 2012); -graphics: the Author

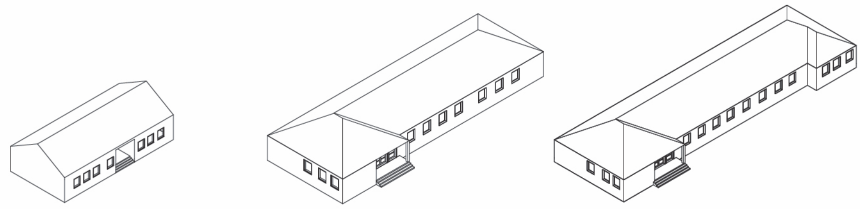
4.6. Recommendations based on Typology and Climate

The analysis of the various school building typologies, an important pillar of the research, aimed the elaboration of refurbishment proposals also for those school buildings with low number of students that hardly can gain the attention as the high capacity ones obtain as defined in law nr.69/2012. After proposing the interventions for the refurbishment of school buildings, now it is time to elaborate the list of interventions to implement in specific typologies in relation to the climate context they are part of. Despite the will to transform into nZEB all the school buildings, it very difficult to find the financial resources that can lead to this result, very evident between those located in the rural and urban areas. For this purpose the recommendation of the interventions will be made for the one, two, three and four-storey building typologies in order to reach a good level of energy performance without excluding the possibility to become nZEB in a near future. When proposing the interventions in relation to the climate context, they will be used the words: (i) Mandatory – to reach/fulfil established value and parameters independently the focus intervention on the specific building component; (ii) Recommended – Interventions to be made during the initial phase of refurbishment because of being followed with advantages to the performance of the building but it must reach/fulfil established value and parameters; (iii) Optional- Interventions that are not regulated by any value to be reached/fulfilled but can impact positively in the energetic performance.

4.6.1. One storey high school building typologies

The 4-1, 6-1 and 8-1 school building typologies, very diffused in the rural areas and likely to undergo to refurbishment sooner than school buildings referring to law nr.69/2012. The nZEB label can be possible but expensive in the same time. Interventions such as mechanic ventilation systems can be neglected unless there is provided the necessary financial efforts. By being one storey high they can implement also efficient shading strategies such as trees that may be more difficult to integrate in the other school building typologies. In all these typologies the ceiling made with reinforced-reed plaster must be removed in order to perform the illumination configuration with the squared lighting fixtures. The location can represent an advantage for the installation of ground-based photovoltaic panels in particular in climate zone A, but even in the other climate zones it is not excluded.

Table 55 Recommendations for one-storey high school buildings in the three climate zones- graphics: the Author

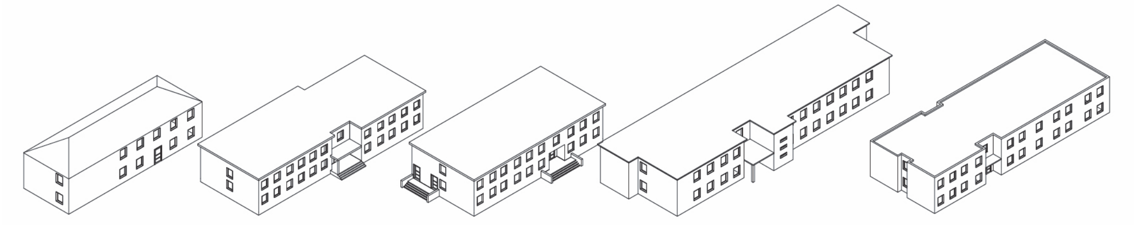


4-1 6-1 8-1

	Climate zone A	Climate zone B	Climate zone C
Building envelope			
Walls	Mandatory: Respect the established U-value. Consider phase shift properties of the insulation materials to retard heat wave.	Mandatory: Respect the established U-value.	Mandatory: Respect the established U-value. Consider phase shift properties of the insulation materials to retard cold wave.
Ground floor slab	Recommended: The two proposal elaborated to meat the U-values can be made in another period unless there is adverted: • Serious structural problems • Problems with humidity		Recommended: Considering the harsh weather conditions during winter it could be at least performed option on
Roof	Mandatory: Respect the established U-value. Consider phase shift properties of the insulation materials to retard heat wave. Reinforced-reed ceiling to be totally removed and replace with gypsym-tiled ceiling in order to facilitate the installation of the light fixtures.		
Thermal bridges	Optional: Insulation of the entry and the bottom of the roof	Optional: The colum at the entry represent a critic point. So, there can be made: • Insulation of the bottom of the roof • Addition, it can be enclosed with a glass façade acting as “greenhouse during” cold moths and openable during the hot ones Inclose it to the building	
Windows and doors	Mandatory. Respect the established U-value. Depending on the type of ventilation can be decide the opening of the window with the type and position of the screening elements Possibility to use deciduous trees for screening in summer whears in winter they permit the rays to pass through.		
IEQ			
Control	Mandatory for every classroom		
Lighting and illumination	Recommended: Gypsym-tyle ceiling but there should be expected openings in case cross-ventilation will be implemented. Linear illumination difficult to be performed because of sloped roof.		
Ventilation	Recommended: All types of natural ventilation can be performed but there can be exploited: • One-sided-during winter or bad weather conditions • Cross ventilation with solar chimney spring and summer		
	Optional: Mechanic ventilation optional. But expect intergration of renwable systems to produce power. If implemented should include heat recovery		
Heating	Reccomended: Radiator		
	Optional: Ceiling units If implemented should include. heat recovery But expect intergration of renwable systems to produce power.		
Renewable Energy			
Solar Energy	Recommended: High Potential for production of Power and DHW for all the year	Optional: Potential for production of Power and DHW for all the year	Optional: But weather conditions may be a distavantage
Geothermal energy	Highly recommended for heating		

4.6.2. Two storey school buildings building typologies

Table 56 Recommendations for two-storey high school buildings in the three climate zones



6-2 8-2-A 8-2-B 12-2-A 12-2-B

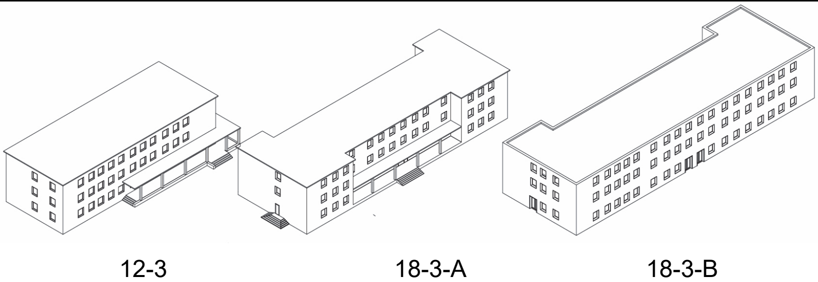
	Climate zone A	Climate zone B	Climate zone C
Building envelope			
Walls	Mandatory: Respect the established U-value. Consider phase shift properties of the insulation materials to retard heat wave.	Mandatory: Respect the established U-value.	Mandatory: Respect the established U-value. Consider phase shift properties of the insulation materials to retard cold wave.
Ground floor slab	Recommended: At least the intervention one, eventhough height of classrooms will be lowered. Deep renovation if encountered: • Serious structural problems. • Problems with humidity/		
Roof	Mandatory: Respect the established U-value for flat and eventual pitched rood Consider phase shift properties of the insulation materials to retard heat wave. In case of pitched roof: Reinforced-reed ceiling to be totally removed and replace with gypsym-tiled ceiling in order to facilitate the installation of the light fixtures.		
Thermal bridges	Recommended: insulation of the canopies at the entry.		
		Optional: Addition can be performed in all the typologies expect the 6-2.	
Windows and doors	Mandatory: Respect the established U-value. Depending on the type of ventilation can be decide the opening		
IEQ			
Control	Mandatory for every classroom		
Lighting and illumination	Recommended: Puntual lighting recommended. Linear lighting in low cycle classrooms		
Ventilation	Recommended: One-sided-during winter or bad weather conditions in all the storeys Cross ventilation with solar chimney only in upper storeys		
	Optional: Mechanic ventilation - But expect intergration of renwable systems to produce power. If implemented should include heat recovery. Consider possible disturb in the illumation of classroom.		
Heating	Recommended: Radiator		
	Optional: Ceiling units, only in uppers storeys with pitched roos If implemented should include. heat recovery But expect intergration of renwable systems to produce power.		
Renewable Energy			
Solar Energy	Recommended: High Potential for production of Power and DHW for all the year	Recommended: Potential for production of Power and DHW for all the year	Optional: But weather conditions may be a distavantage
Geothermal energy	Highly recommended for heating		

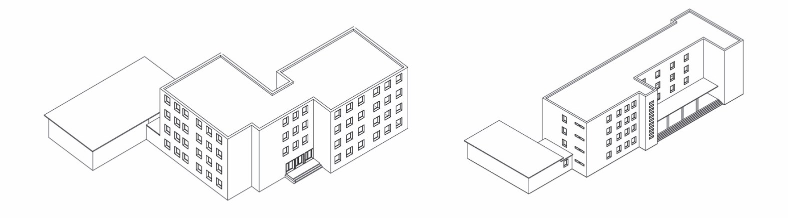
These typologies mostly encountered in the rural areas require more interventions because of the capacity is bigger compared with one-storey high ones. Their transformation into NZEBs should be posed as a possible target with interventions eventually to perform in different time periods. The building envelope and heating system using ground-based heat pumps can be performed at the initial phase whereas the installation of the PV panels to produce power can be installed in a next phase on the roof or eventually ground-based. In case of integration of mechanic ventilation units, besides guaranteeing heat recovery to reduce heat loses, their demand should be considered when calculating the power to generate from PV panels since the design phase. In case the site area is not enough to position PV panels on the ground and within the buildings footprint, it can be produced at least nearby.

4.6.3. Three and four storey school buildings building typologies

The refurbishment of this typologies should aim the nZEB label independently from the costs. Besides the high energy performance they should provide the proper indoor comfort within the classrooms. The installation of PV panels should be expected in case of mechanic ventilation and to compensate the power demand for lighting, no matter how efficient devices will be installed considering also the split of the didactic activity in two rounds. The ventilation of classrooms is recommended to occur naturally but in case it is chosen to perform a mechanic ventilation, it can be alternated in specific periods of the year: for example in the zone C it can be performed the natural ventilation in spring and summer (maximum in autumn) whereas during winter it can be performed the mechanic ventilation that includes recovery to limit heat loses. This measure might reveal two expensive with a long pay-back time but important is to give the best indoor comfort from September to June. The use of geothermal energy is the highly recommended for the production of DHW and heating during cold months, too. In case the site area is not enough to position PV panels on the ground and within the buildings footprint, it can be produced at least nearby.

Table 57 Recommendations for three and four-storey high school buildings in the three climate zones- graphics: the Author





16-4 24-4

	Climate zone A	Climate zone B	Climate zone C
Building envelope			
Walls	Mandatory: Respect the established U-value. Consider phase shift properties of the insulation materials to retard heat wave.	Mandatory: Respect the established U-value.	Mandatory: Respect the established U-value. Consider phase shift properties of the insulation materials to retard cold wave.
Ground floor slab	Mandatory: At least the intervention one, eventhough height of classrooms will be lowered. Recommended: Deep renovation if encountered: • Serious structural problems. • Problems with humidity/		
Roof	Mandatory: Respect the established U-value for flat and eventual pitched rood Consider phase shift properties of the insulation materials to retard heat wave. In case of pitched roof: Reinforced-reed ceiling to be totally removed and replace with gypsym-tiled ceiling in order to facilitate the installation of the light fixtures.		
Thermal bridges	Recommended: • Insulation of the canopies at the entry if they are less than 5 meters long • Demolishon and insulation of canopies at the entry.		
Windows and doors	Mandatory: Respect the established U-value. Depending on the type of ventilation can be decide the opening		
IEQ			
Control	Mandatory for every classroom		
Lighting and illumination	Recommended: • Puntual lighting recommended. • Linear lighting in low cycle classrooms.		
Ventilation	Recommended: • One-sided-during winter or bad weather conditions in all the storeys. • Cross ventilation with solar chimney only in upper storeys.		
	Optional: Mechanic ventilation - But expect intergration of renwable systems to produce power. If implemented should include heat recovery. Consider possible disturb in the illumation of classroom.		
Heating	Recommended: Radiator		
	Optional: Ceiling units, only in uppers storeys with pitched roos If implemented should include. heat recovery But expect intergration of renwable systems to produce power.		
Renewable Energy			
Solar Energy	Recommended: High Potential for production of Power and DHW for all the year	Recommended: Potential for production of Power and DHW for all the year	Optional: But weather conditions may be a distavantage
Geothermal energy	Highly recommended for heating and DHW		

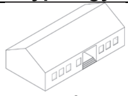
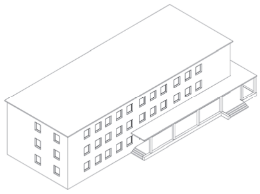
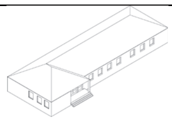
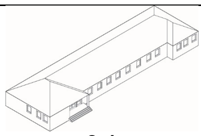
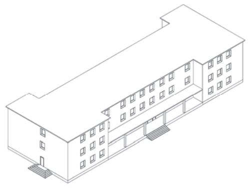
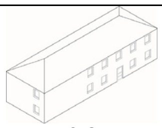
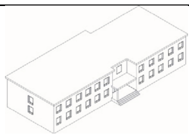
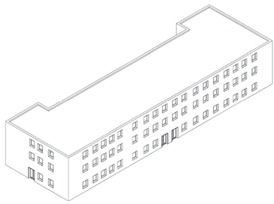
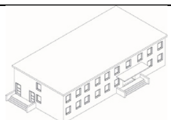
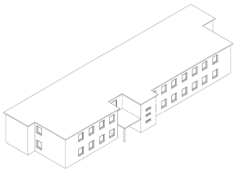
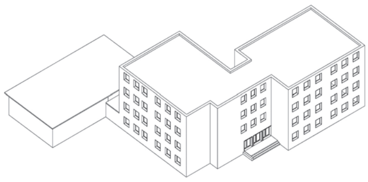
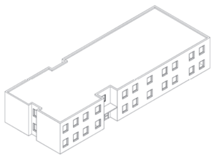
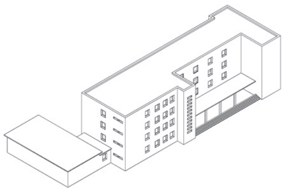
4.7. Increase of the capacity. Benefits of CLT building system.

