Methodology for adaptation of school buildings to climate change in Prague

Capital City of Prague

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Participatory Planning Laboratory

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Cover page: Extension and deep renovation of the Primary School and Kindergarten of Ota Pavel in Buštěhrad - an example of a comprehensive approach including technical measures to address climate change, as well as architectural and layout concept, design of outdoor areas and quality of indoor environment (source: Facebook of the Primary School and Kindergarten of Ota Pavel in Buštěhrad).

Page 5: Centre for Alternative Technology , Wales, England - rammed earth wall of the main lecture hall as an example of the use of natural building materials (source: authors' archive).

Content

Preface

The aim of the Methodology for adaptation of school buildings to climate change in Prague is to improve the adaptation of school buildings to climate change. The aim of the Methodology for adaptation of school buidlings to climate change in Prague is to provide school principals, founders, operators and users with guidance and inspiration on how to use the investment opportunity both to apply measures that will contribute to reducing the negative impact of buildings and their operation on the environment and to use this opportunity to enhance the overall quality of the building, i.e. to perform a broad revision of the existing architectural and operational design.

Meeting the users' current requirements for the operation and quality of the building, together with a technical solution in line with current trends, will extend the moral life of these buildings and contribute to the principles of sustainable construction.

In the territory of the Capital City of Prague, there are around 1000 school buildings and other educational facilities, which gives a huge potential for both mitigating the negative impact of the operation of these buildings on the environment and, in the case of school buildings, a huge potential for education and awareness raising in this area among pupils, teachers and staff, as well as the general public. It would be a mistake to waste this opportunity.

At the same time, technical measures in adapting buildings to climate change must always be assessed and applied in the context of the overall building quality, including its architectural and operational quality, the quality of the indoor environment, energy savings and the economic sustainability of the project. Indeed, in the past, many well-intentioned technical measures, motivated by the desire to reduce the building energy performance, have proven to be unworkable or even counterproductive. Unfortunately, there are cases where such implementation of building insulation has completely devastated the original valuable architectural expression of the building.

There are frequent cases where, with the replacement of windows and sealing of the building envelope and the absence of a mechanical ventilation system with heat recovery, the indoor air quality in the classrooms has been dramatically reduced due to the insufficient air exchange and high CO_2 concentrations. Paradoxically, the remedy of higher ventilation rates in winter ended up resulting in higher energy consumption in many places than before the windows

were replaced. Conversely, there are many examples where the implementation of a specific technical measure or solution to a particular school need has been used synergistically to improve the overall quality of the building both architecturally and operationally and technically.

Thus, the authors' aim was not only to identify individual technical measures to adapt school buildings to climate change but also to place these measures in the context of the overall quality of the building. They also aimed to outline the time sequence of individual steps in the preparation, design and implementation of the construction project and to highlight key milestones in the process of developing the terms of reference (TOR) and in the decision-making process. At the same time, the authors endeavoured to demonstrate the importance of participatory planning and to show possible forms of involvement of target groups, especially in the process of project preparation and development of the terms of reference. The document shows a number of examples that are intended to be an inspiration for school founders, school principals, teachers, parents, pupils and students, as well as the wider public on how to conceptually approach adaptations of school buildings. Even if this document inspires a single comprehensive project, it has fulfilled its purpose. However, let us hope there will be as many such projects as possible.

Team of authors

Introduction

There are currently many methodologies dealing with the quality of buildings and the built environment. In the development of the document Methodology for adaptation of school buildings to climate change in Prague the aim was to bring the requirements of the individual methodologies into harmony with each other and to implement the criteria from these methodologies so that they could be used in case of interest and so that the applied measures could be positively reflected in the overall evaluation. The following methodologies were considered to develop the document: SBToolCZ EDU, Water in the City: Methodology for stormwater management in relation to green infrastructure, and Methodology for planning public spaces of small municipalities.

SBToolCZ is a national methodology for assessing the comprehensive quality of buildings, where the performance of the building and its surroundings is evaluated in relation to sustainable development. The environmental performance of the building, socio-cultural aspects, functional and technical quality, economics and management, and the location in which the building is built are assessed. The SBToolCZ methodology exists for selected typologies of buildings, including a version for school buildings called SBToolCZ EDU. This specific methodology highlights building qualities that are not included in the applicable standards and regulations, which are soft criteria with a broader social impact. These are crucial for the quality of the educational process, important for the development of the child's personality, they are applied in building the relationship between the family and the school and, last but not least, in extracurricular education, in community activities with a broad social impact, thus fulfilling the mission of the school as an educational institution. The methodology is intended for primary and secondary schools of all types.

Water in the City: Methodology for stormwater management in relation to green infrastructure focuses on sustainable stormwater management in urban environments and was developed as part of a two-year collaboration between the teams of UCEEB CTU (University Centre for Energy Efficient Buildings of the Czech Technical University) and Jan Evangelista Purkyně University in Ústí nad Labem with the support of the TAČR CR (Technology Agency of the Czech Republic) and the Ministry of Environment of the Czech Republic. This publication guides city officials through the preparation, planning, implementation and maintenance of stormwater management (SWM) measures in relation to blue and green infrastructure and is intended for city representatives who want to manage stormwater more sustainably and

support other urban systems through this approach. It helps to navigate through the various more technical and nature-friendly SWM measures, describes their process flow from building permit to maintenance, and highlights the positive impacts of SWM measures and the blue and green infrastructure system at the scale of the entire city and individual public spaces. The methodology is available for free download on the website www.vodavemeste.cz.

The Methodology for planning public spaces of small municipalities, which was developed with the support of the Czech Republic's Technical Development Agency and the Central Bohemian Innovation Centre, is the outcome of a three-year effort of urban planners and social science team from UCEEB CTU. It helps representatives of smaller municipalities to understand the issue of public spaces for subsequent negotiations with experts and authorities, guides them step by step through the process of preparation and formulation of the study terms of reference and describes recommended procedures for selecting a study preparer. Several annexes follow this central part - the first set of manuals describes the basic principles of a quality physical (architectural) environment of public spaces as well as ways and procedures on how and why to involve the public and identify their needs. The second set of manuals contains a recommended list of terms of reference chapters for the different types of studies defined in the Methodology. The Methodology is available for free download on the website www.atraktivniobec.cz.

1

Society and Climate Change

Buildings contribute significantly to climate change. In EU countries, 40% of all energy produced is consumed by buildings; thus, the operation of buildings increases energy demand and, therefore, greenhouse gas emissions.

1.1 Overview of Climate Change

The impact of human activity on the planet's climatic conditions, including the average temperatures, is gradually increasing. Human activity produces vast amounts of greenhouse gases (GHG), which trap heat from the sun's radiation on Earth. This phenomenon is known as the greenhouse effect, which is the main cause of global warming. Among the GHG, carbon dioxide (CO_2) is the most significant contributor to global warming. In 2020, its concentration in the atmosphere had increased to 48% above pre-industrial levels (before 1750). The average global temperature in 2019 was 1.1°C above pre-industrial levels. A temperature increase of 2°C above pre-industrial levels would seriously negatively impact the natural environment, human health, and prosperity. Therefore, the international community has agreed on the need to keep the warming below 2°C and continue the efforts to limit it to 1.5 °C.

The main forecasted global warming and climate change impacts for the Czech Republic are long-term drought, floods and flash floods, increasing temperatures, extreme weather events, heavy precipitation, extremely high temperatures (heat waves), extreme winds and natural fires [1].

1.2 Human impact on Climate Change

The human impact on climate change is mainly due to (i) the burning of coal, oil and natural gas, which produces carbon dioxide and nitrous oxide, (ii) the cutting down of forests (deforestation), lowering the power of trees to absorb CO_2 from the atmosphere, (iii) the intensive rearing of livestock, as these produce large amounts of methane during digestion, (iv) the use of fertilisers containing nitrogen, and (v) the use of equipment that emits fluorinated gases.

Two basic types of action can be taken in response to climate change:

- **Mitigation measures**
  Direct or indirect measures to reduce greenhouse gas emissions (e.g. more efficient use of energy sources, use of solar or wind energy, efficient thermal insulation of buildings, etc.).

- **Adaptation measures**
  Measures to adapt a natural or anthropogenic system to actual or projected climate change, including its impacts [1].

1.3 Climate Change, cities and buildings

Buildings

They contribute significantly to climate change. In EU countries, 40% of all produced energy is consumed by the building sector; consequently, the operation of buildings increases the energy demand and the GHG emissions. However, it is essential to highlight that the annual growth rate of new buildings is only about 1%, **the greatest potential for savings is in the renovation of existing buildings.**

Building developments

They significantly change the landscape and the biodiversity of the environment, which is particularly affected in case of extreme weather events; a high density of urban development increases the temperature of the outdoor environment during summer heatwaves. During heavy rains, large paved areas have no capacity to absorb the amount of water and are one of the causes of flash floods, etc.

Transport

It is another major consumer of energy and thus contributes to the production of greenhouse gases. Promoting more environmentally friendly forms of transport in cities and creating the necessary infrastructure in cities and buildings is one of the measures that can help reduce the impact of transport on climate change.

Examples of mitigation measures in buildings include e.g. more efficient use of energy sources, use of solar or wind energy for heating and hot water, insulation of buildings and reduction of heating energy, greenery on buildings, promotion of walking or other alternative non-motorised transport, cycling, electromobility, etc.

1.4 Climate change and its impacts in Prague

Climate change in Prague is manifested by an increase in air temperature, the formation of heat islands in the city and an increasing frequency of heat waves. According to climate projection models, these manifestations will further intensify.

The effect of precipitation is similar. Annual precipitation totals are expected to be similar to the present situation, but winter precipitation totals will increase, while summer precipitation totals will decrease. The number of rainfall-free days and dry spells is expected to rise significantly soon. The frequency and severity of heavy rainfall are expected to grow, as well as the occurrence and duration of rainfall-free episodes and droughts.

Higher frequency and intensity of other extreme hydrometeorological events (e.g. thunderstorms, hailstorms, strong winds) are expected.

The design and implementation of appropriate adaptation measures can gradually mitigate these negative impacts and create adequate living conditions for the inhabitants of Prague.

Consequences of the storm in Prague on 21 October 2021. Wind speeds reached up to 102 km/h. (source: www.nasepraha.cz)

2

Adaptation of school buildings to climate change

The planned renovation of a building is a unique investment opportunity to achieve a higher technical standard of the building, but also to increase the value of the building and make modifications that reflect current trends and the users' operational needs.

2.1 Buildings and their life cycle

The operation of buildings, i.e. energy consumption for heating, cooling, hot water, but also their transport connections and supplies, routine maintenance, etc., contributes significantly to the production of CO_2 emissions into the atmosphere and thus to climate change and global warming.

The real lifetime of these buildings is many decades, while architecturally valuable and timelessly designed buildings can stay for a hundred years or more, if properly maintained and if their technical lifetime is preserved. In contrast, the lifetime of some substructures and elements or technical systems in the building is an order of magnitude lower. The technical infrastructure in the building, e.g. energy sources, terminal equipment, distribution systems, must be replaced several times during its lifetime, while other parts, such as windows, facades, roof cladding and others, are usually replaced at longer intervals. The planned renovation of a building is then an investment opportunity to increase the value of the building and make modifications that reflect the current quality standards and operational needs of the users, thereby increasing the building's moral life. The renovation of existing buildings, provided they meet current technical requirements for their quality, i.e. the use of existing structures, technical and transport infrastructure in cities, is a more valuable approach in terms of sustainable construction than the construction of new buildings.

Given the requirements to reduce the negative impact of buildings on the environment, any such investment is an opportunity to apply climate change adaptation measures.

2.2 Social significance of school buildings

Buildings for education have a number of specific features compared to buildings for housing, administration, production and trade, etc. The school as an institution ensures a quality educational process for pupils and students, but also performs an educational function for the wider public. In addition to teaching, schools influence pupils and students at the most receptive and sensitive period of their development and naturally affect the surroundings and those who come into contact with these institutions, i.e. students' parents and other public visitors. By their architectural expression and aesthetic quality, as well as the way in which they fit in the public

space, school buildings should express their irreplaceable social significance, cultivate the built environment, positively inspire users and visitors and offer a pleasant meeting place for children, teachers, parents and the wider public.

Conversion and extension of a primary and polytechnic school in Schwanenstadt (Austria), PAUAT Architekten, 2007. The original building from the 1960s with a reinforced concrete skeleton and facade panels made of washed concrete was rebuilt using prefabricated wooden elements of the envelope. The new part of the school was built as a timber frame clad with the same prefabricated elements. The aim was to reduce the energy consumption of the building, to use renewable energy sources, to improve the quality of the indoor environment in terms of ventilation, daylighting and acoustics, and to give the building a new architectural expression. This is the world's first conversion of a school building to passive standard and the first renovation of a public building to passive energy standard in Austria (source: Kateřina Mertenová, photo: PAUAT Architekten/Luttenberger).

3

Comprehensive quality of school buildings

The comprehensive quality of a building is determined by its architectural, operational and technical design. All these parts must be in harmony with each other.

The school as an institution plays an important educational and awareness-raising role in society. The overall appearance and architectural quality of a school building should also reflect its social significance, and its technical design should show current trends in construction and architecture and inspire its users, surroundings, and visitors.

3.1 Architectural quality of the building

The architectural quality of buildings for education represents a significant social value. The architectural quality of these buildings is an integral part of educational outreach. With its representative, but at the same time original and contemporary architectural expression, the building should constitute an aesthetic legacy of the time. It is not only about the external appearance of the building but also about the quality of the interiors and functional operational solutions. This is evident in many historic school buildings.

Extension of the after-school care centre at the Újezd Primary School in Pilsen, Projektstudio8, 2018. The modern extension complements the original historical neoclassical school building from the second half of the 19th century in a contemporary form (source: www.archiweb.cz).

3.2 Public space and public areas

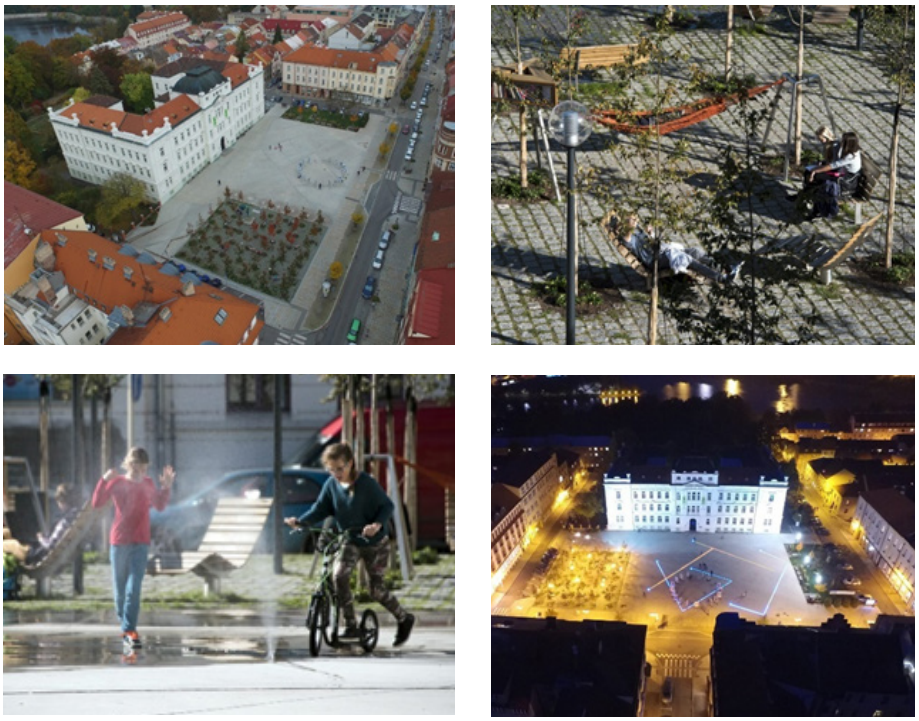
Buildings for education are often located in places of urban planning importance, in squares, major street crossings and parks, they constitute a dominant feature of the area, a natural social centre, and together with their immediate surroundings, the so-called parterre, they significantly complete the public space, the so-called public open space, i.e. the outdoor space accessible to the public without restrictions. Therefore, the architectural quality of not only the school building itself, but also the quality of the public space in the immediate vicinity, in front of the main entrance, etc., is of great importance.

If the building itself constitutes a dominant feature in the locality, then the quality

design of the public space should underline and emphasize this position, both in terms of the imaginativeness of the design itself, the quality of the materials used, the quality of the detail, the quality and design of the furnishings, etc. The design of the entrance parterre should then be consistent with the architectural design of the building itself. The architectural treatment of the public space should respect the locality's character and allow the school building to integrate naturally into the surrounding development.

When designing, it is advisable to consider what function the public space is intended to fulfil, what the possibilities are with regard to its wider use, especially in relation to the traffic congestion of the locality, what age group of pupils the school is intended for, whether it is possible to safely spend time in the place after school hours playing, relaxing, e.g. when waiting for older siblings or parents, or whether it is possible to use the public space for other than school events.

If a public space has the potential for wider use, then it should be safe, contain attractive play elements for pupils of the appropriate age, but also for other age groups, and be presentable and multi-purpose.



TGM Square in Tábor - public space in front of the Secondary School of Agriculture. The square is divided into three zones. The peripheral ones are designed as relaxing areas with the dominance of mature greenery, semi-permeable surfaces and traditional and original seating (e.g., benches and hammocks). A central area made of poured concrete, which can withstand the increased movement of pupils, allows use for cultural and social events organised by the school and the city. This area contains water features that cool the entire space in the summer months (source: www.archiweb.cz).

3.3 Private school premises, school gardens and grounds

A number of schools have more or less extensive grounds that allow creating so-called private school premises. These areas can then be used for a variety of school and extra-curricular activities, such as outdoor learning opportunities, development of pupils' skills and relationships with nature, sports activities, or the possibility of relaxation and cultural and social activities not only within the school but also within the local and broader community, etc. School grounds are usually enclosed, with access only for school staff and pupils, and sometimes for parents. In any case, it is advisable that access to the school grounds is controlled and secured during school hours and when pupils are present. In certain situations (such as after-school clubs, school gatherings, farewells to alumni, Christmas parties, etc.), these areas are accessible to the public related to participants in the events or the institution itself. They become part of the public space, with parents, grandparents and former pupils and staff visiting the school grounds at such times. School facilities have great potential to shape and sustain community togetherness in the long term.

While the main entrance area at the school's front should always be presentable, the school garden should offer a safe space and privacy for internal school activities. Security is of great importance, and the school garden should be fenced, allowing controlled entry of people and preventing outsiders' access while allowing teachers to control the whole area clearly.

The school garden as an educational space is particularly important for pre-school and first-grade pupils, who discover the world around them and its patterns through play, developing their imagination and inner world. At first sight, such school gardens should attract children to be outside, explore, hide, and play. There is no need to use artificial materials and garish colours, which children often do not appreciate. It is better to emphasise using natural materials to encourage children to interact with nature. There is also no need to choose a surface material made of artificial rubber; clay, mud, grass or bark are more suitable solutions.

For pupils and students from the second level and third level of education, the school garden should provide facilities for learning appropriate to the school's specifics and specialisation. Not only for pupils and students but also for teachers and staff, the garden should provide space for sports activities or active rest and relaxation between lessons. A specific theme is the possibility of using the school

garden facilities for the wider community, both for sports and social events. Here, the entrance and security of the site need to be addressed appropriately.

The technical design of the school garden includes the design of vegetation and the design of furniture according to the age structure of the pupils and the preferred use. When designing the play elements, furniture and greenery, priority should be given to ease of maintenance, ensuring a suitable microclimate (combination of shaded and sunny areas, leeward areas) and a suitable operational connection between the school's interior and the garden (e.g., through a terrace or vegetated green roof).

The architectural and design character of the garden elements, i.e. benches, play equipment, lighting and walking areas, additional buildings (storages, gazebos, shelters, etc.), should be integrated to form a single whole. Ease of maintenance and durability is a priority; e.g. clay paths, stone paving, etc., which are not subject to the same degradation as large-format paving, are preferred. For vegetation, species should be chosen that are not only aesthetically attractive, colourful and form a colourful composition in different seasons, but also species that are safe, minimising the likelihood of injury, i.e. thornless species; furthermore, plants with inedible or even poisonous fruits and those that excessively attract insects should be avoided.

It is essential to create facilities for garden use and operational links to the indoor areas of the school or after-school care centre. Basic sanitary facilities should be accessible from the exterior for garden use, whether in the form of a suitable operational connection to facilities within the building or facilities within the garden. Appropriate storage space for mobile outdoor equipment for events and other activities is also important.

As part of the extension and reconstruction of the canteen of the Primary School and Kindergarten of Ota Pavel in Buštěhrad, modifications were made to enable better operational connection to the school garden. The internal space was reconstructed in the next stage, allowing the garden to be used for both school and extra-curricular activities (source: Facebook of the Primary School and Kindergarten of Ota Pavel in Buštěhrad).

3.4 Technical facilities of the school

Technical facilities of the school consist of areas that serve the school's operations and supplies, e.g., warehouses, unloading ramps, waste sorting and storage areas, waste bins, containers, etc. These areas often look unsatisfactory and unmaintained. Especially if they are in close contact with public or private areas of the school or if their operation intersects with the school's operations for pupils and teachers or the public, they negatively affect the overall impression of the building. However, even these facilities, e.g. waste separation areas, can be used in the educational process to present environmentally friendly and responsible behaviour and can be used to motivate and build appropriate habits.

Therefore, these spaces need to be addressed both in terms of architectural design and building operation. The aim is to ensure that supply operations do not conflict with normal school operations. Ideally, the places intended for supply do not visually or operationally degrade the outdoor space, i.e. they are designed within the mass of the building; a ramp handles the supply. The waste storage area shall be ventilated, easy to maintain and clean (smooth and washable surfaces, floor drain, etc.).

If these operations cannot be incorporated into the building mass, the aim is to avoid their crossing with school operations and to relocate them to less visually exposed areas, or to solve their screening with visual barriers, either structural or in the form of greenery. Where these operations cannot be visually screened, care should be taken in managing the maintenance and cleaning, allocating capacity for regular cleaning and resources for faster restoration and maintenance of these areas.

3.5 Technical quality

Even from a technical point of view, buildings for education should also present current and future trends and innovations not only in the construction industry, but also in other technical sectors, and thus be an inspiration for adult visitors as well as for pupils and students.

Technical fields have traditionally been an important sector of the economy in the Czech Republic, so inspiration in this area has a society-wide benefit and buildings for education can play an important function here. The application of the motto "School as a Teaching Tool" can help to

fulfil this mission, as the technical design of the building or its parts can be visually presented, explained and commented on, or directly used in the teaching process. In this way it is possible to present, for example, the use of natural and recycled materials in the structure of a building, energy systems in a building, the use of RES, water and waste management, etc. For visitors to the building, the technological solution can serve as an interesting inspiration.

Forms of fulfilling the motto "School as a Teaching Tool" can be various, e.g. revealing part of the structural and material design of a building with an explanatory description, observable and commented systems of technical building equipment, an observable technical room, information systems presenting current energy consumption and production, etc. This approach places higher demands on both the design and the quality of the actual execution on site so that it is sophisticated, visually attractive and has aesthetic value. It is important to supplement the presented systems with explanatory descriptions and comments.

Interior of a passive kindergarten in Vienna, Schukowitzgasse, architect Georg W. Reinberg, 2006. The systems of technical building equipment, HVAC ducts, and the technical room are part of the interior design concept and can be used in the interactive learning experience within the "School as a Teaching Tool" concept (source: www.reinberg.net).

Reconstruction of school and gymnasium extension, Allentsteig, Austria.
The construction was carried out as a pilot project and the first public building using straw in the EU countries in 2003. During the implementation, emphasis was placed on using locally sourced materials (wood, straw) (photo: A. Brotánek).