Table 58. Building envelope U values for new buildings- graphics: the Author

	Italy **Decreeo Ministeriale 26.06.2015:** *“Applicazione delle metodologie di calcolo delle prestazioni energetiche e definizione delle prescrizioni e dei requisiti minimi degli edifici”*						Greece **Law nr.2367 of 12.07.2017:** *“Έγκριση Κανονισμού Ενεργειακής Απόδοσης Κτι- ρίων”. Οι υπουργοι οικονομικων - περιβαλλοντοσ και ενεργειασ*				Albania Valori possibili		
Climate Zone	A	B	C	D	E	F	A	B	C	D	A	B	C
HDD	**<600**	**601-900**	**901-1400**	**1401-2100**	**2100-3000**	**>3000**	**<1000**	**1000-1500**	**1500-2000**	**>2000**	**<1500**	**1501-2500**	**> 2500**
Building envelope U values (W/m² K)													
Roof	0.35	0.35	0.33	0.26	0.22	0.20	0.45	0.40	0.35	0.30	**0.40**	**0.4**	**0.35**
Floor in contact with the ground	0.44	0.44	0.38	0.29	0.26	0.24	1.10	0.80	0.65	0.60	**0.6**	**0.5**	**0.40**
Walls	0.43	0.43	0.34	0.29	0.26	0.24	0.55	0.45	0.40	0.35	**0.40**	**0.35**	**0.4**
Windows Doors	3.00	3.00	2.20	1.80	1.40	1.10	2.80	2.60	2.40	2.20	**2.80**	**2.70**	**2.60**

The split of the didactic activity in two rounds (morning and afternoon) is the one of the critical issues of existing school buildings. Now that lower cycle and lower secondary cycles are part of nine-year system after being part of seven-year system and for more than 50 years of the eight-year one, the capacity shortage should not be postponed anymore. Recalling (Baker, 2009), refurbishment is more convenient in terms of emissions than demolishing and building a new one, in the short-medium term. Before describing the building system, it is important to investigate two important aspects such as: (i) desired capacity and (ii) free space available. Basically each year of the nine-year cycle has about 100-120 students that are divided in four classrooms named with letters A, B, C and D, meaning that a school building in the urban areas should contain at most 36 classrooms or at least 27 classrooms in urban areas with lower population. The second constraint, is the area available which very important. Indeed, an existing school building of 18 classrooms should double their capacity to become a 36-classrooms ones, without counting the necessary spaces for laboratories, hygienic services etc. A 24-classrooms school has to increase by12 whereas a 16-classroom by 20. In rural areas the highest capacity encountered is generally the 12-classrooms ones and if they have to reach 36 it implies their triplication. Based on the this considerations the school-yard should be so vast to host one or even two replicas of an typology to match with the demand even though it becomes even more difficult if urban distances from the property or street should be respected.

Table 59 Possible transformation of existing school building typologies with new proposed capacities graphics: the Author

Typology	New capacity option		Typology
 4-1	●	●●● ●●●●	 12-3
 6-1	● ●●		
 8-1	● ●●	●●● ●●●●	 18-3-A
 6-2	● ●●		
 8-2A	● ●●	●●● ●●●●	 18-3-B
 8-2B	● ●●		
 12-2-A	●● ●●●	●●● ●●●●	 16-4
 12-2-B	●● ●●●	●●● ●●●●	 24-4

● **9-classrooms-** Each year 1 clasroom or each year.

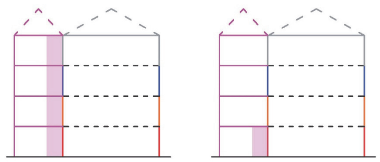
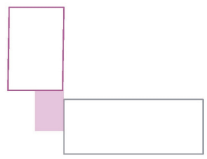
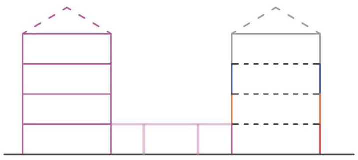
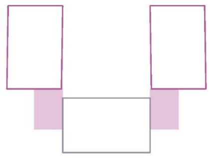
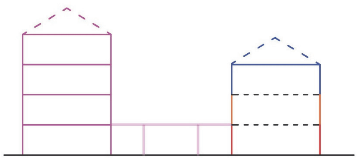
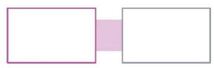
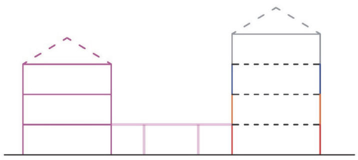
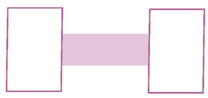
●● **18-classrooms-** Each year 2 clasrooms or each year.

●●● **27-classrooms-** Each year 3 clasrooms or each year.

●●●● **36-classrooms-** Each year 4 clasrooms or each year (potential option if area available).

By having as a main goal to perform the didactic activity during morning and aware of the limits of the area, the increase of capacity should be preceded by a reconfiguration of the classrooms for each year included in the lower cycle and the lower secondary one. Instead of four classrooms for each year, there can be at least three, so the maximum that of the capacity can reach 27 classrooms.

Table 60. Possible combinations of the CLT additions with the existing school buildings- graphics: the Author

Agregation type	Elevation Agregation	Plan aggregation
Lateral* **(stair or canopy)**		
New building - **Same capacity** **		
New building - **Higher capacity** **		
New building - **Lower capacity** **		

* In case of full-height stairs core, connection has to be made in the shortest parts of both buildings.

** The distance between buildings should be at leat the height of the tallest building, regardless it the existing or the new one. Connection through canopy.

This standard can serve as maximum in the rural areas but there should also be set a new standard for the low and medium-capacity typologies as well. The minimal capacity standard should be set at 9-classrooms school buildings and the medium capacity should be set at 18-classrooms. The transformation of the analyzed typologies can occur only if there is enough free space is available, otherwise there can occur the refurbishment of the existing building with the interventions previously described. Even though not analyzed in details, the increase of the capacity in some Albanian schools, particularly in the capital Tirana, have been performed to soften the problem with capacity. The new additions have been built with concrete structure that for the 3- storey addition it requires minimum three to four months only the structure. After analyzing the possible transformation it is now time to deal with the building system to be adopted which is the cross-laminated timber panels, known with the abbreviation as CLT. This building system in unknown in Albania, but considering its benefits it should be taken into consideration. As seen in two examples (Italy and Germany) of the project “Renew school”, the CLT panels where integrated to the existing building resulting with the achievements of the nZEB label. In terms of additions, this building system represents many advantages. The first advantages is time of construction, deriving from being a dry construction system, taking up 60% less time compared with the traditional building systems and by being a sustainable resource. The importance of this resource is not limited in the easier achievement of very low U-values for external walls and roofs but by reducing the use of energy and water during the construction. As specified in Table 60 the connection between the existing buildings with the new CLT addition is recommended to occur by using a stair core or through canopies by respecting the requested distances. As long as additions can be considered as new buildings, there are established U-values for the new buildings (see Table 58), stricter than those for the refurbishment in Table 34, referring to the Italian and Greek normative for the new building values. In comparison with the guidelines used for the refurbishment in this case there with change only the approach of building envelope (expect windows and thermal bridges) and the ventilation schemes for natural and mechanic ventilation whereas the other aspect can be used as valid considerations even in this case.

4.7.1. Building envelope: Walls, Ground floors and Roof

Table 61 CLT Wall combinations-graphics: the Author

		Zone A	Zone B	Zone C
U'n(W/m^2°K)		**0.63**		
Un(W/m^2°K)		**0,40**	**0,35**	**0,30**
ΔRi (m^2°K/W)		**0,913**	**1,270**	**1,746**
Mineral fibre glass wool	0,030	0,027	0,038	0,052
	0,045	0,041	0,057	0,079
Mineral fiber rockwool	0,040	0,037	0,051	0,070
	0,050	0,046	0,063	0,087
Expanded polystyrene (EPS)	0,039	0,036	0,050	0,068
	0,045	0,041	0,057	0,079
Extruded polystyrene (XPS)	0,034	0,031	0,043	0,059
	0,041	0,037	0,052	0,072
Rigid polyurethane foam	0,048	0,044	0,061	0,084
	0,055	0,050	0,070	0,096
Wood fibers	0,038	0,035	0,048	0,066
	0,040	0,037	0,051	0,070
Cork	0,038	0,035	0,048	0,066
	0,050	0,046	0,063	0,087
Insulation material	**λ [W/mK]**	**Si (m)**		
Layers (included in the calculation of the U'n)		1. Plaster 2. Insulation Vapor barrier		3. CLT panel 5 layer 179 centimeters 4. Air gap 5.x2 gypsum board

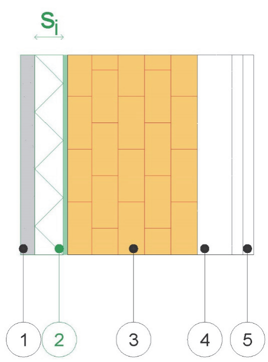


Table 62 Ground Floor insulation- graphics: the Author

		Zone A	Zone B	Zone C
	U'n(W/m²°K)	**1.33**		
	Un(W/m²°K)	**0,60**	**0,5**	**0,40**
	ΔRi (m²°K/W)	**0,915**	**1,248**	**1,748**
Cellular glass	0,040	0,037	0,050	0,070
	0,050	0,046	0,062	0,087
XPS	0,034	0,031	0,042	0,059
	0,041	0,038	0,051	0,072
EPS	0,039	0,036	0,049	0,068
	0,045	0,041	0,056	0,079
Insulation material	**λ [W/mK]**	**Si (m)**		
Layers (included in the calculation of the U'n)		1. Tiles 2. Concrete substrate 3. Waterproof barrier 4. Thermal insulation	5. Vapor barrier 6. Concrete 7. Igloo 30 centimeters 8. Concrete	

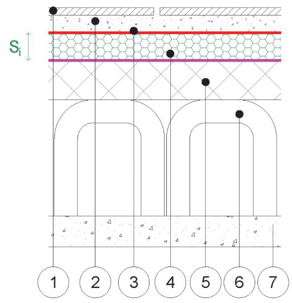
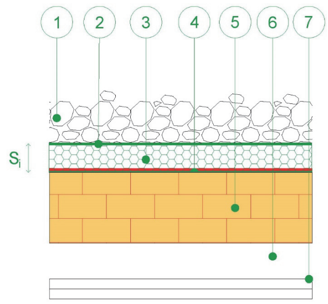


Table 63 Flat roof insulation. Possible scenarios- graphics: the Author

		Zone A	Zone B	Zone C
	U'n(W/m²°K)	**1,25**		
	Un(W/m²°K)	**0,45**	**0,40**	**0,35**
	ΔRi (m²°K/W)	**1,422**	**1,700**	**2,057**
Mineral fibre glass wool	0,030	0,043	0,051	0,062
	0,045	0,064	0,077	0,093
Mineral fiber rockwool	0,040	0,057	0,068	0,082
	0,050	0,071	0,085	0,103
Expanded polystyrene (EPS)	0,039	0,055	0,066	0,080
	0,045	0,064	0,077	0,093
Extruded polystyrene (XPS)	0,034	0,048	0,058	0,070
	0,041	0,058	0,070	0,084
Rigid polyurethane foam	0,048	0,068	0,082	0,099
	0,055	0,078	0,094	0,113
Wood fibers	0,038	0,054	0,065	0,078
	0,040	0,057	0,068	0,082
Cork	0,038	0,054	0,065	0,078
	0,050	0,071	0,085	0,103
Insulation material	**λ [W/mK]**	**Si (m)**		
	New added layers	6. Vapor barrier 7. Insulation 8. Waterproof barrier 9. Gravel		



5. Case study. School building in the municipality of Kamza.

Figure 29 Aerial view of the school - source: asig.al

Table 64 General data of the school- source: the Author

	Main building	Addition	Total
Current Capacity	19-classrooms	11- classrooms	30 classrooms
Orientation	NE-SW	NW-SE	
Area (m^2)	1553,44	709,91	2263,35
Volume (m^3)	4721,02	2131,93	6852,95
Heated Area (m^2)	1480,70	659,94	2140,64
(V) Heated Volume (m^3)	4507,79	1996,40	6504,19
(S) Building Envelope (m^2)	2692,72	1215,26	3907,99
S/V (m-1)			0.600

The “Hillary Clinton” school located in the municipality of Kamza, about 10 km from Tirana, is our case study. Ranked as critic case in Table 21, its problematics go beyond the urgent necessity for refurbishment and better indoor environment for students and teachers. It is made of two main blocks, the main building and a volume in the backyard serving as addition. Classified as an 18-3-A typology in Table 12, it actually contains 19 classrooms from the 18 expected, because one laboratory was “converted” into a classroom due to the high demand. The addition containing 11-

Figure 30 View from the garden- source: the Author

Figure 31 View from the backyard: connection between the main building and the addition – source: the author

classrooms, somehow improved the capacity but it did not solve it because the actual demand is for 44 classrooms. Consequently, the didactic activity is divided in two rounds morning and afternoon. Technological problems apart, the building does not have a suitable location because of the presence of the main road of the

Figure 32 Degradation in the interior and exterior of the school – source: the Author

main road of the municipality that is very unpleasant during rush hours by generating noise and polluting the air too. The last renovation interventions performed more than 10 years ago focused on; (i) floor finishes; (ii) double-glazed windows; (iii) PVC downpipes and; (iv) installation of radiators. Unfortunately these interventions have not brought the expected improvements in terms of better indoor comfort. Precisely, because of the poor quality of the downpipes and waterproofing finishes of the canopy (main building), have facilitated the propagation of the humidity in the classrooms, corridor and entry of the ground floors of the main building, whereas in the addition these problems are not adverted. Although being installed, the radiators are not operative during winter because there has not been installed yet the heating plant to run them.

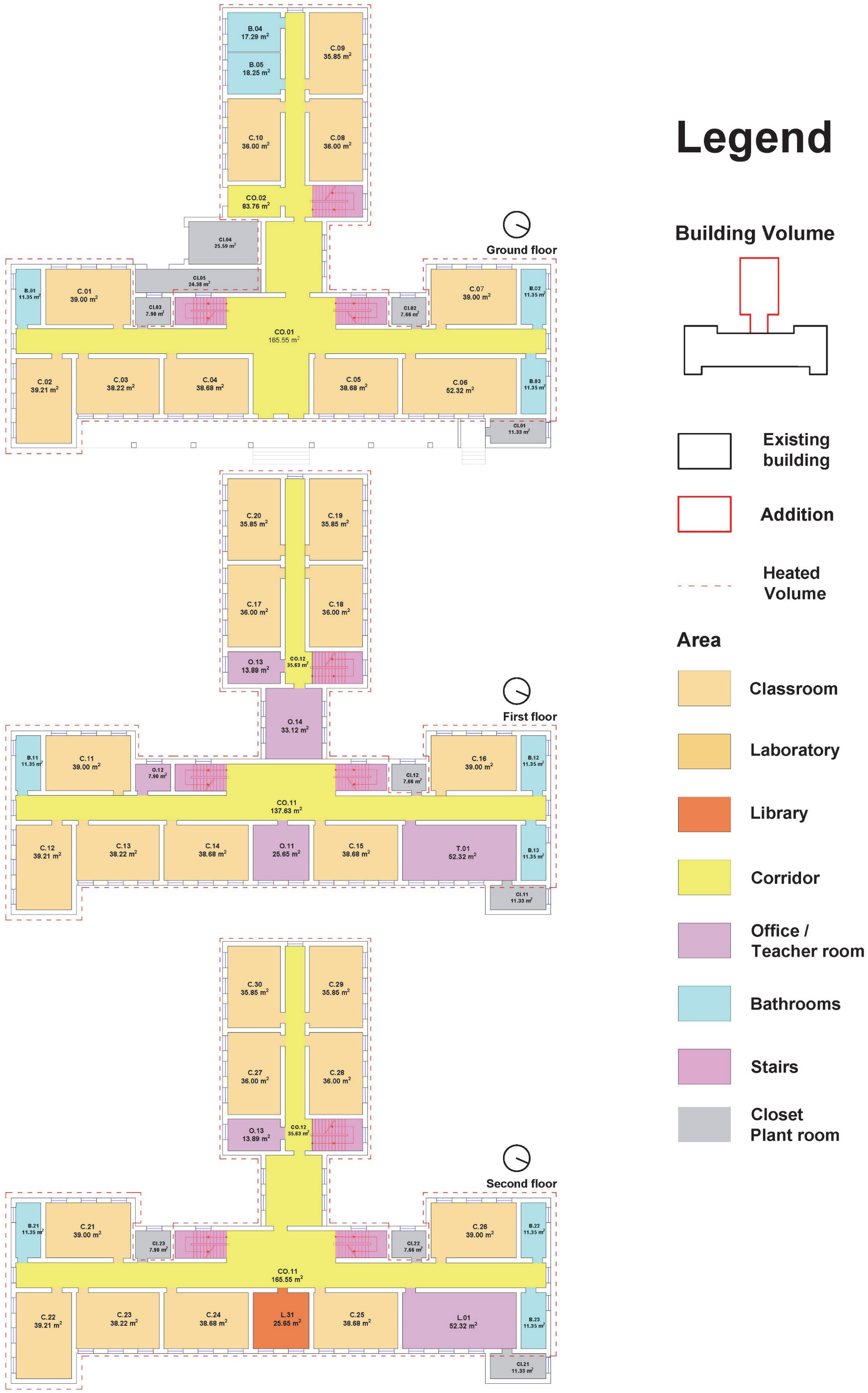


Figure 33 Plans of the existing school building (main+ addition) – graphics: the Author

Not less irrelevant is also the poor illumination of the classrooms and corridors. Each classroom has four lamps but they do not guarantee the right levels of illumination and the same issue is persisting. From this general overview, the situation is more than critic is because the building has problems go beyond energy efficiency and so, it becomes a good case to test the effectiveness of the proposed measure in terms of building envelope, lighting, indoor comfort etc. Besides being close the main street of the municipality, the plot of the area represents two important advantages. First, it is vast enough to increment the capacity of the school in relation to the demand for classrooms and the urban limits that the current normative establishes for new school buildings. Second, the exposition to South permits the installation of Photovoltaic panels to produce electricity for the school buildings itself. On these bases and once the building's demand have been calculated, there will be compared the two scenarios.

5.1. Building's demand

In this part there will be calculated the demand for heating, DHW and power demand of the building. The decree nr.38/ 16.01.2013, is still used in the calculation of heating demand and size of the heating plants, the same for the 6 renovation cases, previously analyzed. Besides not having an energy class system, in most of the EU the countries the energy demand calculations are not limited for heat loses due to transmission and ventilation. There will not be calculated the cooling demand, because there will be adopted the strategies mentioned above.

5.1.1. Transmission heat loses

The heat loses the building envelope elements (external walls, ground floor, roof, door, windows) and those from the thermal bridges will be calculated by using Equation 5 and Equation 6. In absence of the national calculation methodology evaluating the energy consumption of the building according with a certain label (for example: A, B, C class), in the six renovations cases, the heat loses for transmission and ventilation are estimated referring to the decree nr.38 / 16.01.2013, in order to size the heating plant system. In this specific case they will be used as well. The building envelope of the main building and addition are the same as in standard school buildings built during Socialism. The external load-bearing walls are typical the standard school buildings with 44 centimeters load- for the first storey and 31 centimeters for the upper ones. Because of the sites morphology, the ground floor

Equation 5 Calculation of the heat loses for transmission for building envelope elements

$$Q_{tr}=U * A * \Delta T \qquad [W]$$

where:

$$\Delta T=T_{in}-T_{out} \qquad [°C]$$

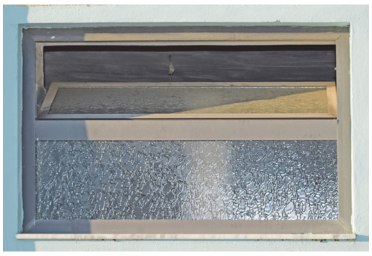
U_n - Transmittance of building element (W/m^2°K)
A - Area of the building envelope element (m^2)
T_{in} - Internal temperature: For classrooms it is equal to 20 °C
T_{out} - External temperature: equal to 0 °C

Equation 6 Calculation of the heat loses for thermal bridges

$$Q'_{tr}= (U \times A+ U_{tb} \times L) \times \Delta T \qquad [W]$$

U - Transmittance of building element part of the thermal bridge (W/m^2°K)
A - Area of the building envelope element (m^2)
U_{tb} - Transmittance of thermal bridge e element (W/m°K) it is equal to 0.05
L - Length of the building envelope element (m)
T_{in} - Internal temperature: For classrooms, it is equal to 20 °C
T_{out} - External temperature: equal to 0 °C

Table 65 Window layout encountered in the “Hillary Clinton” school- graphics: the Author

Layout Dimensional data					
					
Window type 1: 133 x160 centimeters		**Window type 2: 133 x105.5 centimeters**		**External door: 160 x 250 centimeters**	
Glass	**Frame**	**Glass**	**Frame**	**Glass**	**Frame**
A_g = 1.42 m^2	**A_f =** 0.66 m^2	**A_g =** 0.95 m^2	**A_f =** 0.45 m^2	**A_g =** 1.90 m^2	**A_f =** 2,10 m^2
(68.2 %)	(31.8 %)	(67.9 %)	(32.1 %)	(47.5 %)	(52.5 %)
l_g = 9.56 m		**l_g** = 6.35 m			
Ψ_g (W/m°K)	0.02	**Ψ_g** (W/m°K)	0.02	**Ψ_g** (W/m°K)	0.02
U_w = 4.68 W/m^2°K		**U_w = 4.58** W/m^2°K		**U_w = 6.40** W/m^2°K	
Note: Double-glazed, 10 mm air-gap		**Note:** Double-glazed, 10 mm air-gap		**Note:** Double-glazed 5 mm air-gap	

slabs are elevated for 60 centimeters (main building) and 15 centimeters (addition) from the ground, but the interior finish level is the same in both. For calculation purposes, consider the layers of the ground floor in the addition with as similar with the main building as described in Table 36. As can be seen in Figure 29, the roofs

Table 66 Heat loses for transmission- source: the Author

	Element	Area (m^2)	U ($W/m^{2\circ}K$)	Q (kw)
Building envelope	Windows	311,74	4,58/ 4,68,/ 6,16	31,22
	Door	12.80	6,40	02,54
	Wall 44 centimeters	573,74	1,34	17,00
	Wall 31 centimeters	1174,86	1.77	46,00
	Ground floor slab	825,00	3.09	51,00
	Pitched roof	800,00	1.49	23,84
	Flat roof	290,00	1.36	07,89
	Q_{tr} (kw)			**178,65**
Thermal bridges	Canopy at the entry (L=42.52 m)	98,31	1.36 (Canopy)	2.71
			3,09 (Ground floor)	6.11
	Q'_{tr} (kw)			**8,82**
Total (kw)				**187,47**

Table 67 Correction percentage applied to building envelope elements based on the orientations- source: decree nr.38/16.01.2013

Orientation	S	S-E	E	N-E	N	N-W	W	S-W
Correction %	0	2 ÷ 5	5 ÷ 10	10 ÷ 15	15 ÷ 20	15 ÷ 20	10 ÷ 15	5 ÷ 10

besides being different are both uninsulated but more critic is the situation the main building. Unlike the other critical cases, the windows are double-glazed with an aluminum frame and the same is for external doors. Depending on the orientation, a correction factor will be applied for the final U-value (see Table 67). The main thermal bridges are represented from the canopy and basement beneath, with the same layers as the ground floor slab. So referring to the total loses from transmission are equal to 187, 47 kW where the ground floor slab and external walls as the most critic.

5.1.2. Ventilation heat looses

Equation 7 Calculation of the heat loses for ventilation

$$Q_{ventilation}=0.3 \times \dot{V} \times c \times \rho \times (T_{in}-T_{out}) \quad [W]$$

where:

$\dot{V}$ - air flow rate (m^3/h)

c - specific air heat: in standard conditions: equal to 1 (kJ/kg^oK)

ρ - specific air density: equal to 1,2 kg/m^3

T_{in} - Internal temperature: for classrooms it is equal to 20°C

T_{out} - External temperature: equal to 0°C

Table 68 Calculation of the heat loses for ventilation- source: the Author

	Destination	Volume (m^3)	Air change rate (h^{-1})	V (m^3/h)
Air flow rate	Classroom volume	3343,6	6	20061,60
	Bathrooms	400,1	6	2400,60
	Corridors + stairs	2103	4	8412,00
	Laboratories	306	10	3060,00
	Offices	350	6	2100,00
			$\dot{V}$ (m^3/h)	**36034,20**
			(m^3/s)	**10**
				0.30
			c (kJ/kg^oK)	1
			ρ (kg/m^3)	1,2
			T_{in}-T_{out} (°C)	20
			Total (kw)	**72**

The ventilation of classrooms is necessary to remove air pollutants but it is counted in the overall loses, too. For this purpose there will be used the Equation 7. By using the air change rates that are defined in the manual for the school design manual the total loses for ventilation are equal to 72 kW.