4

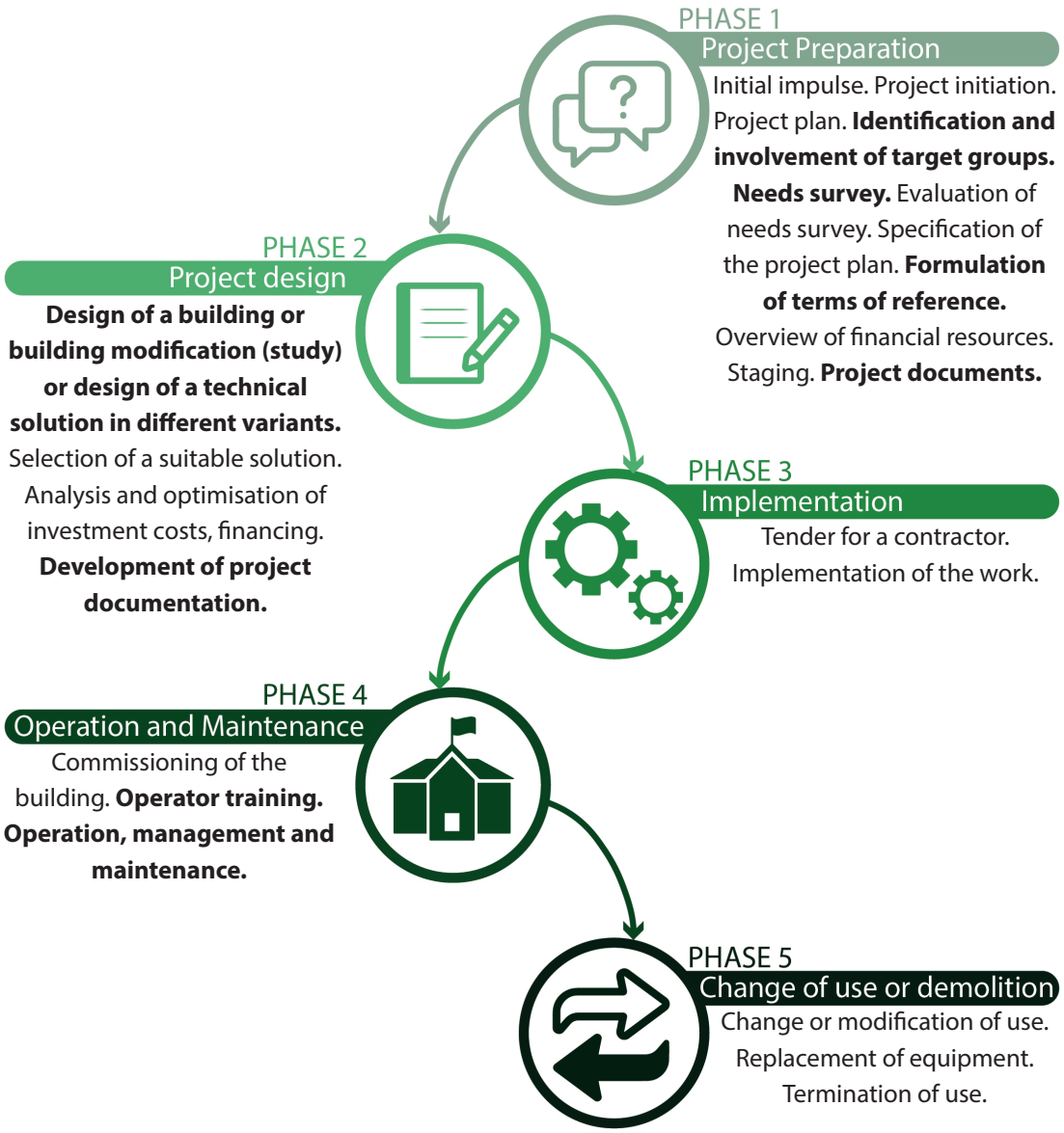
Project Management

One of the specifics of the construction process is its length and the number of participants. The project, from the conceptual design to the implementation and commissioning, takes several months to years, depending on its nature. During the process, in various stages, it is necessary to communicate with a wide range of participants and coordinate the various steps.

Construction projects, new buildings and renovations, extensions or additions are very complicated managerial tasks. Their specifics include: (i) the demanding process of preparation and actual implementation, the originality and uniqueness of the entire project, individual architectural and technical, (ii) technical solution of each specific project, (iii) great number and a wide range of participants and target groups with whom it is necessary to communicate during the project, (iv) the specifics of public procurement, (v) renovations and adaptations.

4.1 Project phases

The whole process of implementation of the construction (investment) plan includes 5 main phases, which contain further sub-steps:



It is clear from the above overview that pre-project and project preparation include a number of important steps and decisions that are critical to the future direction of the project. Many of these directly involve users and target groups who help define the terms of reference and thus directly contribute to the outcome. On the one hand, they can influence the direction of the project through their preferences, and on the other hand, they are co-responsible for the outcome. Unfortunately, this preparatory phase is often underestimated at present.

While climate change adaptation measures are technical, they also affect the overall quality of the building and must therefore always be considered in the context of the whole building.

4.1.1 Project preparation

Initial impulse. Project initiation. Project plan

The **initial impulse** for a construction project might be the achievement of the technical or moral lifetime of a building, its substructures or elements or systems of technical building equipment. The technical lifetime may concern, for example, certain types of envelopes, such as the metallic curtain walls, window openings, etc. In the case of systems of technical building equipment, this includes, in particular, the ageing of boiler rooms, heat exchanger stations or specific distribution systems. Achieving moral lifetime technically refers to building envelopes and the need to insulate them, the need to repair plasters, coatings, etc. Achieving moral lifetime also relates to inadequate layout and operational arrangements, or the solution of insufficient capacities, either in terms of undersized or oversized conditions.

The project initiation is the milestone at which the decision is made. The initiator may then be the founder, operator or user,

Existing building of the Postřekov Primary School was built in 1972 according to the project of Arch. V. Filsak as an experimental wooden pavilion school building according to the Finnish model with a planned lifetime of 15 years. Despite the unsatisfactory technical condition, the building is still in use, exceeding its planned lifetime more than three times. The operational and architectural design is very advanced for its time and completely functional, as evidenced by the very positive evaluation of the current operation in the sociological survey. A complete refurbishment is currently under preparation. Photo from the technical inspection of the building before the preparatory phase of the construction process (source: authors' archive).

or member of one of the target groups that is not satisfied with the existing situation. This party initiates the solution to the unsatisfactory situation. The initiator also predefines the **project plan**, i.e. the main objective of the planned investment project. The preliminary definition of the project plan can be prepared by a layman, it does not need to have a professional basis; it is further defined in the following stages of project preparation.

Identification and involvement of target groups. Needs survey

One of the important tasks in the project preparation is **identification of the affected target groups**. This task is the responsibility of the initiator, or the founder or manager (coordinator) of the project. Even seemingly narrowly limited investment projects can affect a wider range of participants, and it is therefore advisable both to identify their needs and suggestions and inform them appropriately about the progress of the project.

The role of the affected target groups is crucial in the preparatory phase of a construction project when individual actors give input to the preliminary project plan through a **needs survey**. The project plan is then further elaborated and refined. This is the so-called **participatory planning process**. Involving target groups in the process brings the following benefits:

- **identification of operational or technical problems** within the participatory planning process that can be synergistically solved with the intended project plan,
- **the possibility of influencing the whole process from the beginning leads to a higher acceptance rate of changes or constraints during construction**,
- the involvement of users allows for the explanation of trade-offs.

Unfortunately, participation and communication with target groups is often an underestimated, yet crucial part of project plan preparation. How we involve future users in the project and enable the transfer of information to the implementers is crucial for the quality of the final result. The best technical solution and an army of experts on the implementer's side will not ensure the desired effect and user satisfaction if the terms of reference are incorrectly or carelessly formulated.

Every project should define a communication strategy with the target groups. Their involvement can be handled in different ways and varies according to the relevant phase of the project, but does not have to be time-consuming, technically or financially demanding. Examples of communication strategies for different target groups are given in the following chapters.

Evaluation of the needs survey. Specification of the project plan. Formulation of the terms of reference

An important step is the correct **evaluation of the needs survey**. It is necessary to filter out irrelevant comments and categorise and prioritise suggestions for the project plan. There are often harsh evaluations in the survey that stem from frustration with the status quo or the current mode of communication. These remarks should not be ignored but instead commented on or explained. At the same time, unrealistic suggestions and demands may occur, and these responses should also be commented on factually, and the possibilities and limits of the specific construction project explained.

Based on the needs survey results, **the project plan is updated and specified**. Its final form should be presented and explained to the addressed target groups.

The result of this stage is the **formulation of the terms of reference** for the preparers of the relevant parts of the project documentation. For larger investment projects, an architect or a designer/engineer/expert in the relevant technical field can assist with the formulation of the terms of reference. Professionally formulated terms of reference will be easier to understand.

Overview of financial resources. Staging

In connection with the specification of the terms of reference, it is necessary to review the **financing options for the construction project** or to address the project in different alternatives. In several cases, some **staging** may be applied, whereby the project plan primarily addresses the current part of the project, but the investment project is prepared for follow-up investments and projects. In the optimal case, the implementation of individual measures is carried out in accordance with the long-term investment plan.

Project documents

As part of the preparatory phase, **project documents** for the intended project plan need to be secured. The scope of the project documents corresponds to the expected scope of the project plan. This usually includes documentation of the current condition of the building, surveys of current condition of the equipment, technical surveys of the building, and surveys of the surrounding area.

Building architectural survey - it is

essential for cultural heritage, but also buildings with so-called recognised historical value. Even a building that is not subject to preservation of monuments can be valuable for its authentic period architectural design or functional design, and it is advisable to preserve these values for future generations during building modifications. This can apply not only to historic buildings from the second half of the 19th or first half of the 20th century but also to buildings from the post-war era. The assessment of architectural value should be carried out by a professional.

Building and engineering survey - this is an often neglected but very important part of the documentation for a comprehensive and correct design of renovations, extensions, additions or modifications. High-quality building and engineering survey will enable a more accurate determination of the costs of the investment project, where the necessary investments in the security of existing structures are already envisaged in the design of the solution. The building and engineering survey includes a detailed study of the existing condition of the building, assessment of the overall condition of the building and its main structural parts, surveys of moisture status and salinity of the masonry, a mycological survey, and a structural assessment of the existing structures.

Building site survey - in the case of an extension, addition or other building modification extending the existing building programme, the technical condition and surroundings of the building should be assessed. This relates to, e.g., a topographical and elevation survey of the site or the existing state of the building, foundation conditions, cutting of mature vegetation etc. For these purposes, a hydrogeological, radon or dendrological survey is prepared. The scope of surveys for a particular project plan may be determined by the project manager or the contractor for the relevant part of the project.

4.1.2 Project

Design of a building or building modification (study). Design of a technical solution

Depending on the nature of the investment project, an architectural study or technical design is prepared in the first phase.

The **architectural study** shall include the design of the architectural and/or layout solution of the extension, addition or modification. The project promoter (initiator) should be continuously consulted during the preparation phase. The conceptual design does not have to be elaborated in all details and particulars in the first stage, on the contrary, it should be solved conceptually and in variants.

These variants should then be shared with the target groups, and the further direction of the project should be decided transparently. The project should then be refined according to the comments.

The design of a technical solution pertains mainly to investment projects that address the technical systems in the building. In the vast majority of cases, this is a technical matter; however, there are always solution options with a broader impact on the operation of the building. An expert in the field should prepare the technical solution options, and the project initiator or manager should then assemble a closer working team representing the target groups to assess the suitability of the proposed solutions. In the case of technically complex tasks, the project initiator or manager may approach an independent expert to consult on the proposed solutions.

Selection of an appropriate solution

A **suitable solution shall be selected** based on the options presented. This must, in any case, be transparent. In choosing the appropriate solution, it is important to compare the final state with the terms of reference defined in the project preparation phase and assess how the requirements and suggestions of the target groups have been met.

Analysis and optimisation of investment costs, financing

The resulting solution must be confronted **with the expected investment costs**. It may happen that in the effort to meet all requirements, the financial limits set are substantially exceeded. In this case, it is necessary to either seek additional financial resources, optimise the resulting solution, or spread the proposed solution over a more extended time, e.g., by project staging.

Development of project documentation

Depending on the nature of the investment project, a specialist contractor prepares the project documentation for the relevant phases based on an architectural study or a technical design. The contractor deals with the related engineering activities at this stage, e.g., issuing planning permission, building permits, etc. The result is the documentation for the execution of the construction or the documentation for the documentation for a tender. At this stage, the project initiator or the project manager, or a professional body authorised by him/her, checks the progress of the design work and compliance with the terms of reference.

4.1.3 Implementation

Tender for a contractor

A tender for a contractor is subject to Act No. 134/2016 Coll. on public procurement. Particularly for larger investment projects, a specialist firm can conduct a tender for the entity and ensure procedural correctness.

Implementation of the work

The implementation of adaptation measures and related interventions in the building is professional responsibility of the contractor. From the point of view of the users and affected target groups, it is important to require the contractor to provide a clear timetable for the works, to specify the restrictions on regular traffic or to seek solutions that will minimise the restrictions on regular traffic. This includes, in particular, the closure or interruption of existing traffic links, restrictions due to noise and dust during the construction works, or restrictions on regular traffic during the supply of the construction.

Restrictions on regular traffic must be clearly defined in time and determined by the schedule of works, any changes to the schedule and associated restrictions must be communicated by the contractor to the client or project manager.