5.1.3. Domestic Hot Water Demand

Equation 8 Demand for Domestic Hot Water

$$Q_{DHW}= \frac{\rho \times c \times V_w \times (\theta_{out} - \theta_{in}) \times N}{1000} \quad [kWh/year]$$

where:

$$V_w = a \times n \ [L/day]$$

V - water supply (L/day)
a - daily DHS demand per person (L/day): equal to 5
n - number of users: equal to 1364 (67 teachers+ 1297 students)
c - specific water heat: equal to 1.162 Wh/kgºK
ρ - specific water density: equal to 1 kg/L
θ_{in} - entry water temperature: equal to 10.33°C
o_{ut} - final water temperature: equal to 60°C
N - number of days school is active: equal to 220

Table 69 Calculation of DHW demand- source: the Author

Air flow rate	**n**	**a** (L/day)	**V** (L/day)
	1364	5	**6820,00**
		V (L/day)	
		c (Wh/kgºK)	1.162
		ρ (kg/L)	1,00
		o_{ut} - θ_{in} (°C)	29,67
		N (days)	220
		Total (kwh/year)	**51.728,00**

Even though not included in the decree, this parameter is considered in almost all the energy certification systems in Europe and worldwide, too. Considering its inclusion in future, it will be calculated even if resulting with an increase of the building's energy demand, considering the number of users in this case n= 1364 (including teachers and students). It will be calculated only for hygienic purposes and not for the purpose, in this case is just for the bathrooms and not for kitchens or things like that. Referring to Equation 8, the total demand with a school year is equal to 51.728 kWh in a year.

5.1.4. Power for Illumination

Besides the calculation of the demand for illumination by the Lighting Energy Numeric Indicator LENI, there will be also analyzed the bills payed by the Municipality of Kamza for the period from September 2018 to August 2019. Referring to Figure 34 and Table 70, the building's power consume is different in various seasons of the year. During winter, particularly in February, power consumes are about five times higher than in September where the school year begins. On the other hand, spring and autumn consume is lower. The total power consume amounts for 16,640 kWh/year for an expense of Albanian Lek ALL206,330.00[45] (nearly Euro 1,680.00[46]).

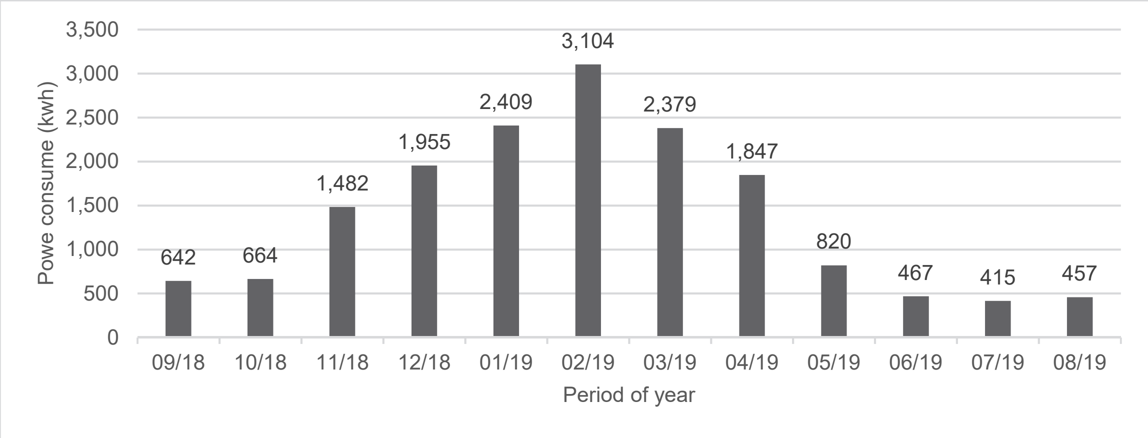


Figure 34 Graph of the power consume from 09/18 to 06/19- source: Kamza municipality

Table 70 September 2018- 2019 and equivalent power consume- source: Kamza municipality

Month/Year	Month Bill (ALL)	Cost (ALL/kwh)	Power Consume (kwh/month)
09/18	7,963	12,4	642
10/18	8,231	12,4	664
11/18	18,379	12,4	1,482
12/18	24,242	12,4	1,955
01/19	29,870	12,4	2,409
02/19	38,488	12,4	3,104
03/19	29.500	12,4	2,379
04/19	22,898	12,4	1,847
05/19	10,163	12,4	820
06/19	5,795	12,4	467
07/19	5.140	12,4	415
08/19	5.661	12,4	457
Total (ALL)	**206,330.00**	**Power Consume (kWh/year)**	**16,640.00**
Total (Euro)	**1,680.00**		

Table 71 Power demand for illumination calculated- source: the Author

	Existing building non-refurbished		**Note**
Lighting terminals LED	(n= 186) 20 W/ 90 lumens/W	Total installed power: 3720 W	
Didactic activity	Morning and afternoon: t_D =1800 h t_N =1200 h		t_N is supposed 6 times higher than normative considering the activity. For the normative t_N =200 h
Type of control	Manual control: F_d=1,0; F_o=1,0;F_c=1,0		
$W_{P,t}$ (kWh)	2,263		No emergency lighting installed only. Pci= 1 kwh/m^2/year. Simplified procedure according to the normative
$W_{L,t}$ (kWh/year)	11,160		
W (kWh/year)	13,423		

[45] Calculated according the cost established by OSHEE for the year 2018 : link https://oshee.al/category/tarifat-e-energjise/
[46] Conversion rate 1 EU = ALL 122.8 in December 2019

Equation 9 Calculation of LENI

$$LENI=\frac{W}{A}=\frac{W_{p,t}+W_{L,t}}{A}\quad [kWh/m^2/year]$$

where:

$W_{P,t}$ - parasitic energy consumed in period t, by the charging circuit of emergency lighting and by the standby control system controlling the luminaires (kwh/year)
$W_{L,t}$ - energy consumed in period t, by the luminaires to fulfil the illumination function and purpose in the building (kwh/year)
A - Total useful floor area of the building (m^2)

Equation 10 Calculation of $W_{L,t}$

$$W_{L,t}=\sum\frac{P_n \times F_c \times F_0 \times (t_D \times F_D+t_N)}{1000}\quad [kWh/year]$$

where:

P_N – Power of all luminaires in the room or zone (W)
F_C – Constant illuminance factor relating to the usage of the total installed power when constant illuminance control is in operation in the room or zone: equal to 1
F_0 – Occupancy dependency factor, relating the usage of the total installed lighting power to occupancy period in the room or zone: equal to 1
F_D – Daylight dependency factor, relating the usage of the total installed lighting power to daylight availability in the room or zone: equal to 1
t_D - daylight time usage. Operating hours during the daylight time: equal to 1800 (h)
t_N - daylight time usage. Operating hours during the non-daylight time: equal to 1200 (h)

Equation 11 Calculation of $W_{P,t}$

$$W_{P,t}=\sum\frac{P_{pc} \times [t_y-(t_D+tn)]+P_{em} \times t_{em}}{1000}\quad [kWh/year]$$

P_{pc} - total installed parasitic power of the controls in the room or zone (W)
P_{em} - total installed charging power of the emergency lighting luminaires in the room or zone (W)
t_y - time taken for one standard year to pass: equal to 8760 (h)
t_{em} - operating hours during which the emergency lighting batteries are being charged in hours:(h)

Equation 12 Illuminance calculation

$$E_v=\frac{P \times \eta}{A}\quad \left[\frac{lumens}{m^2}\right]$$

where:

$$1\,\frac{lumen}{m^2}=1\ Lux$$

P - total installed power (W)
η - the luminous efficacy (lumens/W)
A - area of the room (m^2)

The power consume for illumination, is influenced by the didactic activity as well. Despite the use of 20-W LED lamps, very advantageous for consuming less power, the split of the didactic activity is not very advantageous in this point of view. The European normative EN 15193, calculated the annual illumination demand by using Lighting Energy Numeric Indicator LENI. Considering that the didactic activity is split in two rounds, an aspect not considered in the normative, the operating hours during the non-daylight time t_N will be equal to 1200 hours and not 200 as it is specified. So about 80% of the annual power consume is due to illumination and the rest from other appliances and heating fixtures used during winter. The normative in power indicates 400-500 LUX the illumination intensity for classrooms. Referring to Equation 12, it emerges that the level of illumination of the classrooms is not at the decent level. Indeed, for a 38 square classroom with n=4 LED bulbs of 20 W with 90 lumens/W, it emerges that the total illuminance is equal 189 Lux, clearly below the standards. Even with six lamps, there would have been enough to reach the 300 Lux (precisely 284 Lux). So in this perspective the illumination

5.1.5. Energy performance index

It includes the sum of the heating, DHW, and power for illumination. First is necessary to calculate the heating demand by using Equation 13 and Equation 14 as specified in the decree, whereas the DHW and power for illumination, even if not included in the decree, will be calculated in relation to the buildings area. Therefore, the energy performance index EPi is equal to 319.04 kwh/square meters/year that in energy label certification system means G or H energy class, the lowest ones indeed.

Equation 13 Calculation of annual heat loses for transmission

$$Q''_{tr} = \frac{HDD \times Q_{tr} \times 24}{1000 \times A \times (T_{in} - T_{out})} \quad [kWh/m^2/year]$$

HDD - Heating Degree Days: equal to (2110 °C)
A - Heated Area of the building: is equal to 2140,64 m^2
T_{in} - Internal temperature: For classrooms it is equal to 20°C
T_{out} - External temperature: equal to 0°C
Q'_{tr} - Heat loses for transmission including thermal bridges (W)

Equation 14 Calculation of annual heat loses for ventilation

$$Q'_{ventilation} = \frac{HDD \times Q_{ventilation} \times 24}{1000 \times A \times (T_{in} - T_{out})} \quad [kWh/m^2/year]$$

HDD - Heating Degree Days: equal to (2110 °C)
A - Heated Area of the building: is equal to 2140,64 m^2
T_{in} - Internal temperature: For classrooms, it is equal to 20 °C
T_{out} - External temperature: equal to 0 °C
$Q_{ventilation}$ - Heat loses for ventilation (W)

Table 72 Existing situation. Calculation of Energy Performance Index (EPi) - source: the Author

		ΔT(°C)	**HDD** (°C)	**A** (m^2)	**Total** (kWh/m^2/year)
Q''_{tr}	**Q'_{tr} = 187,47 kw**	20	2110	2263,35	**209.72**
$Q'_{ventilation}$	**$Q'_{ventilation}$ = 72,00 kw**	20	2110	2263,35	**80,54**
Q'_{DHW}	**Q_{DHW} = 51.728,00 kwh/year**			2263,35	**22.85**
LENI	**Q_{ill}= 13.423 kwh/year**			2263,35	**5.93**
Epi (kWh/m^2/year)					**319,04**

5.2. First scenario

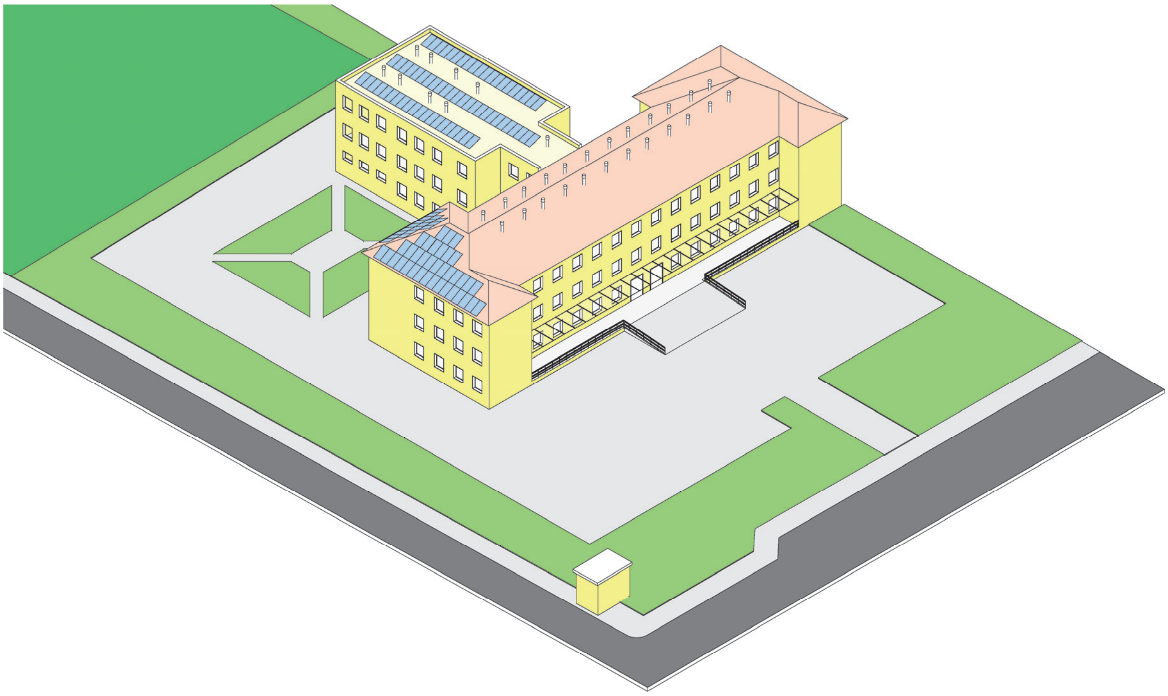


Figure 35 Refurbishment proposal for the first scenario- source: the Author

Table 73 Brief description of the interventions included in the first scenario source: the Author