4.1.4 Operational stage

Commissioning of the building. Operator training

The commissioning of a building or technical installation marks the completion of the project plan. The actual commissioning is preceded by an **inspection or approval procedure**, depending on the nature of the project. These actions should be taken by the contractor and should be part of the contractual arrangements.

It is important for the client (initiator) or the person authorised by the client (administrator, school janitor, facility manager) to be thoroughly **familiarised with the actual condition and the maintenance and inspection plan** of the building or technical equipment.

For the users themselves, thorough **equipment operator training** is then necessary. In the case of a large-scale event that affects a wider range of target groups, the commissioning of the building is a good opportunity to **organise a festive gathering**. Such events informally deepen relationships and bonds between users and have a positive social impact.

Primary School and Kindergarten of Ota Pavel in Buštěhrad. Ceremonial handover of the extension of classrooms and canteen (source: authors' archive).

Operation, management and maintenance

The management and maintenance of the building or technical equipment is entirely the responsibility of the operator. It is important to proceed in compliance with the maintenance and inspection plan that has to be a part of the handover documentation.

4.1.5 Change of use or demolition of the building

Change or modification of use. Replacement of equipment

A request to change or modify the use of a building or portion thereof, or a request to replace equipment, brings the entire cycle back to the beginning of the project preparatory phase. This starts the process again from the beginning and follows the steps outlined above.

Termination of use

In rare cases, operator or founder may decide to terminate the use of the building. The affected target groups concerned should be informed well in advance of such a step.

4.2 Participants, target groups

The wide range of participants in construction projects for public buildings, including school buildings, is one of the important specificities. The following overview of the participants in the process aims, in particular, to show the inclusion of target groups as partners in participatory planning and to describe their role in the relevant phases of the project.

Initiator

He/she/it gives the founder the initial impulse for change. The initiator is usually motivated by a desire to improve the status quo. The initiator can be a user (teacher, pupil, member of staff, user or visitor), founders (relevant sections of municipal districts, private founders), etc. The initiator is usually familiar with the existing situation and is also the first to formulate a basic idea for changes and adaptations. This initial idea should be consulted with the affected target groups and experts. The initiator acts at the beginning of the construction project and is involved in the whole process.

Founder

He/she/it gives the initial impulse and creates the conditions for founding an educational facility, setting the principles and rules for its operation. Schools and educational facilities may be established by a region, a municipality, a voluntary association of municipalities, or a ministry, registered churches and religious societies, other legal entities or natural persons. The founder monitors or coordinates the individual construction projects.

Users and target groups

Users and target groups are all those who either directly use the school and its facilities or come into contact with it somehow. The primary users are:

- **pupils and students,**
- **teachers,**
- **staff and non-teaching staff,**
- **parents of pupils,**
- **target groups** that use the school's facilities outside the school hours - e.g., cultural and interest groups and associations, natural persons or legal entities who rent the school premises commercially for their activities, residents of the locality who use the school's services and facilities, e.g., for catering, etc. The range of target groups can be vast and varies according to the nature of the educational establishment and the extent of the facilities.

The affected target groups are part of the construction project throughout its duration. In the **Preparatory Phase**, the target groups are actively involved, helping shape the project terms of reference through a needs survey, commenting on the proposed design options, and ideally participating in selecting the final option. During the **Design Phase** and the **Construction Phase**, they are informed about the current progress of the works, the schedule of works and its changes, or

measures affecting their activities. In the **Building or Modification Commissioning Phase**, they are to be familiarised with the new condition or trained to operate newly installed equipment. They can then give valuable feedback on the outcome of the construction process during actual operation.

Project manager, coordinator

The role of the project manager is to guide the initiator, the founder or the user through the entire process of the construction project and to help them with the preparation of the terms of reference, the development of the concept, communication with the target groups and the contractors of the individual parts. In practice, the role of coordinator is often played by the founder or the school's principal. Unfortunately, due to the lack of expertise and time commitment and the need to deal with other operational tasks, this role is not sufficiently secured, which often leads to procedural errors that negatively affect the outcome of the event. The project manager (coordinator) manages the entire construction process; he/she is the key person and is part of the whole process throughout its duration.

Facilitator

A person who seeks consensus in the case of major disagreements between different target groups in the process of formulating the terms of reference. A facilitator is present when stakeholders cannot reach a consensus on the project's future direction. The project initiator or manager usually recommends the presence of a facilitator.

Preparers of subparts in the preparatory phase and the design phase

These are qualified experts who prepare documents for the initiator, the founder or the users in the individual phases and stages of the project for communication with the target groups or as a basis for the contractor. These professions are:

- **psychologist, sociologist** - they help with the identification of target groups, communicate with them in the preparatory phase, prepare and evaluate the needs survey, participate in the development of the terms of reference;
- **architect in the preparatory phase** - in the initial phase he/she can help with the development of the terms of reference, preparation of conceptual documents (feasibility study) for communication with target groups within the needs survey, helps to formulate the terms of reference;

- **engineering activities for founders** - mainly applicable to renovations, extensions, additions of existing buildings or replacement of existing technical equipment of buildings, preparation of a building and engineering survey of the existing condition of the building or assessment of the technical condition of the equipment;
- **architect as a design preparer** - based on the terms of reference, he/she prepares design options;
- **architect/designer as a supplier of specific parts of the project documentation in the relevant phase** - in accordance with the architectural design or other terms of reference, ensures the preparation of project documentation, including relevant engineering activities;
- **expert consultants** - invited experts providing specialised consultancy in the relevant field, e.g. energy specialists, grant specialists, consultants in the field of complex building quality, companies providing tenders for public contracts, etc. Expert consultants are involved at the appropriate stage of the project according to the nature of the tasks they are providing. Their role is time-limited.

Investor (client)

A person in a contractual relationship with the general contractor of the work or its part.

Contractor

A natural person or legal entity providing the supply and execution of the subject of the contract/work.

Technical supervision of the investor

A person inspecting the progress of construction or other works or delivery of the work and their compliance with the contract and the project that has been approved by the investor.

4.3 Participatory planning

Participatory planning is one of the tools to achieve a comprehensive quality of a building or building modification in terms of aesthetics, operational and technical aspects. Involving the project's target groups can help better understand the context in which the new solutions will be implemented.

There are always several options for each building project. These should be conceptually designed and discussed with the target groups at the initial design phase. On the basis of preferences and the participatory planning process, it is then possible to select a preferred option, which is elaborated in detail for design purposes

and subsequently implemented. In this way, the diverse needs and perspectives of the different target groups can be taken into account and an optimal solution can be achieved that fully suits everyone.

Target groups often deal with common operational problems that are not directly related to the proposed project. This perspective should also be perceived and, if possible, placed in the context of the prepared project plan. Even with seemingly irrelevant suggestions, building users can provide valuable information about how a building currently works and highlight technical or operational issues that need to be achieved. Many of these suggestions can then be addressed synergistically as if "beyond" the project's scope.

Furthermore, it is crucial to understand how key stakeholders perceive the proposed solutions. If their concerns and perceived benefits are based on distorted information or assumptions, it is advisable to address these concerns in further communication, ideally with the support of external experts.

All target groups should be adequately involved in the participatory process, and the form of participation may include questionnaire surveys (in person, online, etc.), thematic workshops, lectures, discussions, etc.

4.4 Communication with target groups in the participatory process

Identifying target groups is one of the key steps for a successful participatory and needs mapping process. This applies mainly to target groups that use or could potentially use the school facilities for social, cultural, educational, sporting or commercial activities. Buildings for education should not only fulfil their function during school hours, but also in non-teaching time (afternoons and evenings, weekends, holidays, etc.), they should provide facilities for wider social, educational and sporting activities in the locality.

Particularly for more investment-intensive events, it is advisable to actively reach out not only to direct users (pupils, teachers and staff, and parents of pupils) but also to interest groups and associations or entrepreneurs operating in the area. In particular, commercial activities can have economic benefits for the school in addition to social benefits.

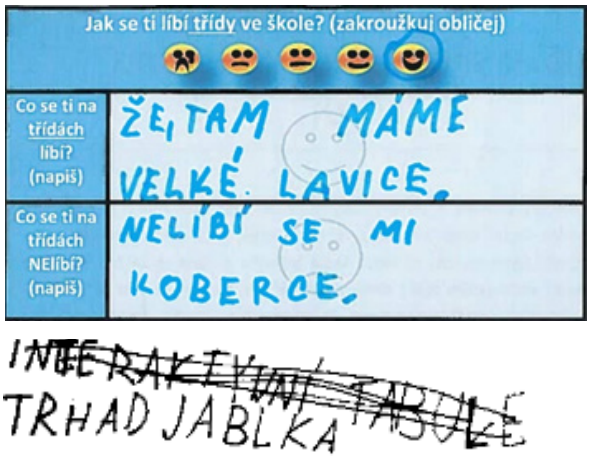
Pupils and students

Pupils and students, together with teachers and school staff, are the main target groups. The aim is to offer pupils an inspiring, creative and functionally non-conflicting environment. The forms of teaching are mainly a professional topic of the teachers, so the pupils comment mainly on operational matters, possibilities of relaxation and recreation in non-teaching time. Relaxation between lessons is an important part of the educational process and pupils should have enough stimulation outside of classes, both mental and physical, to return to class mentally refreshed and fully focused on learning. A varied range of opportunities for relaxation, both mental and physical, is a good complement to the teaching facilities.

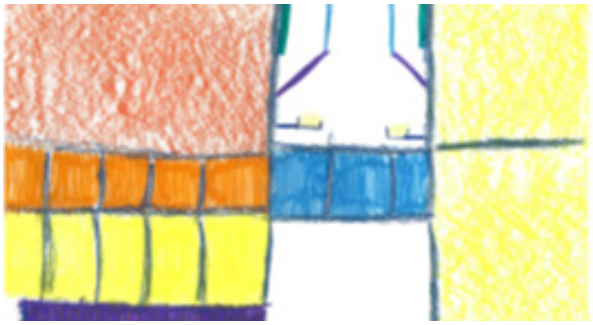
Pupils and students should be addressed in a specific form appropriate to the educational level and year of study. Communication with them has two levels:

- **factual level** – the aim is to map the needs of the pupils, identify any problems in operation, the lack of infrastructure for the actual teaching and relaxation. Naturally, reaching out to pupils and students of higher grades leads to more precise feedback; however, even pupils of the first level of primary school can often aptly name what is bothering them.
- **informative level** – through pupils and students, their parents are informed about the planned investment project, which can also stimulate the interest of this target group in the envisaged project.

There are different ways to approach pupils and students. For factual information, the questionnaire form is suitable, where pupils answer specifically formulated questions, ideally in the context of an appropriate subject. In the case of lower grades, the teacher should guide the pupils through the questionnaire. For upper grades, the questionnaire can be electronic for easier evaluation, whereas for younger students a written form is preferable, and for the lowest grades it is possible to answer using pictures. There is also the possibility of a discussion with the students, a workshop, etc. However, these events are more demanding in terms of factual evaluation. It is crucial to involve all pupils and students across all grades. If the school implements a major investment project that will fundamentally affect the current operation or appearance of the school, it is advisable to treat the project as a "school-wide" theme and implement it in an appropriate form in the curriculum. In Czech language classes, pupils can write literary pieces on the theme of "My new school"; in foreign language classes, it can be a topic of conversation; in art classes pupils can work on visual concept of the building or interiors, etc.



Mapping the needs of pupils of the first level of the primary school: examples of questionnaires for pupils of the first and second grade (source: authors' archive).



Examples of involvement of pupils of the first level of the primary school: graphic work on the theme "My School" (source: authors' archive).

Teachers

Teachers' satisfaction with full-fledged facilities for teaching and its various forms, with the operational arrangements and facilities at the workplace is crucial for a high level of teaching quality.

Teachers can be approached using a questionnaire, a discussion, or a thematic training session, which will show new trends in teaching and serve as a basis for a subsequent discussion of preferences. The actual form of teacher involvement should be specified on the basis of debate within the teaching staff.

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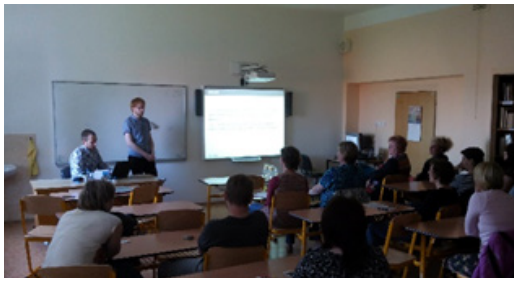

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Teacher involvement. 1. Needs mapping in the form of a guided discussion. 2. Presentation of options for proposed solutions. 3. Workshop and discussion with teachers and staff on proposed solutions. 4. Exhibition of designs of building modifications in the school premises for pupils, teachers, staff and the public (source: authors' archive).