• **Building envelope -** Respect the established U-value in Table 34.	
Walls	• As insulation material will be used EPS in the necessary thickness, because of being cheap and diffused in the national market.
Ground floor slab	• Option 1: Increase of the slabs thickness • Insulation material: Cellular glass, very performant energetically and to compression.
Roof	• For the flat roof (Addition) there will adopted the option with the gravel finish. • For the pitched roof (Main building) will be adopted the option with the ventilated chamber by preserving the existing tiles too. Total remotion of reinforced-reed ceiling and replacement with gypsum-tiled ceiling. • Insulation material: EPS in the necesarry thickness.
Thermal bridges	• The canopy at the entry thill be demollished and replaced with a new one in glass that will be sustained by inclined joist as illustrated in Table 45. Besides being lighter it will facilitate the façade's insulation and classroom with not suffer shadow. • The elevated base with not be subject to anny intervention.
Windows and doors	• The windows and main doors will be at least double-glazed with air-filled gap. The unheated spaces with external access are not constrained to have. • Sun-screening stategy: Overhang elements (South) and external roller blinds for the other fronts as determined in Table 46
IEQ	
Control	• Mandatory for every classroom to monitor the Indoor quality in the classroom
Lighting and Illumination	• Based on the orientation there will be incorporated sun-screening elements as shown in Table 46 and Table 34. • 30x30 centimeters square based LED fixtures at least 4 per classroom. LED 3000 K (white) and 30 W/ 120 lumen/W
Ventilation	• Natural and one-sided for classrooms from the ground floor. • Croos-ventilated with solar chimney in top floors
Heating	• Existing Radiators will be used even though not operative since they were installed
Renewable Energy	
Solar Energy	• PV panels in top of the flat roof to produce the electricity.
Geothermal energy	• Heat pump with COP= 4.0 and DHW and heating

In this part it will be comprehended the effectiveness of the measured proposed for the building envelope, illumination, heating, DHW by preserving the actual capacity. As can be seen in Figure 35 and Table 73, the importance of better illumination and constant air change of the classrooms that can be controlled through the apposite device installed to monitor the level of CO_2 inside it. Although not included in the calculation EPi, the cooling of classrooms will occur through the screening strategies proposed in Table 46. The illumination of the classrooms with be subject as well to renovation in order to reduce consume and guarantee a proper illumination of the classrooms.

5.2.1. Heat loses

Table 74 Heat loses reduction for scenario 1- source: the Author

	Element	**Area** (m^2)	**U** ($W/m^{2\circ}K$)	**Refurbished (kw)**	**Non-refurbished (kw)**	**Δ (kw)**	**(%)**
Building envelope	Windows	311,74	3.00	18.70	31,22	-12,52	-40,10
	Door	12.80	3.00	00,77	2,54	-1,77	-69,69
	Wall 44 centimeters	573,74	0.50	05,73	17,00	-11,27	-66,29
	Wall 31 centimeters	1174,86	0.50	11,75	46,00	-34,25	-74,46
	Ground floor slab	825,00	0.75	12,38	51,00	-38,62	-75,73
	Pitched roof	800,00	0.45	07,20	23,84	-16,64	-69,80
	Flat roof	290,00	0.45	02,61	7,89	-5,28	-66,92
	Q_{tr} (kw)			**59.14**	**178,65**	**-119,51**	**-66,90**
Thermal bridges	**Q'_{tr} (kw)**			**06,11**	**8,82**	**-2,71**	**-30,73**
T1: Transmission heat loses (kw)				**65,25**	**187,47**	**-122,22**	**-65,19**
T2: Ventilation heat loses				**72,00**	**72,00**	**0**	**0**
T3: Total heat loses (kw)				**137,25**	**250,65**	**-113,40**	**-45.24**

A satisfying outcome emerges from the measures proposed in the building envelope because the heat loses are drastically reduced by over 65 %. In particular, the heat loses in ground floor are cut by 75 % with an intervention requiring less time, even though resulting with a reduction of the internal height by six centimeters. Regarding the thermal bridges, the demolition of the canopy, at the entry of the main building is advantageous in terms of: (i) continuity of the insulation in the façade; (ii) the thermally-broken frames that do not create new thermal bridges; and (iii) more shelter and light to the classrooms in the ground floor. Important results are achieved in the replacement of the windows, where heat loses are cut by 40 %. The heat loses for ventilation remain the same, because ventilation of the classrooms will occur naturally.

5.2.2. Heating and DHW

Because of impacting in the buildings consumption heating and production of DHW will occur using ground based heat pump water-water with COP= 3.5. Considering that once refurbished the building demands 137 kW (heating) and 26 kW (DHW) the total power is 163 kw but considering eventual peaks there will be used 170 kW one.

5.2.3. Illumination demand

Figure 36 Square-base LED fixture 30x30 centimeters, 30W/ 120 L/W (source: factorled.com)

Table 75 Power demand for lighting in scenario 1- source: the Author

Didactic activity : Morning and afternoon: t_D =1800 h t_N =1200 h				
	Existing building non-refurbished	**Scenario 1**	**Δ**	**Δ (%)**
Lighting terminals LED	n= 186 20 W, 90 lumens/W	n= 246 30 W, 120 lumens/W	+60	
Total power installed (W)	3720	7380	+ 3.660	+98,38
	Manual control F_d=1,0;F_o=1,0;F_c=1,0			
$W_{P,t}$ (kWh/year)	2,263	13,580		
$W_{L,t}$ (kWh/year)	11,160	22,140	+22,997	+166,11
W (kWh/year)	13,423	35,720		
	Manual control F_d=1,0;F_o=1,0;F_c=1,0	Dimming Control F_d=0,6; F_o=0,8; F_c=0,9		
$W_{P,t}$ (kWh/year)	2,263	13,580		
$W_{L,t}$ (kWh/year)	11,160	12,115	+12,273	+91,40
W (kWh/year)	13,423	25,695		

In this first scenario, with the didactic activity occurring in the morning and afternoon, but unlike the actual situation it will installed referring to the normative in power in Albania, the lighting fixtures will be approached as: (i) guaranteeing the appropriate illumination and; (ii) reduce consume of energy. In order to achieve the appropriate level LUX's, in each classroom there will be set six square-based lighting fixtures (see Figure 36) according to the layout proposed in layout configuration in Table 50. Indeed the total level of illumination is equal to 568 Lux, higher than the normative but on the other hand it results with an increase of the power of the lighting fixtures to 180 W (from 80 W in the initial configuration). The increase of the number lighting fixtures is followed with an increase of power, but by using a dimming command it is possible to contain the consume of power without comprising the appropriate illumination of the classrooms and other spaces within the building. As illustrated in Table 75, there is a huge difference between the dimming and manual control of this lighting fixtures with consume of energy nearly five times lower.

5.2.4. PV energy

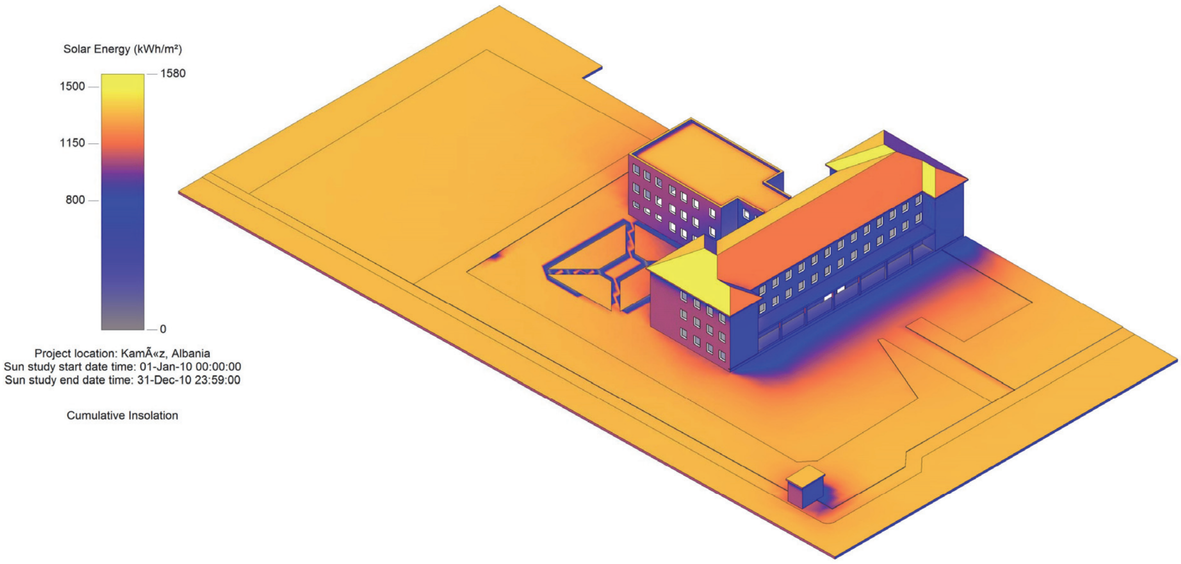


Figure 37 Annual solar analysis of the area performed with Revit Insight Solar- source: the Author

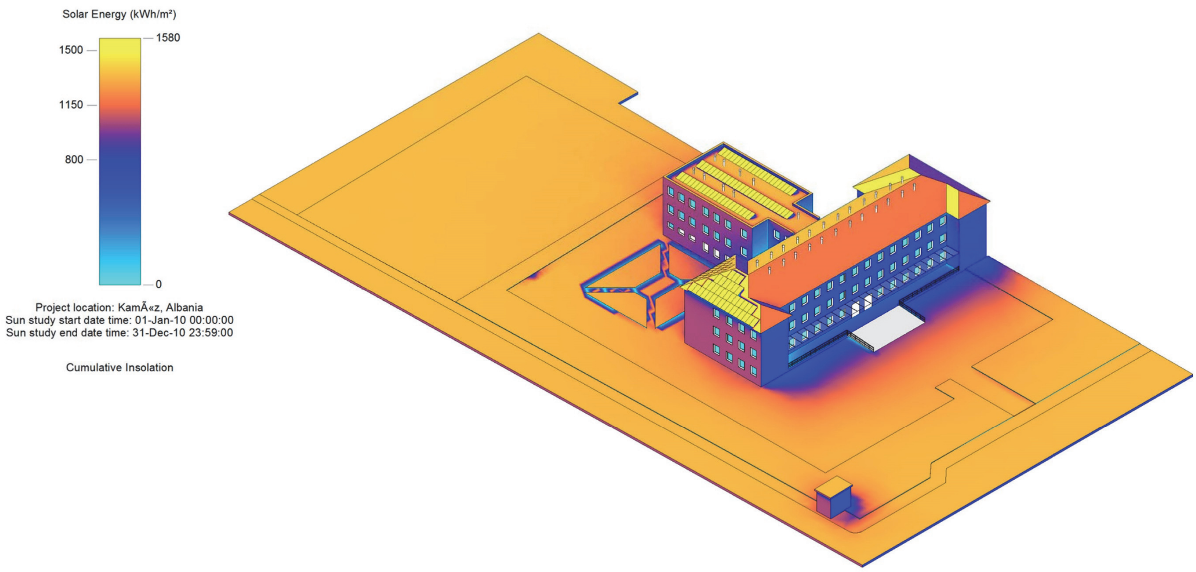


Figure 38 Installation of PV panels of the first scenario with Revit Insight Solar - source: the Author

Table 76 Possible scenarios depending on the efficiency of PV based on simulation made with Revit Insight Solar- source: the Author

Number of panels installed	**Efficiency 16 %**	**Efficiency 18 %**	**Efficiency 20 %**
Annual energy produced (kwh/year)	39.238	45.614	50.028
Cost of energy in Albania (ALL/ kWh)			12,4
Savings (ALL)	486.551,20	565.613,60	620.347,2
Savings (EURO)	3.962,14	4605.98	5051.68
Cost of the panels (Euro)	129 panels x 99 Euro/panels =12.771,00 Euro		
Payback time (years)	3.2	2.8	2.5
Annual energy per square meter (kwh/year/m2)	17.33	20.15	22.10

The exploit of solar energy is undoubtedly an important potential. As illustrated in Figure 27, the municipality of Kamza has an annual solar exposure between 1500-1550 kwh/square meters/year and sunshine 2500-2700 hours. But in order to comprehend the potential and suitable position of the PV panels. Referring to Figure 37, it emerged that the area has a good potential to exploit solar energy. Consequently the distribution of the n= 129 solar panels went in those parts that the exposition is higher. Considering the presence of the solar chimneys to permit the cross-ventilation of the classrooms in the upper floors, it necessary the avoid of shadows that may negatively affect the PV panels operation and that is the reason they have been positioned in the configuration of Figure 38, also by avoiding shadows among each other. In this configuration, there are expected n= 363 PV panels that depending on the efficiency give the respective annual energy and in impact in the buildings energy performance for this scenario. The cost[47] of panels amounts around Euro 32.670,00 and the payback periods ranging from 2.5 to 2.9 years.