Staff

School staff is an integral part of the team. They provide services required for the school's operation and, therefore, their satisfaction with the working environment and the functioning of the school's operation is also important.

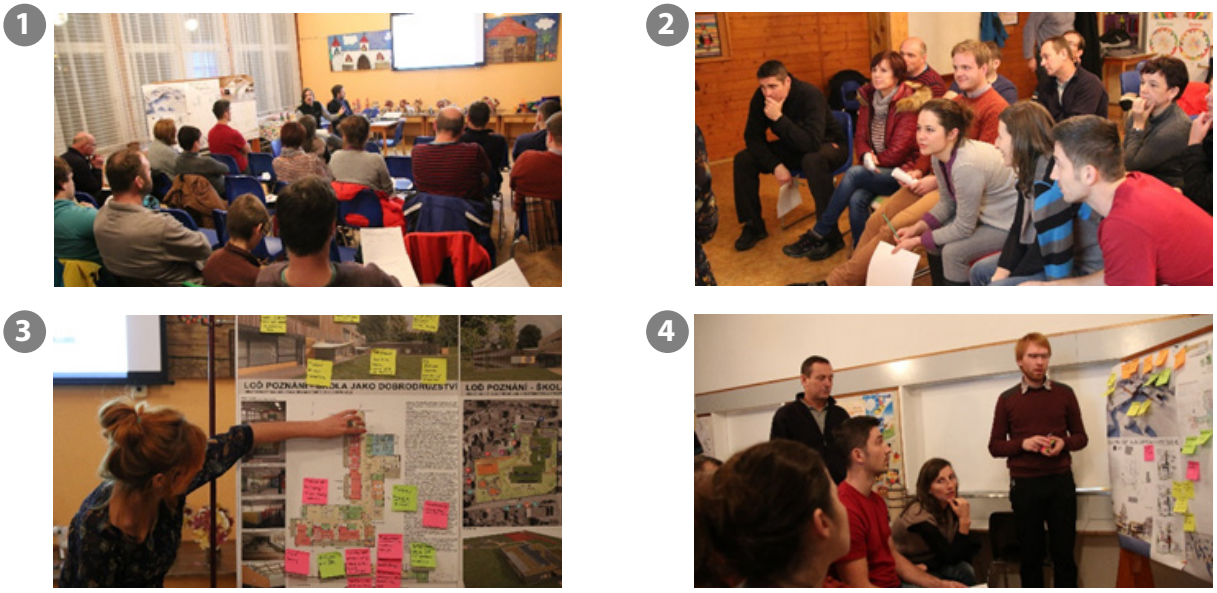
Given the nature of their work, it is advisable to reach out to these members of staff in the simplest and least time-consuming way possible, e.g. through a questionnaire tailored to their activities. However, in the case of a broader debate over a major investment project, it is advisable to hold the discussion together with teachers and staff, where each of them can better understand the other's perspective and priorities, and harmony can be more easily found.

Involvement of staff and non-teaching staff - discussion between architects and school canteen staff (source: authors's archive).

Parents of pupils

Parents of pupils are primarily interested in the quality of the facilities for their children's learning process, the quality, inspiring, creative and functionally non-conflicting environment, and the offer of various forms of relaxation. At the same time, the offer of

spaces for family interaction with the school is important, i.e. the possibility of parties, exhibitions, pupil performances, garden festivals, joint workshops, etc. These school activities have a wider social impact both in the family-school relationship and among the pupils. Communication with parents is nowadays very often done through the school's electronic information systems, or by e-mail, so it is most effective to address parents in this form, with links to online questionnaires, or through a joint discussion with teachers or other staff.



Involvement of parents and target groups: 1. Needs mapping in the form of a guided discussion 2. Presentation of options for proposed solutions, 3. 4. Group work and workshop on the proposed solutions (source: authors' archive).

Other target groups

These include cultural and sports associations, interest groups, companies and private persons who can use the school premises and facilities for their activities. The range of target groups is extensive and varies according to the nature of the educational establishment and the extent of the facilities, as well as the location.

For operational use in the non-teaching time, i.e. in the afternoons and evenings, at weekends, during holidays, etc., it is offered e.g. the use of teaching facilities for organising courses, trainings, seminars, gathering spaces for cultural and social events, sports facilities for sports activities, canteens for the possibility of catering for local residents and seniors, etc.

These target groups in the locality need to be correctly identified, addressed in an appropriate way and their needs, priorities and suggestions mapped. Information leaflets with links to online questionnaires etc. may be an appropriate form.

5

Technical measures to adapt school facilities to climate change

When applying technical measures, it is always necessary to respect and emphasise a comprehensive view of the building, including its aesthetic and operational quality, the quality of the indoor environment and public spaces.

As mentioned in the introduction, the operation of buildings and their energy consumption, large areas of residential structures that increase the negative phenomena associated with climate extremes during heat waves, torrential rainfall or drought, and transport as a major energy-consuming segment: all contribute significantly to global warming and climate change. Therefore, technical measures for adaptation of buildings to climate change **focus on reducing their energy consumption, water conservation, blue and green infrastructure, promoting environmentally friendly transport and motivating users to behave in an environmentally friendly and responsible way**.

When applying these technical measures, however, it is always necessary to respect and emphasise a holistic view of the building, including its aesthetic and operational quality, the quality of the internal environment and public spaces.

5.1 Reducing buildings energy consumption

Emphasis on reducing the consumption of primary energy from non-renewable sources throughout the **entire building life cycle** is crucial in minimising the impacts of construction on climate change. Energy consumption is assessed in the so-called **building production phase**, when the impacts associated with the energy performance of the building materials and structures used are monitored. From this point of view, it is also necessary to take into account their lifespan and the frequency of replacement, i.e. the Life Cycle Assessment (LCA).

- **Use of environmentally friendly materials** | Preference for building materials with a low carbon footprint, renewable, recycled and recyclable components.

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1. Kindergarten in Líšnice as a wooden building (source: www.haas-fertigbau.cz). 2. New building of the school pavilion, Allenmoos (CH) - walls made of steamed unfired clay (source: www.lehmtonerde.at). 3. Centre for Environmental Education Sluňákov - walls made of unfired bricks in reinforced concrete skeleton (source: authors). 4. Reconstruction of COPTH secondary school in Prague - new lightweight ENVILOP wood-based envelope (source: authors' archive).

In the so-called **building operational phase**, the energy consumption is evaluated in terms of the energy demand associated with the actual operation, i.e. energy for heating, cooling, hot water, consumer energy, etc. The following measures help to reduce the energy consumption of buildings:

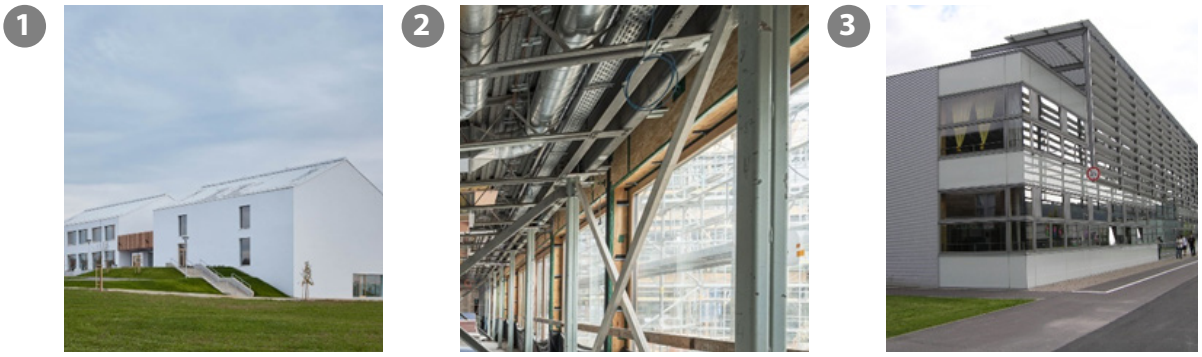
- **Minimisation of heating energy** | Passive energy standard of the building or its part, insulation of the building envelope, replacement/refurbishment/renovation/re-glazing of windows, airtightness of the building envelope.

- **Minimisation of energy for ventilation and emphasis on indoor air quality** | Installation of mechanical ventilation systems with heat recovery.

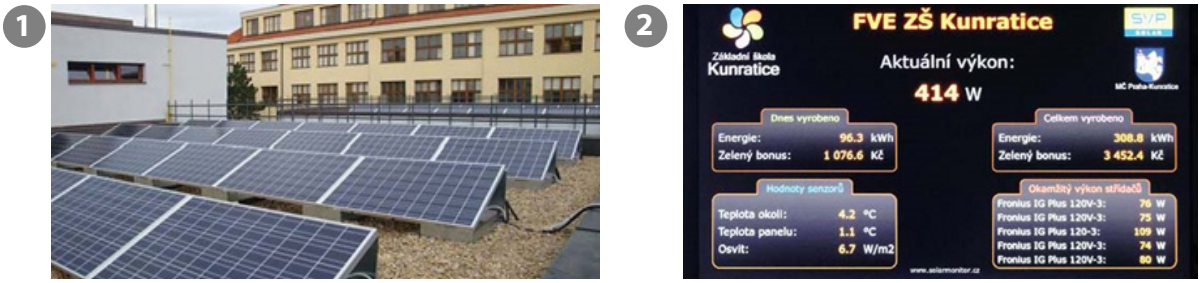
- **Minimisation of cooling energy** | Installation of efficient shading systems for large glazed areas, automatic shading control systems.

- **Use of renewable energy sources** | Solar panels for hot water heating, photovoltaic systems to cover operating energy, biomass energy sources, etc.

- **Energy-saving terminal devices** | Appliances, lighting, automatic control systems, etc.



1. Passive primary school AMOS, Psáry, SOA architekti, 2019 (source: www.s-o-a.cz). 2. Mechanical ventilation systems with recuperation: reconstruction COPT secondary school - Technical and Economic Vocational Training Centre (source: authors's archive). 3. Energy-saving school Linz, Austria - movable shading elements as part of the architectural concept of the building (source: authors's archive).



1. Installation of a PV power plant on the roof of a primary school in Prague Kunratice, 2011. In the first 9 months of operation, the plant produced more energy than planned for the whole year. The total output is 59 kWp. 256 Schott poly 230 W modules and 5 Fronius IG Plus 120 inverters are installed on the roof. The school uses the generated electricity and sells the surplus to the PRE grid (source: authors' archive). Visitors can also see the current power output of the plant in the entrance hall (source: www.tzb-info.cz).

5.2 Water efficiency and Blue Infrastructure

Efficient use of drinking water and the use of rainwater for the operation and maintenance of the building, grounds and greenery on the property are important climate change mitigating measures that reduce drinking water consumption, retain water in the environment and help reduce the heat load on the environment.

Some of the most technically simple and least costly, yet highly effective measures that promote water reduction include the **installation of water-saving terminals**. The guideline value of annual water demand for school facilities in the Czech Republic is 3 m^3 per pupil (teacher) for toilet and washbasin without hot water and 5 m^3 per pupil (teacher) for toilet and washbasin with hot water. Studies of drinking water consumption in schools show that there are significant savings in drinking water when water saving terminal features are installed, e.g. dual flush toilets, tap aerators and stop valves on washbasins or touchless taps,

etc. Another possible technical solution is to **harvest rainwater on the property and use it for the operation and maintenance of the building and its surroundings**. These measures are already among the more technically demanding ones, as the stormwater drainage system must be equipped with a storage tank and pipelines must be set up to use the stored water. Technically, these measures are implemented as follows:

- **Rainwater is accumulated and evaporated from the open surface or vegetated areas of the building and its surroundings** | Ponds, water areas, but also soakaways or permeable surfaces of paved and handling areas, green roofs and green facades are used for accumulation. These measures both reduce the effects of torrential rainfall and contribute to reducing the heat load on the environment.

- **Rainwater is accumulated and, after proper treatment, used for maintenance of the building surroundings** | i.e. for watering the garden, green roofs and facades, and maintenance and cleaning of outdoor areas, etc. These measures reduce the need for drinking water and, through functional greenery, the heat load on the environment, and can also reduce costs of water and sewerage charges.

- **Rainwater is accumulated, purified and used inside the building** | This is the most technically demanding solution, the internal use includes mainly toilet flushing, cleaning etc. These measures save drinking water consumption and can also reduce costs of water charges.