5.2.5. Impact

As can be seen from Table 77, the impact of the measures proposed for this scenario result with evident improvements in the final energy performance of the building by improving it with more than 96 %. The reduction of the heat loses by 65,22 % beside and followed by impact of the heat pump serving for heating and DHW reveal with the reduction of polluting emissions, too. Regarding the lighting system, the increase of the number of lighting in the classroom resulting above all

[47] Calculation from private furnitor https://www.panelebesi.com/. This voice is expected in the manual of constructions costs approved by the government

Table 77 Energy performance index and impact of scenario 1- source: the Author

		ΔT(°C)	**HDD** (°C)	**A** (m^2)	**Total** ($kWh/m^2/year$)
Q''_{tr}	Q'_{tr} = 62,25 kw	20	2110	2263,35	72.93
$Q'_{ventilation}$	$Q'_{ventilation}$ = 72,00 kw	20	2110	2263,35	80.54
Q'_{DHW}	Q_{DHW} = 51.728 kwh/year			2263,35	22.85
LENI	Q_{ill} = 25.695 kwh/year			2263,35	11.35
$Q'_{PV\ panels}$	$Q_{PV\ panels}$ = 50.028 kwh/year			2263,35	22.10
$Q'_{heat\ pump}$	$Q'_{heat\ pump}$ = 170,00 kw	t= 9 h x 220 =1980 h		2263,35	148.71

	Existing building non-refurbished	**Scenario 1**	**Δ**	**Δ %**
Q''_{tr}	209.72	72.93	-136.79	-65,22
$Q'_{ventilation}$	80.54	80.54	0	0
Q'_{DHW}	22.85	22.85	0	0
Q'_{ill}	5.93	11.35	+5.42	+91,00
$Q'_{heat\ pump}$	-	148.71	+148.71	+100,00
$Q'_{PV\ panels}$	-	22.10	+22.10	+100,00
Epi ($kWh/m^2/year$)	**319.04**	**21.86**	**-297,18**	**-93.11**

with an increase of installed power but the dimming control system reduces theconsumes compared to the manual one. The impact of the installed PV panels within the building's footprint, represents a further advantage not only in the building footprint but in the same time to the environment. If considered the sustainability of our grid, this first scenario can be easily considered an example leading to the decarbonization of the school building stock in Albania. This positive result does not mean that the problem is solved because the split of the didactic activity in two rounds and the absence of a gym, puts a question mark on the reliability of this result if considered the inadequate capacity of the building.

5.2.6. Cost of the intervention

Table 78 Total value and cost of the interventions- source: the Author

Voice	ALL	Euro	Note
Building envelope	13,245,296	107,861	Includes: – Replacement of openings (windows and doors) with sun-screening elements – Ground floor, Walls, and roof insulation, waterproofing and addition of new finishes – Demolishing and replacement of the canopy – Solar chimneys for ventilation
Lighting system	1,150,599	9,369	Includes: Installation of the Replacement of the existing ones and dimming control.
Ground-based heat pump	3,684,000	30,000	Includes: Price of pump ground excavation work and installation of vertical probes
PV panels	1,568,279	12,771	Includes: Installation and circuit mechanism
5% fund	982,409	8,000.	Includes extraordinary works
VAT (20 %)	4,519,081	36,800	
Total (including VAT)	27,114,484	220,803	
Cost (per sqm)	11,979	97.55	

The estimation of the cost of these kind of interventions, involving a deep refurbishment of the building, are difficult to estimate because the market in Albania does not offer a wide range solution compared to most of the EU countries. So for this reason the prices assumed in the calculation of the cost are in part referred to the manual of construction prices approved by the government in 2017(building envelope and PV panels) and in part from privates (PV panels, lighting system and Ground-based heat pump.) As detailed in Table 78, for this first scenario the cost emerges to be about ALL 11,979.14 or Euro 97.55 per square meter

5.3. Second scenario: Refurbishment and Increase of capacity.

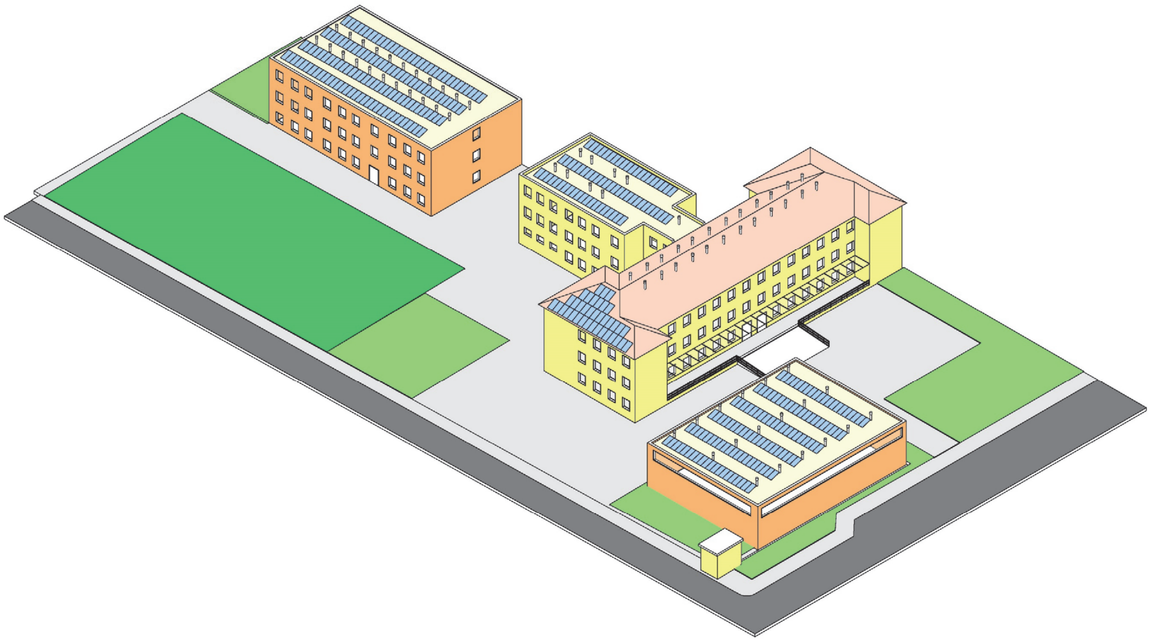


Figure 39. Scenario 2. Refurbishment and increase of capacity- source: the Author

This step, with an important focus on energy-efficiency, gives the possibility to comprehend the real demand of the building when working in its adequate capacity with the didactic activity performed during the morning for all the classrooms. The approach of this issue, is important to comprehend if the refurbishment of the existing building and increase of its capacity with the proposed solutions and building system is better than it's demolish and building of a new one with the adequate capacity. The desired capacity of the 45 classrooms is beyond of the limit set in Table 59 and Table 60 but there will be posed as goal, considering the low number of schools in existing block of 30 classrooms (main building + addition). The new building will be designed according to the normative in power, decree nr.319 the Council of Ministers approved in 2017 entitled "Standartet e projektimit për shkollat[48]" in terms of: (i) Distances from nearby buildings, property limits and main streets; (ii) Internal layouts-area, height, internal dimensions etc.; (iii) openings/floor area ration and air change rate. The building envelope requirements and U-Values will be same as established in Table 58. Usually school buildings include a gym, but the school actually does not the municipality. The new addition will include 15 new classrooms to be added to have one but it will be included as well in the intervention because it is necessary for the didactic activity when weather conditions are not the best. The new volumes are divided because the plot of the area and the

Table 79 Capacity of school in the second scenario - source: the Author

	Existing buildings	**New Addition**	**New Gym**	**Final Configuration**
Capacity	30-classrooms	15- classrooms		45-classrooms + Gym
Orientation	NE-SW and NW-SE	NW-SE	NW-SE	
Area (m^2)	2263,35	1488	600	4291,35
Volume (m^3)	6852,95	4960	3240	15.052,95
Heated Area (m^2)	2140,64	1488	535	4163,64
(V) Heated Volume (m^3)	6504,19	4960	3210	14.674,19
(S) Building Envelope (m^2)	3907,99	2015	1644	7566.99
S/V (m-1)	0.60	0.41	0.51	

Table 80 Brief description of the interventions included in the second scenario for both buildings- source: the Author

Building envelope- Respect of the established U-value in Table 58	
Walls	• EPS will be used as insulation material in the necesarry thickness.
Ground floor slab	• As insulation material will be used the Cellular glass, very performant energetically and to comprension.
Roof	• The flat roof solution with gravel finish will include the EPS as insulation material, obviously in the appropriate thickness.
Thermal bridges	• Not expected
Windows and doors	• Respect the established U-value in Table 34. • The windows and main doors will be double-glazed with air-filled gap.
IEQ	
Control	• Mandatory for every classroom to monitor the Indoor quality in the classroom
Lighting and Illumination	• Based on the orientation there will be incorporated sun-screening elements as shown in Interior, valid also for the aluminum shutters. This considerations are very important because there is avoided the installation expensive of mechanic ventilation units. and Table 34. • 30x30 centimeters square based LED fixtures at least 4 per classroom. LED 3000 K (white) and 30 W/ 120 lumen/W
Ventilation	• Natural and one-sided for classrooms from the ground floor. • Croos-ventilated with solar chimney in top floors
Heating	• Radiators run by ground-based heat pump
Renewable Energy	
Geothermal energy	• Heat pump with COP= 4.0 and DHW and heating
Solar energy	• PV panels to produce power.

[48] [ALB] "Standard for the design of school buildings"

requirements to contain outdoor sports courts from the decree does not facilitate a unique one. Organized in three floors, in each floor there are present 5 classrooms (according to the approved layouts), a bathroom per floor, and rooms for the teachers. Regarding the gym, it positioned close to main entry because it is considered as the best position for its layout. Both will be built with the with the CLT system according to the U-values in Table 58 and respective layers specified in Table 61,Table 62 and Table 63, whereas for the windows the reference will be same as in the first scenario.

5.3.1. Heat loses

Table 81 Heat loses in for the buildings expected in the second scenario- source: the Author

ADDITION				
Building envelope		Area (m^2)	U (W/m^2°K)	Power(kw)
	Windows	126	2.80	7,54
	Door	8	2.80	0,55
	External wall	890,4	0.40	7,34
	Ground floor slab	496	0.60	5,95
	Flat roof	496	0.45	4,64
			T1: Transmission heat loses (kw)	**26,02**
Air change rate	**Destination**	**Volume** (m^3)	**Air change rate** (h^{-1})	**V** (m^3/h)
	Classroom volume	2632,50	6	15.795
	Bathrooms	522,00	6	3.132
	Corridors + stairs	2420	4	9.640
	Offices	126	6	756
			$\dot{V}$ (m^3/h)	**29.323**
			(m^3/s)	**8,15**
				0,30
			c (kJ/kg°K)	1,00
			ρ (kg/m^3)	1,20
			T_{in}-T_{out} (°C)	20,00
			T2: Ventilation heat loses	**58,68**
			T3: Total heat loses (kw)	**84,70**
GYM				
Building envelope		Area (m^2)	U (W/m^2°K)	Power(kw)
	Windows	141	2.80	7.90
	Doors	8,00	2.80	**0.50**
	External wall	508	0.40	4.10
	Ground floor slab	600	0.60	7.20
	Flat roof	600	0.45	5.40
	T4: Transmission heat loses (kw)			**25.10**
Air change rate	**Destination**	**Volume** (m^3)	**Air change rate** (h^{-1})	**V** (m^3/h)
	Main court	3240	6	19440
	Bathrooms	60	3	180
	Corridor	180	4	720
	Locker rooms	120	4	480
			$\dot{V}$ (m^3/h)	**20820**
			(m^3/s)	**5.78**

	0.30
c (kJ/kg°K)	1
ρ (kg/m^3)	1,2
T_{in}-T_{out} (°C)	20
T5: Ventilation heat loses	**41.62**
T6: Total heat loses (kw)	**66.72**
T3 + T6: Total heat loses (kw)	**151.42**

The calculation of the heat loses for the new addition containing 15 classrooms and gym is equal to 151.42 kW. Considering that the size of this school is nearly doubled, the heat loses of these two volumes are very acceptable and the impact of CLT building system in guaranteeing building envelope elements with low U-Values is evident.

5.3.2. Heating and DHW demand

Table 82 Heat demand in the second scenario- source: the Author

	Existing building non-refurbished	Scenario 2		
		Existing building refurbished	**New building**	**Gym**
Transmission heat loses (kw)	187,47	65,25	26.02	25.10
Ventilation heat loses (kw)	72,00	72,00	58.68	41.62
Total heat loses (kw)		137.25	84.70	66.72
	257,47	288,72		
Required power for DHW production (kw)	26,00	26,00		
Total Demand for heating and DHW	284,47	314,00		

In this scenario the DHW demand will remain the same because it is not expected an increase in the number of students. Surprisingly, the second scenario results with heat loses about 10 % more than the current situation. If considered that the addition is performed by building separately and not with adding volumes to the existing building this results gains even more importance. In order to fulfil the demand for heating and production of DHW the geothermal heat pump should have the 320 kW power in order to compensate the eventual peaks.

5.3.3. Illumination demand

The power demand for illumination in the second scenario changes because the entire didactic activity is expected to occur during morning. The growing number of the fixtures and consequently will grow the installed power, too. Depending on the control type, the annual consume is different. Indeed, by installing a manual-control switch system in all the three buildings, the consume will be more than two and half times higher than the current situation. A different impact will be registered with the dimming control mode with just a thousand kilowatt per hour more.