The most technically demanding solution is the **use of greywater**. These are wastewaters that do not contain faeces and urine and that flow from washbasins, baths, showers sinks, etc. Greywater, especially from restrooms, can be used as service water (so-called white water) for flushing toilets and urinals or maintaining the outdoor areas; thus, it can reduce drinking water consumption, both indoor and outdoor.

Soakaways with retention grooves between pavilions of the Masaryk University campus in Brno-Bohunice (source: www.tzb-info.cz).

5.3 Green Infrastructure

The use of greenery in the inner city and municipalities is one of the important measures contributing to the reduction of the impact of climate change on the environment. **Greenery has a positive effect on reducing the thermal load** of the environment and buildings, including heat stress. **Greenery has a positive effect on air cleanliness** - leaves, plant roots, soil and micro-organisms act symbiotically to form a complex ecosystem that is able to assimilate some pollutants such as CO_2, SO_2, HCl. Trees, moreover, capture and store heavy metals over the long term. **Greenery also has a positive impact in terms of reducing environmental noise levels** - trees do not constitute an effective barrier against noise propagation, but when placed between buildings they reduce reverberation time. **The positive effect of greenery on the human psyche** is also important. The view of greenery reduces stress (lowers blood pressure) and promotes positive feelings (happiness, friendliness), while suppressing negative emotions such as sadness, fear and sullenness, or evoking pleasant aesthetic experiences, increasing concentration and speeding up mental recovery. This is a very important factor for schools, the concentration of pupils and students, as well as teachers and staff.

One of the technically simplest treatments is to **maximise the green areas on the site**, which can be addressed by, for example, grassed paved areas, planting mature greenery, using grassed blocks and stencils for paved areas, etc.

Green roofs are another, albeit more technically demanding option. Extensive green roofs with a substrate thickness of up to about 15 cm are planted with plants extending (with minimum maintenance) into the area. These are mainly perennials, rock plants, grasses or mosses that can withstand extreme conditions of alternating heat, drought and frost. Intensive green roofs are suitable for creating gardens using herbs, shrubs and low trees, and the substrate can be up to 1.3 m thick.

The covering (shading) of the opaque and non-transparent parts of the facade can be achieved in the form of so-called **green facades**, either in the form of climbing plants or plants in containers with substrate.

The architectural concept of the building can include **greenery in the interior**, e.g. in the form of interior green walls, mature greenery in central common areas, etc.

Planting of mature greenery is another possible measure. Deciduous trees complete the overall functional and aesthetic composition with the building; in summer, trees in front of

the south, east and west facades can contribute to effective shading of windows or facades, while in winter and transitional periods they allow passive solar gains to be made. The changing colour of deciduous trees is a factor that has an aesthetic effect in the outdoor spaces. The trees themselves create shady places in the parterre for rest and relaxation.

In order to preserve the original biodiversity, it is advisable to **use green planting elements with the original plant material of the site**, based on an assessment of the dendrological potential of the plant material on the site. Ecosystems formed in this way provide habitats for a range of animals, such as birds and insects, which are often important for nature conservation.

The concept of green space on the building and site should include a development care plan, which is a manual on how to care for the greenery (intensity of mowing, watering, etc.). The months and years after planting are often crucial for the greenery to thrive. A care plan is therefore an essential part of keeping the greenery in good condition. From the care plan, the financial requirements for managing the greenery can be derived.

Bamboo garden on the roof of the FEI Brno office building. An example of an intense green roof realised with the help of flower pots with grown bamboo, which with its thickness and density of greenery gives the atrium a refreshing touch (source: www.greenville.cz).

Unique green roof with teaching spaces on the extension of the kindergarten and primary school in Ostopovice, Brno - countryside. Initially, a routine renovation was to be carried out, but instead the requirement for a modern facility with an emphasis on energy-efficient operation, which also serves as a community centre for the whole village, was raised. The original school building was thus complemented by a new building, on which a green roof was built in the next phase. A green roof garden solves the problem of the lack of outdoor space on the school site. (source: www.greenville.cz)

5.4 Promoting sustainable transport

Transportation of children and teachers to schools is a pressing problem today. Climate change adaptation measures should aim to make **adjustments that promote environmentally-friendly forms of transport**, e.g., safe and collision-free walking routes, cycle paths, including bikes and scooters on school premises, secure storage options for unicycles, skateboards, roller skates, Segways, etc. Other measures include the **promotion of electromobility**, i.e., the possibility of charging electric bikes and electric cars on-site in specific parking lots. These measures are intended to cover all potential users (the target groups), i.e. pupils and students, teachers and staff, parents and the wider public.

The promotion of walking or other alternative non-motorised transport is aimed at vehicle within walking distance of the school or on foot in connection with public transport. The aim is to provide safe and collision-free routes, technical solutions that allow the use of pedestrian and other alternative transport, and adaptations that allow the safe storage of aids for these forms of transport. These include:

- **Collision-free pedestrian traffic** | The main pedestrian entrance to the building or site is separated from the main access road for cars and supplies.

- **Use of alternative forms of transport** | The main pedestrian access road includes a separate lane for alternative modes of transport, e.g. scooters, skateboards, roller and inline skates, Segways, etc. - this lane for alternative methods of transportation has an asphalt surface.

- **Safe storage of alternative modes of transport equipment** | In the school premises it is necessary to provide spaces and areas for storage of scooters, skateboards, roller skates, inline skates, unicycles and Segways and their security, e.g. in the form of a separate lockable room, spacious lockers, etc.

The **promotion of cycling** is implemented in particular by providing secure and ideally covered parking for bicycles and scooters. It is necessary to address the **availability of parking**, e.g. an outdoor rack, a covered outdoor rack, a bike room inside the building, etc., or equipment of parking places, e.g. equipment for pumping up bikes and small workshop equipment for bike repair. Furthermore, the **security arrangements** need to be addressed, ranging from the basic locking option the provision of CCTV security for the parking spaces, to the connection of the space to the central building security and surveillance systems.

In connection with the promotion of cycling, it is also necessary to put in place the **associated infrastructure for cyclists**, i.e. showers and changing rooms need to be available in the school premises or bike room areas. Showers must be separate for pupils and staff (teachers and staff) and, in the case of pupil showers, separate showers for boys and girls. It should be also possible to store cycling equipment, e.g. in sufficiently spacious lockers, etc.

The promotion of electromobility can be implemented both by installing an electric bike rack with a charging station and by building parking spaces for electric vehicles. These measures are intended primarily for teachers, staff and visitors to the school, or for pupils of upper grades. This should be also reflected in the operational design and transport connections. In connection with these measures, it is advisable to **install photovoltaic systems**, which can then be used directly to charge electric bicycles and electric vehicles.

Encouraging and incentivising shared transport for staff and pupils is also one way of reducing traffic load and thus contributing to reducing climate change impacts. These measures are usually not directly linked to the actual building design; however, minor modifications in the parterre, such as a covered bus stop, a bus turntable near the main school entrance, can be linked to the building design of the public or private areas of the school.

Covered bicycle racks secured by a CCTV security system are located in the front gardens of the Dukelská Primary School in České Budějovice, around which the E route of the České Budějovice cycle path runs (source: www.c-budejovice.cz).

Project of common transport of children from the first level of primary school in Jesenice (CZ) consequent to a survey among parents that led the municipality to offer a special school bus line. Currently, 2 buses run, each making 2 rounds in the morning for around 170 children. The project was implemented with the support of OP Employment in 2016-2018. The municipality management decided to continue the project after the grant funding was exhausted, solving the critical situation in the morning hours for about 900 children (source: www.esfcr.cz).

5.5 Environmentally responsible and friendly behaviour of users

Everyday environmentally friendly behaviour and small steps can contribute to the protection of the environment and reducing the impacts of climate change. Precisely in schools, good examples of this behaviour should be encouraged and presented. Motivational measures can be very diverse and can be linked to the professional focus of the school.

These include e.g. the **installation of waste sorting bins** in the school premises, **the presentation of a responsible approach to drinking water consumption**, **the installation of presentation systems of implemented climate change adaptation measures**, such as an indicator of current energy production from PV systems, the current status of rainwater use, etc. These systems can be presented in the building or its surroundings and shown on the school website or social media, etc.

5.6 Synergic effects

Investment projects, even those on a smaller scale, often present an opportunity to improve the quality of a building in other respects. Although these interventions partly increase the investment costs of the original building plan, they usually represent only a partial increase in price, but in particular they often improve the quality of daily operation or aesthetic quality. It is important that the terms of reference of these modifications are clearly specified, ideally on the basis of a survey of the needs of the target groups, and that the design is prepared by a qualified person - an architect. These may be modifications to the **architectural design of the building**, e.g. in connection with thermal insulation, window replacement, construction of extensions, additions, etc.

Similarly, **aesthetic modifications** to the interior, replacement of surfaces, renovation of sanitary facilities, etc. may be carried out in connection with, for example, modifications to boiler rooms, energy systems in the building, etc. It is highly advisable that these design modifications are carried out by an interior specialist to ensure that they are of an appropriate aesthetic quality.

A number of technical solutions can also be combined with **more extensive layout and operational modifications**, which may include, for example, innovative solutions for teaching

spaces, facilities for teachers and staff, areas for physical activities and quiet relaxation for pupils and students, teachers and staff, modifications enabling better interaction between the school and the family (indoor and outdoor meeting and presentation spaces and areas such as multi-purpose halls, exhibition areas, etc.), modifications that increase the usability of the facilities by the public.

6

School buildings in Prague - Options for climate change adaptation measures

In Prague, in total, there are almost 1000 school facilities, many of which consist of multiple buildings. Their renovation thus represents a significant potential for the application of climate change adaptation measures.

School buildings in the capital city of Prague include a diverse portfolio of buildings in terms of architectural and structural design, as well as in terms of the operational and functional content of these buildings. School facilities include buildings for grammar schools, secondary and higher vocational schools, primary schools, kindergartens, youth homes, children's homes, primary art schools, children's and youth homes, school canteens and pedagogical and psychological counselling centres.

In Prague, there are almost 1000 of these facilities; about 200 are under the jurisdiction of Department of Education, Section of Education and Youth of the Prague City Hall. Each of these institutions uses, operates and manages its own building or set of buildings and additional facilities. **Thus, renovations of these buildings represent a significant potential for the application of climate change adaptation measures.**

The specificities of these buildings include, among other things, the different periods of construction, the architectural and historical value of the original building and, consequently, the various technical possibilities and approaches towards application of climate change adaptation measures. In terms of the possibility of applying these measures, buildings can be divided according to the period of construction into:

- Buildings before World War II,
- Buildings after World War II,
- Prefabricated buildings between the 1960s and the 1980s,
- Construction in the1990s,
- Contemporary architecture.

6.1 Buildings before World War II

These are mainly buildings from the second half of the 19th century, the turn of the 19th and 20th centuries and buildings from the 20s and 30s of the 20th century, i.e. from the period of late Classicism, Neo-Renaissance, Art Nouveau, Traditionalism, Modernism and Functionalism. These buildings, or parts of them, have their own distinctive architectural or structural-historical value and reflect the authenticity of the respective building period. Their renovation and technical interventions should therefore be carried out in such a way that these values are not devastated. Often these buildings are subject to one of the levels of preservation of monuments.

Práčská Primary School, Prague 10

It is a detached building built in 1905. The exterior walls are made of burnt solid bricks, 500 and 650 mm thick, without thermal insulation. The floor on the ground is original, without thermal insulation. A 150 mm thick cinder embankment constitutes the ceiling to the attic. Wooden double-glazing windows characterise the building. Possible technical measures are described below.

REDUCTION OF ENERGY CONSUMPTION

The original decorative façade cannot be modified; thus, exterior thermal insulation cannot be considered. The building envelope thermal quality can be improved by re-glazing the windows with double glazing and by refurbishing the existing windows, or replacing them with replicas, or exceptionally with new windows while maintaining the original building layout, as well as by insulating the pitched roof or the ceiling to the attic. It is possible to consider the insulation of non-original parts of the masonry or masonry in the courtyard (in consultation with the architect). Modification of technical and energy systems, i.e. controlled ventilation with heat recovery, modernisation of the heating system, thermal zoning, use of RES, measurement and control system, modernisation of the artificial lighting system (pro-cognitive lighting), external shading on architecturally and visually unexposed facades will lead to significant benefits.

WATER CONSERVATION AND BLUE INFRASTRUCTURE

Water conservation measures can be fully applied, e.g., from the installation of water-saving terminal devices to rainwater storage and its use for watering, maintenance and cleaning of outdoor areas, or for toilet flushing and cleaning, or the reuse of greywater.