Table 83 Power demand for illumination in the second scenario- source: the Author

		Scenario 2		
	Existing building non-refurbished	Existing building refurbished	New building	Gym
Lighting terminals LED	n= 186 20 W, 90 lumens/W	n= 246 30 W, 120 lumens/W	n= 107 30 W, 120 lumens/W	n= 15 30 W, 120 lumens/W n= 15 100 W, 180lumens/W
Total power installed (W)	3720	7.380	3.210	1.950
		12.540		
Didactic activity	Morning and afternoon t_D =1800 h t_N =1200 h	Morning and afternoon t_D =1800 h t_N =200 h		
Power Consume (kWh/year)	Manual control F_d=1,0; F_o=1,0;F_c=1,0	Manual control F_d=1,0; F_o=1,0;F_c=1,0		With Dimming F_d=0,6; F_o=0,8; F_c=0,9
$W_{P,t}$ (kWh)	2,263	25.000		25.000
$W_{L,t}$ (kWh)	11,160	25,080		11.557
W (kWh/year)	13,423	50,086		36.557

5.3.4. PV energy

The PV energy production is expected to occur by installing the PV panels within the buildings' footprint (in this case the roofs) in order to not occupy space in the ground floor. Also the simulation made with the expected configuration for this scenario, highlighted the high annual solar exposure of the roofs. In order, to avoid eventual shadows from the solar chimneys (permitting the cross-ventilation of the classrooms in the upper floors) and between the panels, the proposed configuration avoids them, as illustrated in the simulation in Figure 40. There are expected n= 363 PV panels that depending on the efficiency give the respective annual energy and in impact in the buildings energy performance for this scenario. The cost of panels amounts around Euro 32.670,00 and the payback periods ranging from 2.3 to 2.9 years.

Table 84 Possible scenarios depending on the efficiency of PV based on simulation made with Revit Insight Solar- source: the Author

Number of panels installed	**Efficiency 16 %**	**Efficiency 18 %**	**Efficiency 20 %**
Annual energy produced (kwh/year)	110,074,00	128,075.00	141,160.00
Cost of energy in Albania (ALL/ kWh)	12.4		
Savings (ALL)	1,364,917,60	1,588,130.00	1,750,384.00
Savings (EURO)	11,114.96	12,932.65	14,253.94
Cost of the panels (Euro)	363 panels x 90 Euro/panels =32,670,00 Euro (In the new buildings: 234 x 90 Euro/panels = 21,060.00 Euro)		
Payback time (years)	2.9	2.5	2.3
Annual energy per square meter (kwh/year/m²)	26.43	30.76	33.90

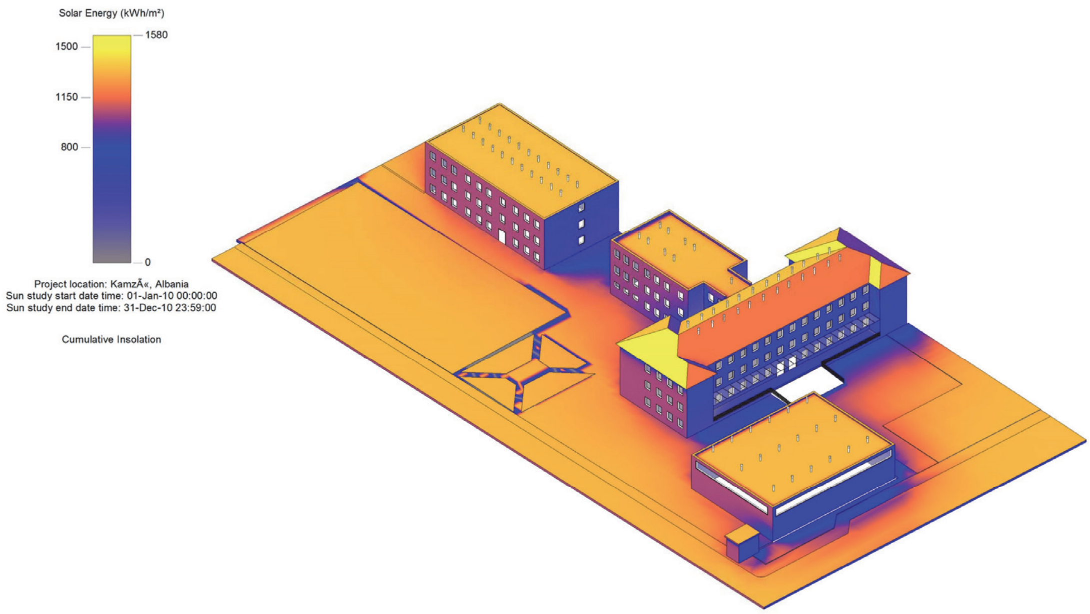


Figure 40 Annual solar analysis of the area performed with Revit Insight Solar in the second scenario- source: the Author

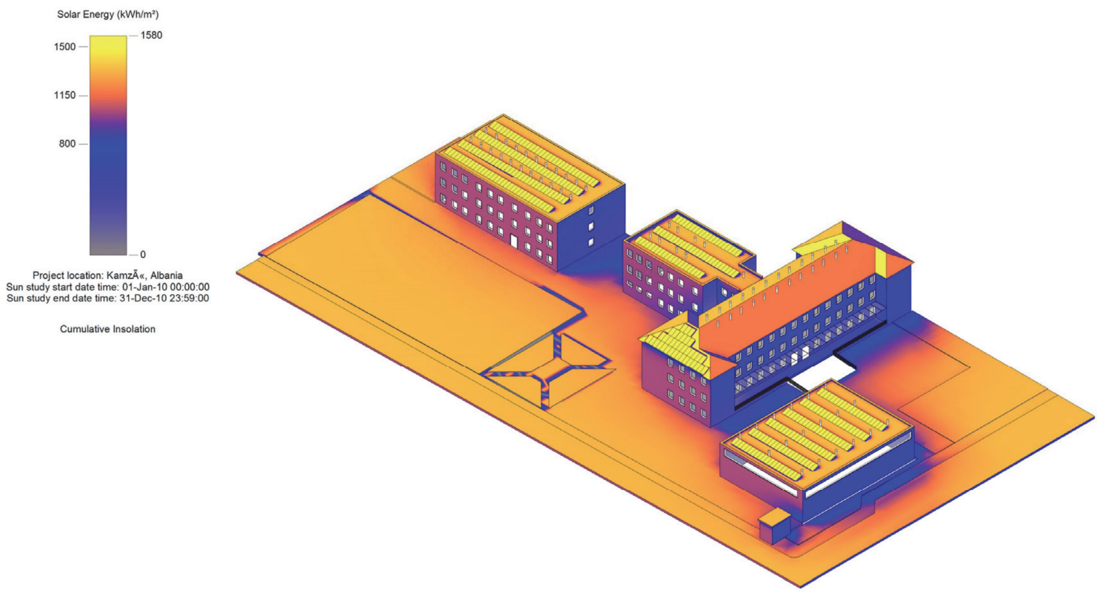


Figure 41 Installation of PV panels of the second scenario with Revit Insight Solar- source: the Author

5.3.5. Impact

Because of having three separate buildings, they should have separate Energy performance index. As can be seen from Table 85Table 77, despite the increase of capacity the final energy performance is 82.69 % less than its actual situation. The new volumes, thanks to the high thermal properties of the CLT panels, result very positive in terms of reducing loses by 66.25 %. The ground-based heat pump for heating and DHW, with a double power compared to the first scenario, contributed

Table 85 Energy performance index and impact of scenario 2- source: the Author

		ΔT(°C)	**HDD** (°C)	**A** (m^2)	**Total** (kWh/m^2/year)
Q''_{tr}	Q'_{tr} = 116.37 kw	20	2110	4,163.64	70.76
$Q'_{ventilation}$	$Q'_{ventilation}$ = 171.95 kw	20	2110	4,163.64	104.56
Q'_{DHW}	Q_{DHW} = 51,728 kwh/year			4,163.64	12.42
LENI	Q_{ill}= 36,557 kwh/year			4,163.64	8.78
$Q'_{PV\ panels}$	$Q_{PV\ panels}$ = 141,160 kwh/year			4,163.64	33.90
$Q'_{heat\ pump}$	$Q'_{heat\ pump}$ = 320 kw	t= 6 h x 220 =1320 h		4.163,64	101.45

	Existing building non-refurbished	**Scenario 2**	**Δ**	**Δ %**
Q''_{tr}	209.72	70.76	-138.96	- 66.25
$Q'_{ventilation}$	80.54	104.56	+20,02	+19.14
Q'_{DHW}	22.85	12.42	-10.43	- 45.64
Q'_{ill}	5.93	8.78	-2.85	+48.00
$Q'_{PV\ panels}$	-	33.90	+33.90	+100.00
$Q'_{heat\ pump}$	-	101.45	+101.45	+100.00
Epi (kWh/m^2/year)	**319.04**	**61.17**	**-257.87**	**-80.82**

a lot in the calculation besides reducing emissions. The lighting system with dimming control guarantees more or less the same performance the non-refurbished building but with better illuminance in the classrooms too. Not totally irrelevant is the organization of the didactic activity entirely in the morning in this point of view. The overall increased footprint, allows a higher possibility to increase the number of installed PV panels, being a Dry construction method this building systems is also very positive in an environmental point of view because it requires less energy and water during the building process. The addition and gym, require around 3000 square meters of CLT panels, approximately 540 cube meters. If one cube meter of CLT (or XLAM) removes more 800 kg of CO_2 in a year (Xlamdolomiti, 2019) our building saves up to 4320 kg. Also this scenario leads to decarbonization of the school building stock by increasing its capacity.

5.3.6. Cost of the intervention

The calculation of the cost for this scenario, will include the cost for the new buildings adding the refurbishment of the existing building performed in the first scenario. Unfortunately even for this scenario the CLT panels are not present in the national market. Building costs in neighboring countries will be used as a reference, in this case Italy where according to (Wunderhaus, 2013) the cost of ultimate buildings ranges from 1,100.00 to 1,400.00 Euro per square meter. In our specific case the cost will set equal to 700.00 Euro per square meter, with transportation costs will be considered equal to zero. To comprehend the difference with the local construction

Table 86 Cost estimation of the new buildings included in the second scenario- source: the Author

Voice	ALL		Euro		Note	
New Buildings	Reinforced concrete structure	CLT	Reinforced concrete structure	CLT	Costs – CLT : 700 Euro/m^2 – Reinforced concrete : 400 Euro/m^2 Includes: –Openings (windows and doors) with sun-screening elements –Ground floor, Walls, and roof insulation, waterproofing and addition of new finishes –Solar chimneys for ventilation –Electric installation –Plumbing works	
Addition (1488 m^2)	73,090,560	127,908,480	595,200	1,041,600		
Gym (600 m^2)	29,472,000	68,768,000	240,000	560,000		
Total	102,562,560	196,676,480	835,200	1,601,600		
Lighting system	654,907		5,333		Includes: – Installation LED lighting fixtures with dimming control.	
Heating system + Ground-based heat pump (150 kw)	10,438,000		85,000.00		Includes: – Price of pump ground excavation work and installation of vertical probes – Installation of radiators ()	
PV panels (n=234)	2,586,168		21,060		Includes: – Installation and circuit mechanism	
5% fund	5,812,082	10,517,778	47,330	85,650	Includes extraordinary works	
VAT (20 %)	24,410,743	44,174,667	198,785	359,729		
Total (including VAT)	146,464,460	265,047,999	1,192,707	2,158,371		
					Difference (only for Euro)	
Cost (per sqm)	70,146	126,939	571.22	1,033.70	+462	80.96%

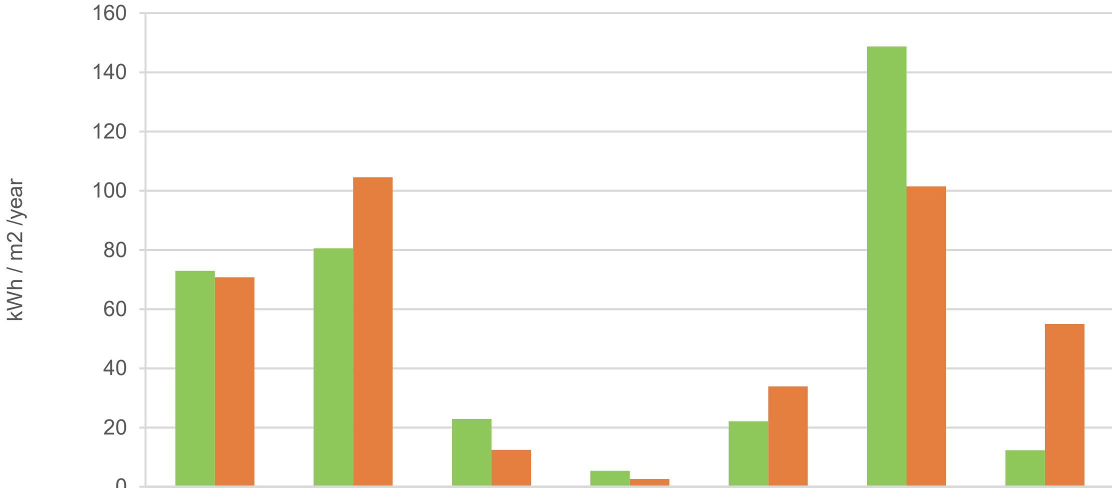
Table 87 Second scenario. Total cost of the intervention- source: the Author

Voice	ALL		Euro		Difference (only for Euro)	
New buildings	Reinforced concrete structure	CLT	Reinforced concrete structure	CLT	Δ	Δ (%)
	146,464,460	265,047,999	1,192,707	2,158,371	+965,664	+80.96 %
Refurbishment existing building	27,114,484		220,803			
Total (including VAT)	173,578,904	292,162,607	1,413,510	2,379,174	+965,664	+68.32 %
Cost (per sqm)	41,689	70,170	339.49	571.42	+232	+68.32 %

cost, there will be made a comparison the national construction cost referred to reinforced concrete structures mainly. Referring to (EKB, 2016), since 2016 there has not been published any update, so it will be taken an approximate cost equal to Euro 400.00 per square meter. Referring to Table 86, the CLT building system is about 81 % expensive than a reinforced concrete building, although the assumed cost may be higher. When adding the refurbishment of the existing building is added the total cost of the intervention to turn the building close to nZEB with the didactic activity during the morning the cost difference is lowered the average cost was equal to ALL 39,281 per square meter (Euro 320 per square to 68.32 % between the building systems. Even though the assumed cost of the CLT building system is assumed as imported product, in situation of a consolidated industry in the country the cost may be even lower and considering the advantages it may be worthy to give incentives in order to promote this industry. Besides the initial cost that may be lower, a three-storey high reinforced concrete structure requires at least 3 months to be completed and at least other three to be completed. On the other hand a similar building in CLT panels can be assembled within a month or even less. Not least important is also the sustainability of building process, where the CLT reveals very advantageous, too.

5.4. Comparison of the scenario

After having carefully analyzed each scenario now it is time to compare them. Besides the evident improvements the analysis of the two scenarios represent very contrasting facts. In the first scenario, there is achieved a very low level of energy consumption but the didactic activity remains the same as before. On the other hand the second scenario is more realistic when considering how should work a school building on full capacity with the didactic activity performed during the morning in the morning. Even though the first scenario is more likely to be considered as nZEB when referring to the EPi, the second one is more important considering the increase of capacity resulting with reduce of operation hours, too.



	Q''tr	Q'ventilation	Q'DHW	Q'ill	Q'PV panels	Q'heat pump	Epi
Scenario1	72.93	80.54	22.85	5.35	22.1	148.71	12.33
Scenario 2	70.76	104.56	12.42	2.6	33.9	101.45	54.99

Figure 42 Comparison of the scenarios- source: the Author

Table 88 Payback comparison between the first and second scenario- source: the Author

	Scenario 1- Refurbishment		Scenario 2 – Refurbishment + CLT	
	ALL	Euro	ALL	Euro
Total cost	27,114,608	220,803	292,162,567	2,379,174
Heating savings	1,279,694	10,420.96	2,391,461	19,474.44
Ground-based heat pump	1,391,209	11,329.06	1,745,925	14,217.63
PV energy production	884,869	7,205.77	1,750,228	14,252.67
Annual savings	**3,555,771**	**28,955.79**	**5,887,614**	**47,941.74**
Pay-pack time (years)	**7.6**		**49.6**	

Note:
- Savings are calculated in terms electric kilowatt-hours because the heating of the classrooms in the actual condition is made with individual heating units. The ratio is 1 kWh (electricity) = 3 kwh (thermal)/
- Kilowatt-hours cost: 1 kwh = ALL 12,4
- Exchange rate: Euro 1.00 = ALL 122.8

Table 89 Payback comparison for the second scenario options- source: the Author

	Scenario 2- Reinforced concrete structure		Scenario 2 - CLT	
	ALL	Euro	ALL	Euro
Total cost	173,579,028	1,413,510	292,162,567	2,379,174
Heating savings	2,391,461	19,474.44	2,391,461	19,474.44
Ground- based heat pump	1,745,925	14,217.63	1,745,925	14,217.63
PV energy production	1,750,228	14,252.67	1,750,228	14,252.67
Annual savings	**5,887,614**	**47,941.74**	**5,887,614**	**47,941.74**
Pay-pack time (years)	**29.5**		**49.6**	

Note:
- Savings are calculated in terms electric kilowatt-hours because the heating of the classrooms in the actual condition is made with individual heating units. The ratio is 1 kWh (electricity) = 3 kwh (thermal)/
- Kilowatt-hours cost: 1 kwh = ALL 12.4
- Exchange rate: Euro 1.00 = ALL 122.8

Precisely this uncertainty about the buildings energy performance in terms of capacity, was one of the reason to not set an Energy label system. In terms of heat loses, the CLT building systems has a positive impact in the building envelope U-values of the new buildings. The natural ventilation of the classrooms, in the second scenario are obviously higher but the operation of the ground-based heat pump is decreased compared with the first one. The power for illumination (LENI) is about the about 50 % less if the didactic activity is performed entirely during the morning, indicating that besides the highly efficient lighting also the working hours have their impact as well. The installed PV panels produce an amount of power enough to abandon the grid that is sustainable in the same time, and this means that the reaming amount can be sold in order to generate incomes for the school. A particular advantage is given from the sites orientation that allows the installation of the solar panels within the buildings footprint, in this situation the roofs. Even in this case the second scenario prevails toward the first one. Although the calculation of the financial efforts to investment highlighted the difference between the two scenarios is very evident in the calculation of the payback period. Indeed it emerged that the refurbishment of the existing building is the best option in this aspect with a 7.6 years in comparison to the 49.6 years of the second scenario (CLT system). In case of using the reinforced concrete structure to increase the capacity, the payback becomes more “soft” by 29.5 years. Considering this last comparison the first scenario becomes very acceptable but there will be always a didactic activity split in the two rounds. In order to reach a low energy consume that will be close to zero, in the first scenario there can be installed more ground-based PV panels, which is the most effective measure. Regarding the second scenario, the most effective measure within the site is to install at least heat recovery units in the gym or in the new addition to reduce ventilation heat loses, otherwise there should installed PV panels nearby the site.

6. Conclusions

Recalling the first question of the research[49], the current situation of the Albanian school buildings is very critic in terms of energy efficiency, indoor environmental quality and capacities above all. The architecture of these buildings, once suitable for the seven and eight-year cycle system and for the demographic configuration of the country during Socialism, is in front of important crossroad because the demographic balance of the country is different and the educational system including for the elementary and lower secondary cycle are organized in a 9-year cycle system. The illumination of the classrooms is very poor and alarming in the same time because it affects the performance of pupils and teachers. The heating solutions of the past (wood stoves) and the actual ones (electric heating units) are inefficient and contribute to increase of power consumes too. Air control with is also problematic because their rigid layout allows only one type of ventilation. Schools in remote rural areas are much penalized, from the criteria ranked in the Law nr.69/2012 that privilege the most the renovation or refurbishment of school buildings with bigger number of classrooms. Not less irrelevant is the shortage of classrooms that constraints the split of the didactic activity between morning and

[49] Are the existing school buildings in Albania decent learning spaces?

afternoon in the urban centers the most but even in the rural areas as well. The design approach in the past very different for the schools in the rural areas compared to those of the urban areas, has driven to modification of their interior layout by sacrificing spaces dedicated for classrooms to incorporate hygienic services within the main building, once expected outside it. Furthermore, indoor gyms are absent in almost 90 % of the critic cases, a consequence of the past design approach extended in the urban and rural centers. In light of this problematic situation, the existing school buildings can be improved only by elaborating a strategy driving their transformation in relation to the capacities and facilities demand for the nine-year cycle system and the necessity to refurbish in order to transform them into nearly Zero Energy Buildings (nZEBs). Separating these two issues will not resolve the current situation, for these reason it is required the collaboration between government and municipalities to elaborate a roadmap.
Recalling the second question of the research[50], the refurbishment of the existing school buildings in Albania with interventions aiming their transformation into nZEB is possible in presence of regulated energy efficiency framework with an energy certification system and requirements for the building envelope as well. Despite the good will to transpose in the national legislation the two important EU directives in the national legislation (EPBD recast 2010 and EED 2012), the approval of the necessary acts to activate them should not be postponed anymore. In light of the undefined situation, the refurbishment of the six analyzed cases, highlighted the absence of a clear goal to pursue in terms of energy efficiency. The refurbishment in an nZEB perspective is possible because the energetic scenario of the country is different in comparison with the EU where most of the power demand is produced from nonrenewable sources. Considering that about 93 % of the national power demand is produced by from hydropower stations, the refurbishment of the existing school buildings in an nZEB perspective can lead to scenarios that in the EU are expected to occur in 2030 and 2050. The decarbonization of the school building stock is possible in a shorter period, if renewable sources (sun and geothermal sources) are exploited by the refurbished school buildings. The refurbishment of existing schools should be facilitated by wider range of technological solutions

[50] Should existing school buildings in Albania undergo to refurbishment or demolished?

focused in the improvement of the building envelope elements and renewable energy systems. Fiscal incentives can help to stimulate the refurbishment of school buildings, considering the potential outcomes.

Recalling the third question of the research[51], a refurbished nZEB school building will not be a cost but a resource for the municipalities, responsible for their management. The refurbishment interventions may not reveal very effective if aiming only warmer classrooms during winter rather than places with a high indoor environmental quality in the entire year. In this perspective, an integrated design approach is fundamental to combine energy performance with the constant control of the environmental quality. The combination of sun-screening strategies with the natural ventilation ones is more effective compared to air-conditioning units in order to keep classroom cool by consuming zero of energy for cooling. The typological classification of the school buildings in the national territory, in relation to the capacity was very important to map their number and comprehend their design aspects. The proposed interventions in the building envelope were elaborated by the taking in consideration the building technology and the possible combination depending on the type of insulation used to achieve the established U-values. Through this approach it possible to reduce heat loses by at least 66,90 % and by over 75 % in ground floor slabs that are constantly avoid in the renovation interventions in Albania. Illumination of the classrooms, approached in an energy saving perspective if designed to achieve the required illumination levels (expressed in LUX) and combined with diming control, a school building can consume less power annually with a higher number of lighting fixtures in comparison with a low number of lighting fixtures that do not provide the necessary illumination. Power consume for illumination may become zero if there are installed PV panels to produce power and the residual power can be used to generate incomes for the school, a goal that is more than possible if referred to solar exposure map of the country. Totally, unexploited for heating and domestic hot water production is the energy deriving from geothermal sources. The benefits go beyond the economic aspects because the emissions of greenhouse gases are set to zero, aspect that should make the government to promote the exploit of this resource.

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[51] What the benefits by transforming existing school buildings into nearly Zero Energy Buildings?

Recalling the fourth question of the research[52], besides the differences of the energetic panorama in Albania and in the European Union, the morphology of the school building stock constrains the adoption of two approaches leading to the transformation of the existing school buildings into nZEBs. The first consisting in the refurbishment of the existing buildings by preserving the capacity whereas the second one included the refurbishment and increase of capacity. The importance of this approach deriving from the limited capacity of the existing school building in Albania and constraining the split of the didactic activity in two rounds (morning and afternoon) is crucial to the strategy. Depending on the availability of free space, to increase of capacity of school even the energetic consumes change in this aspect. This problem carried out in decades should end because a normal didactic activity cannot occur for some classes in the morning and for the rest in the afternoon. In a technological point of view, the solution is represented by implementing dry-construction methods, where rapidity of the construction process is combined with high thermal properties of the building system. The cross-laminated timber panels include these two properties but they are unavailable in the national market so the only solution remains to import them. Considering the reduction of the building construction time by nearly 70 % percent compared to traditional building systems, the government should seriously take this solution as chance to solve the "evergreen" question of the school building capacity and to stimulate a the creation of new model of production in the building industry in the country.

The "Hilary Clinton" school, chosen as case study, gave interesting results by comparing the two possible scenarios in terms of: (i) Energy Performance index (EPi); (ii) cost; and (iii) payback of the intervention. The first scenario, aiming the refurbishment of the existing building resulted with EPi equal to 12.33 kWh/square meters/year and a total cost of Euro 220,803 (ALL 27,114,484), whose payback time was of 7.6 years. On the hand the second scenario resulting with an EPi equal to 54.99 kWh/square meters/ year and a total cost of Euro 2,158,371 (ALL 265,047,999), whose payback time was of 49.6 years by using the CLT building system, and dropping to 29.5 years with traditional reinforced concrete buildings. Despite the enormous difference in the payback time, the increase of capacity with

[52] What the best solution to resolve the capacity problems of the school buildings in an nZEB perspective?

traditional building systems may be cheap but slow compared the expensive and fast CLT building system.

The first scenario, economically very advantageous, cannot be considered very rewarding for those attending the classes in the afternoon. In case the capacity, this approach is the best possible, but in most of the urban areas it is not. So, the refurbishment of the school buildings in an nZEB perspective, is more critical than imagined. But despite the costs, they are more convent than the total demolish of and the build of the new school with the desired capacity. In this perspective, we have to give credit (Yudelson, 2008) when affirming that the initial “hard” costs are followed with “soft” benefits including energy, water savings and productivity gains.

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3. Lezha
4. Kurbin
5. Mat
6. Diber
7. Kamza
8. Divjaka

9. Lushnje
10. Belsh
11. Selenica
12. Pogradec
13. Devoll
14. Korce
15. Kolonje
16. Vau Dejes
17. Patos
18. Rrogozhina

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