GREEN INFRASTRUCTURE

Given the historic facades and pitched roofs with traditional trusses, green roofs or greenery on the facade cannot be considered. These options can be explored in the courtyard or ancillary buildings. The landscaping can include maximising of grassed areas, replacement of paved areas with permeable surfaces, or planting of mature greenery. Similarly, the

installation of vegetation can be considered as part of interior improvements. Measures for green infrastructure should be designed in line with measures for sustainable stormwater management.

ENCOURAGING SUSTAINABLE TRANSPORT

Measures encouraging sustainable transport can be fully implemented, taking into account the school's spatial capacity.

MOTIVATION FOR ENVIRONMENTALLY FRIENDLY BEHAVIOUR

Motivation measures can be fully implemented taking into account the nature of the adaptation measures.

Špitálská Grammar School, Prague 9 - Vysočany

The complex includes functionalist buildings of the grammar school and primary school from 1927-1937. Both buildings are considered cultural monuments. The façade cladding with light grey ceramics imitating masonry is punctuated by strip windows, a vertical row of circular windows marks the staircase – wooden windows with double glazing. The building load-bearing structure consists of a reinforced concrete skeleton lined with solid bricks with an exterior wall thickness of 450 mm and 600 mm. The horizontal structures are made of reinforced concrete hollow-core slabs. The roofs above the 5th and 6th floors are constructed by asphalt strip roofing without additional insulation. The roof over the dining room on the 1st floor has been partially reconstructed with a green roof. Double-glazed wooden windows, as a thermal insulation, show signs of wear and do not match the original metal fillings.

REDUCTION OF ENERGY CONSUMPTION

Due to to the original facade with ceramic cladding, thermal insulation cannot be considered. The non-original existing windows could be replaced with new ones with subtle aluminium frames and better thermal performance. Due to the original ceramic cladding and the composition of the façade, thermal insulation of the façade is problematic; technical solutions are available but very expensive. Exterior shading systems are not part of the original architecture, i.e. in this case the only option is to select glazing that minimises internal gains

on exposed sunlit facades. A major benefit will be the modification of technical and energy systems, i.e. controlled ventilation with heat recovery, modernisation of the heating system, zoning, use of RES, metering and control system, modernisation of the artificial lighting system (pro-cognitive lighting).

WATER CONSERVATION AND BLUE INFRASTRUCTURE

Water conservation measures can be fully applied, i.e. from the installation of water-saving terminal devices, to rainwater storage and its use for watering, maintenance and cleaning of outdoor areas, etc., or for toilet flushing and cleaning, or the reuse of grey water.

GREEN INFRASTRUCTURE

Due to the façade, greenery on the façade cannot be considered. However, green roofs can be designed, and this measure has already been partially applied. The landscaping can include maximising of grassed areas, replacement of paved areas with permeable surfaces, or planting of mature greenery. Similarly, the installation of vegetation can be considered as part of interior improvements. Measures for green infrastructure should be designed in line with measures for sustainable stormwater management.

ENCOURAGING SUSTAINABLE TRANSPORT

Measures encouraging sustainable transport can be fully implemented, taking into account the school's spatial capacity.

MOTIVATION FOR ENVIRONMENTALLY FRIENDLY BEHAVIOUR

Motivation measures can be fully implemented, taking into account the nature of the adaptation measures.

6.2 Buildings after World War II

The architecture of many buildings from the 1950s is reminiscent of the era of so-called socialist realism in the ornamentation of the facades, details, or art elements on the facades and in the interiors; in these cases, it is necessary to preserve these elements as part of the architectural heritage, or to consult with experts on the extent of intervention.

Buildings from the 1960s are often explicitly utilitarian, i.e. focused on utilitarian function, working with compositions of large masses, facades are articulated by large glass surfaces and are usually without decorative elements. The extent of structural and technical interventions in these buildings is usually very high; it

is possible either to completely preserve the original architectural concept, i.e. the articulation of facades, windows, etc., but it is also possible to completely modernise and rebuild the building and give it a new and contemporary architectural expression.

Secondary School - Technical and Economic Vocational Training Centre, Prague 9

The school was opened on 1 September 1950, originally as the Centre for Working Youth at the Stalingrad Workers' Commissary. The main building of the complex has three floors and a partial basement. The gable roof is without insulation. The load-bearing walls are made of 600, 450 and 300 mm thick solid bricks. The perimeter walls are insulated with EPS boards, 140-160 mm thick. The perimeter structures of the 3rd floor are not insulated. Windows are plastic with double glazing. The ceiling of the 2nd floor to the unheated attic is insulated with 180 mm thick insulation. The existing unattractive appearance of the building, given by the picturesque colouring of the facades and the jumble of billboards, is a great opportunity for an overall architectural modification of the building. At the same time, it would be advisable to think conceptually about the use of the 3rd floor and attic space.

REDUCTION OF ENERGY CONSUMPTION

Due to the existing condition, a comprehensive change in the architectural design of the building should be considered, including the thermal rehabilitation of the building envelope, the solution of external shading systems, or other modifications. The concept must include technologies for an efficient envelope thermal insulation and the use of the third floor and attic. The zoning of the building must be addressed in the modification of the energy systems. All types of measures are possible to reduce the energy consumption of the building, i.e. installation of more efficient sources, controlled ventilation with heat recovery, modernisation of the heating system, use of RES, metering and control system, modernisation of the artificial lighting system (pro-cognitive lighting).

WATER CONSERVATION AND BLUE INFRASTRUCTURE

Water conservation measures can be fully applied, i.e. from the installation of water-saving terminal devices to rainwater storage and its use for watering, maintenance and cleaning of outdoor areas, or for toilet flushing and cleaning, or the reuse of greywater.

GREEN INFRASTRUCTURE

Any solution for greenery on the facade or implementation of green roofs should be sought in accordance with the overall architectural concept of the building. The landscaping can include maximising of grassed areas, replacement of paved areas with permeable surfaces, or planting of mature greenery. Similarly, the installation of vegetation can be considered as part of the interior landscaping. Measures for green infrastructure should be designed following rainwater harvesting measures.

ENCOURAGING SUSTAINABLE TRANSPORT

Measures encouraging sustainable transport can be fully implemented, taking into account the school's spatial capacity.

MOTIVATION FOR ENVIRONMENTALLY FRIENDLY BEHAVIOUR

Motivation measures can be fully implemented, taking into account the nature of the adaptation measures.

SYNERGIC EFFECTS

Improved architectural quality of the building and quality of public spaces.

6.3 Prefabricated buildings between 1960s-1980s

Prefab construction represents a phenomenon of socialist architecture of the 1960s-1980s. The increasing distance in time and hindsight offers an unbiased professional view of this era of architecture. In this context, selected projects from this period may be so unique that they deserve a respectful approach and an effort to preserve the original architectural expression. On the other hand, this approach will apply only to truly exceptional projects from this era. In most cases, a radical approach seems to be appropriate, because it will give the buildings a contemporary architectural expression and at the same time enable their comprehensive energy rehabilitation.

The advantage is that most of the buildings from this period are large-scale facilities, very often having extensive grounds that allow for a variety of uses for school and extracurricular activities, or the addition of missing functions. Large glazed areas offer plenty of light in the interior, visual and operational connections to the exterior. However, summer overheating is a common problem.

The extent of structural engineering interventions in these buildings is usually

very high, given the simplicity of materials and shapes and large facade areas, the passive standard is technically relatively easy to achieve.

Practical and Special Primary School Ružinovská, Prague 4 - Krč

The building was built in the 1970s. It has not undergone any partial reconstruction since then and all the external structures are original. The structural system of the building is a reinforced concrete precast frame with perimeter sandwich panels with continuous window strips divided by inter-window inserts. The facades are insulated apparently with 50 mm thick polystyrene slabs, within the sandwich panel composition. The roof structure consists of lower reinforced concrete ceiling panels set on purlins and probably a wooden structure forming the slope of the flat roof. The internal partitions are made of prefabricated reinforced concrete panels. The floor on the ground is without thermal insulation. The fillings of the openings are original. The windows are wooden with double glazing and the doors are steel, partially glazed.

The building offers a unique opportunity for structural and energy rehabilitation, achieving a passive energy standard and applying the principles of sustainable construction and climate change adaptation measures.

REDUCTION OF ENERGY CONSUMPTION

Due to to the existing condition, a complete architectural redesign of the building should be considered, including a complete thermal rehabilitation of the building envelope and a solution to the external shading systems. To reduce the energy consumption of the building, all types of measures are possible, i.e. installation of more efficient sources, controlled ventilation with heat recovery, modernisation of the heating system, use of RES, metering and control system, modernisation of the artificial lighting system (pro-cognitive lighting).

WATER CONSERVATION AND BLUE INFRASTRUCTURE

Water conservation measures can be fully applied, i.e. from the installation of water-saving terminal devices, to rainwater storage and its use for watering, maintenance and cleaning of outdoor areas, or for toilet flushing and cleaning, or the reuse of greywater.

GREEN INFRASTRUCTURE

Greenery on the facade and green roofs can be part of the new architectural concept. The landscaping can include maximising of grassed areas, replacement of paved areas with permeable surfaces, or planting of mature greenery. Similarly, the installation of vegetation can be considered as part of the interior landscaping. Measures for green infrastructure should be designed following rainwater harvesting measures.

ENCOURAGING SUSTAINABLE TRANSPORT

Measures encouraging sustainable transport can be fully implemented, taking into account the school's spatial capacity.

MOTIVATION FOR ENVIRONMENTALLY FRIENDLY BEHAVIOUR

Motivation measures can be fully implemented, taking into account the nature of the adaptation measures.

SYNERGIC EFFECTS

Improved architectural quality of the building and the quality of the adjacent public spaces.

6.4 Construction in the 1990s

The 1990s is a social phenomenon that awaits deeper sociological analysis - the transience of the times, social changes, newly acquired freedoms, seemingly unlimited possibilities of self-realisation, the influence of post-modernism in architecture, the low sophistication of investors, the so-called entrepreneurial baroque, the general lack of respect for architecture. The ordinary construction of this period is considered to be below average; the paths to quality architecture were, with a few exceptions, still being sought.

Even in terms of structural and engineering aspects, this period is characterised by hasty construction, when speed and volume often triumphed over quality and precision. Buildings from this construction era usually offer a wide range of possibilities for the application of climate change adaptation measures.

Secondary Technical College (SPŠ) Na Proseku, Prague 9 - Prosek

The Secondary Technical College Na Proseku consists of a complex of 3 interconnected buildings (a gymnasium, the main school building and an economic pavillion). Pavillions have a different number of floors, from one up to three. The building envelope is made of ceramic hollow bricks, 300 mm thick, with thermal insulation of extruded polystyrene, 100 mm thick. The ceiling structure is made of reinforced concrete hollow-core slabs, 200 mm thick. The building has been continuously renovated; the original windows were replaced with plastic ones with insulating glazing in 2006, in 2015 the roofs were additionally insulated with 200 mm thick thermal insulation, the floor on the ground in the laboratories was additionally insulated with 80 mm thick polystyrene.

REDUCTION OF ENERGY CONSUMPTION

Due to the current building condition, a complete architectural redesign of the building should be considered, including the thermal and technical rehabilitation of those parts of the building envelope that have not yet undergone it and the installation of external shading systems. To reduce the energy consumption of a building, all types of measures are possible, i.e use of more efficient sources, a controlled ventilation system with heat recovery, upgrading of the heating system, use of RES, metering and control system, modernisation of the artificial lighting system (pro-cognitive lighting).

WATER CONSERVATION AND BLUE INFRASTRUCTURE

Water conservation measures can be fully applied, e.g., from the installation of water-saving terminal devices to rainwater storage and its use for watering, maintenance and cleaning of outdoor areas, or for toilet flushing and cleaning, or the rainwater accumulation.

GREEN INFRASTRUCTURE

Greenery on the facade and green roofs can be part of the overall architectural concept. The landscaping can include maximising of grassed areas, replacement of paved areas with permeable surfaces, or planting of mature greenery. Similarly, the installation of vegetation can be considered as part of the interior landscaping. Measures for green infrastructure should be designed following rainwater harvesting measures.

ENCOURAGING SUSTAINABLE TRANSPORT

Measures to encourage sustainable transport can be implemented in full, taking into account the spatial possibilities of the school.

MOTIVATION FOR ENVIRONMENTALLY FRIENDLY BEHAVIOUR

Motivation measures can be fully implemented, taking into account the nature of the adaptation measures.

SYNERGIC EFFECTS

Improved architectural quality of the building and quality of public spaces.

7

Examples of school building adaptations

The following examples illustrate possible process and technical approaches for applying climate change adaptation measures to school buildings.

7.1 House for Children and Youth, Český Krumlov

The oldest documented building on the site of the existing House for Children and Youth was built in 1679 as a building responding to the needs of the burgher armed regiment. It was completed in another form with a garden restaurant in 1879. The building underwent a further alteration in 1909 and was converted into a restaurant with a bar, club rooms and a hall and orchestra hall on the second floor. The appearance of the building was last modified in the second half of the twentieth century, and in the 1970s the last remnants of the historic façade were torn down; fortunately, they were documented, plotted and described in detail before being removed. Later, the windows were also replaced with plastic ones, whose shape did not match the scale of the dimensions of the whole house.

The renovation project began in 2013, when the requirement to reduce the building energy consumption was defined as a requirement to insulate the building. The project was developed in cooperation with the National Heritage Institute; the aim was to find a solution that would be in line with the requirements of preservation of monuments in the historic environment, but which would also allow to increase the building technical quality and lead to energy savings.

In cooperation with the conservationists, a contact insulation system made of mineral wool was designed, which respects the original articulation and profile of the facades. The requirement was to carry out the final finishing touches of plastering work in the manner preserving the authentic character. It was not possible to use a conventional external thermal insulation system because it would not statically support the decorative stucco elements on the façade. The solution was a careful selection of mineral plaster, detailed design of tectonic elements, cornices, bossages, columns and their carving out of mineral

House of Children and Youth, Český Krumlov, 2017, projects Sládková, co-author architect Radek Janošík. Condition of the building before and after reconstruction (source: www.projekty-sladkova.cz).

material. The thermal insulation work was carried out by real experts with knowledge of the plastering trade. The cut-out VEROFILL elements were supplied by the company STO. Similar to the façades, the windows were also dealt with in a similar way, with replicas of the original windows being installed. Thanks to the good cooperation with the conservationists, the insulation was successfully implemented in this case. The project is a breakthrough both in Český Krumlov and at the regional and national level.

7.2 Renovation of the COPTH building, Českobrodská 32a, Prague 9

The school building belonging to COPTH, the Technical and Economic Vocational Training Centre, was built in the 1970s in the KORD construction system; a brick extension was built in the 1990s. The building was morally and technically obsolete before the revitalisation started. The lightweight envelope, internal prefabricated partitions, soffit and roofing contained asbestos. The project is an example of a comprehensive renovation using sustainable building principles that also applies climate change measures. The project was awarded the SBToolCZ gold certificate.

As part of the overall renovation, a new layout was designed to ensure high quality learning spaces and better operational links. The energy concept includes the design of a smart, sustainable and energy active building. Along with the building, the outdoor areas are revitalized to allow relaxation for students and teachers, including sports activities on the work-out court, outdoor ping-pong, chess and table football. Covered and uncovered bicycle parking facilities, including charging stations, as well as parking for electric vehicles with charging are provided on the school grounds.

The original load-bearing structure of the building is equipped with a lightweight ENVILOP wood-based suspended envelope in a passive energy standard, which is the result of applied research at the UCEEB CTU in Prague.

The concept works significantly with greenery. The south façade in the atrium with classrooms and the west façade with the corridor is covered with climbers throughout and will thus create a very pleasant light atmosphere in the growing season. Outside of the growing season the leaves will fall and nothing will prevent daylight and solar gains. Parts of the flat roofs are designed as green. The building

will thus be like a living organism that changes over time.

Heating, hot water and cooling are provided by ground-source heat pumps with sixteen 120 m deep boreholes. A 30 kW electric boiler serves as a backup bivalent source and a dry chiller for cooling. Waste heat from the hot water is used for preheating. Approximately 450 photovoltaic panels with a total output of 150 kWp are located on the roof and on the south façade. The energy is stored in a battery system with a capacity of 300 kWh. The overarching predictive control works with the building's consumption, the PV power generation and the spot hourly electricity prices for the following day and sets a strategy with a preference for maximum building self-sufficiency, electricity prices in hourly steps and battery discharge and recharge prices. Water from showers and sinks, i.e. grey water, is treated and used for toilet flushing. Rainwater is stored and used for watering. In case of shortage of grey or rain water, the storage tanks will be replenished with water from the well. Rainwater runoff is further slowed by retention basins.

Much attention is focused on the quality of the indoor environment. The entire building is forced ventilated by 5 air handling units located on the roof where the air will be pre-heated or pre-cooled. In each room the air will be thermally treated in four-pipe fan coils. Ventilation is controlled by combined CO2-VOC-humidity-temperature sensors. If the windows are opened, the sensors in the windows switch off the ventilation system and thus the heating and cooling. South, west and east windows are equipped with external blinds. Indoor lighting fittings are controlled by sensors that react by dimming the lighting according to the current intensity of outdoor daylight. The teacher can use a touchscreen tablet to control the various elements that affect the quality of the indoor environment.

Reconstruction of the COPTH Secondary School - Technical and Economic Vocational Training Centre in Prague - general view of the building with PV installation on the roof (top, view of the eastern facade (left), installation of the wood-based lightweight perimeter cladding using the ENVILOP system (middle), heat pumps as one of the energy sources (right) (photo: Jiří Tencar).

7.3 Primary School and Kindergarten of Ota Pavel in Buštěhrad

The project to expand the capacities of the Primary School and KIndergarten of Ota Pavel in Buštěhrad, implemented in 2015-16, is an example of a comprehensive approach where synergistic effects have significantly improved the quality of the building and its surroundings. At the same time, the building modifications were carried out with a view to future steps. The project management was developed in cooperation with a team of architects, sociologists and energy specialists from the University Centre for Energy Efficient Buildings of the CTU in Prague.

The original terms of reference required to increase the capacity of the school by 4 classrooms and in this context also increase the capacity and perform complete reconstruction of the school kitchen and canteen.

The operation of the school takes place in two operationally separate buildings. The original building from the turn of the 19th and 20th centuries is used for teaching pupils from the first level of primary education, while the buildings from the 1960s and 1970s house a kindergarten,

classrooms for pupils of higher levels of primary school, school principal's office, a canteen with a kitchen, an afterschool care centre and a gymnasium.

Despite the very limited time for the comprehensive preparation of the project, a needs survey was carried out with a team from UCEEB, involving all target groups from pupils, teachers and staff to parents and interest groups. Teachers and staff were involved through a structured discussion guided by a facilitator, parents through an electronic questionnaire, and students from the first level of primary school and the second level of primary school through an age-appropriate survey. The involvement of pupils also included thematic work in the lessons of Czech language, art education, informatics, foreign language on the topic "Primary school in Buštěhrad in two years, or if I were an architect" and the so-called "future scenario", i.e. the joint creation of possible alternatives to the future state.

The aim of these activities was mainly to raise awareness about the project, but also to get suggestions for the formulation of the terms of reference for the upcoming architectural workshop. The biggest operational issues identified were the operational interconnection of the old and new buildings and barrier-free operation, traffic conflicts on access routes and at the school entrance, control of entrances, lack of teachers' facilities, as well as increased connectivity of teaching spaces with the school garden.

These topics were incorporated into the terms of reference for architects along with the expansion of the school's capacity. Four studios with experience in school building design participated in the workshop.
The commission recommended for further elaboration the design of the studio ADR, s.r.o. which, solved in conceptual terms a new traffic connection and interconnection of the two buildings. The layout and architectural design of the building reflects this operational concept. Technically, the project was designed to reflect the sustainable principles to the maximum extent. The extension is designed as a prefabricated wooden building. The quality of the envelope of the extension is of a low-energy standard. Emphasis is also placed on solving summer overheating by active shading. The installation of a 1 kWp or 2 kWp PV system on the roof of the extension was recommended, as it allows all the energy to be consumed locally in the building (without the need for battery storage). A forced ventilation system with heat recovery is designed for the new classrooms, offices and canteen. The implementation of extensions took place in 2016, followed by other projects that addressed the modification of the school's parterre.

Extension of the primary school and kindergarten in Buštěhrad - the layout and structural design of the extension was prepared with a view of possible operational interconnection of the old and new building (author ADR, UCEEB coordinator, 2015).

8

Financing of adaptation measures in school facilities in Prague

Financing options for adaptation measures depend on the type of school and the founder. The following chapter provides a basic overview of the available financial resources for school buildings in Prague.

Secondary schools are usually established by the regions (in the case of Prague, secondary schools are established by the capital city of Prague), which finance their operation and investments, except for funds for staff salaries, which are provided by the state.

Primary and kindergarten schools, on the other hand, are usually established by municipalities (in the case of the capital city of Prague, by municipal districts), whose budgets are then responsible for financing their operations and investments, again with the exception of staff salaries, which are covered by the state.

The city can set an example in implementing adaptation and mitigation measures, especially for its own investment projects - renovations and constructions of new public buildings, in this case, school facilities.

8.1 Financing options through the Prague City Hall

The main guarantor of the implementation of adaptation measures in the capital city of Prague is the **Section of Environmental Protection of the Prague City Hall**, which is in charge of the **Strategy of climate change adaptation of the capital city of Prague** and manages the related Implementation Plan. **The Implementation Plan includes a project pool approved by the Prague City Council** (e.g. in 2021, it contained 16 projects in the chapter Implementation of adaptation measures on buildings). The list of projects is available here: https://adaptacepraha.cz/implementacni-plan-2020-2024/).

The **project pool** is updated annually, and new projects are approved every year. For the creation of the project pool and its annual update, the relevant sections of the Prague City Council, that are concerned with the topic of adaptation of the city to climate change, are always contacted, as well as the city's contributory organisations that manage and administer the property, land, technologies and processes of the capital city of Prague, and also all municiipal districts of the capital city of Prague are contacted for its update. The inclusion of a project in the project pool is the first possibility of **generating financial resources for the reconstruction or construction of an adapted school building - primary schools and kindergartens report upcoming projects to the project pool through the municipal district, and secondary schools through the Section of Education of the Prague City Council.** Those interested in being included in the pool of adaptation projects can contact the Section of Environmental Protection of the Prague City Hall, **Department of**

Environmental Projects - contact person is Mgr. Tereza Líbová, e-mail: Tereza.Libova@praha.eu or adaptace@praha.eu.

The **Section of Environmental Protection** also allocates **capital expenditure in the chapter Implementation of energy saving and adaptation measures and in the chapter Pilot projects in the environment**. Inclusion in the list of investment projects is done through the **Department of Environmental Projects**. Contact persons are Ing. Miroslav Zeman and Ing. Ivan Jacko, e-mail: Miroslav.Zeman@praha.eu and Ivan.Jacko@praha.eu.

Other sections of the Prague City Hall concerned with the implementation of potential adaptation projects in school buildings are the **Section of Education, Youth and Sport, the Section of Investment, the Section of Property Management and the Section of Monument Preservation**.

Another option for financing smaller adaptation modifications is the use of the Grant Programme for Supporting Projects to Improve the Environment of the Capital City of Prague. Both natural persons and legal entities can apply for a grant or subsidy. For the purposes of adaptation measures, the following chapters are particularly suitable:

- **Chapter I. Public green space, subchapter 3. Improvement of school facilities,**
- **Chapter II. Green classrooms,**
- **Chapter VII. Adaptation to climate change.**

The City of Prague, through the Prague City Council, also annually supports the municipal districts in the development of **blue-green infrastructure projects** (for example, in 2021 it was approximately CZK 170 million).

8.2 National grant opportunities and external financial sources

- **Operational Programme Environment (OPE)** - this is a grant programme that allows to draw down financial resources for the protection and improvement of the environment from EU funds. The programme is intended main-ly for the public sector, i.e. municipalities, regions, state and local government organisations, research and scientific institutes, educational institutions. The priority axis that focuses on adaptation measures in schools is in particular Priority Axis 5. Energy Savings.

- **National Environment Programme (NEP)** - this programme supports projects and activities that contribute to environmental protection in the Czech Republic. The programme is designed to be complementary to other grant titles, especially the Operational Programme Environment and the New Green Light to Savings Programme.

- **National Recovery Plan (NRP) - this is a thoroughly discussed plan that contains the priorities of the Czech government. The individual components, including financial allocations, are designed to help the Czech economy out of the crisis triggered by the COVID-19 pandemic and contribute to meeting reform and investment requirements.** Within the National Recovery Plan, Pillar 2 **Physical Infrastructure and Green Transition** is critical for climate change adaptation. This pillar addresses three main areas: improving physical infrastructure, decarbonising the Czech Republic and preparing for the negative impacts of climate change. Interesting for climate change adaptation is the component **2.2 Reducing energy consumption in the public sector**, which aims to increase energy efficiency through building renovation and modernisation of the public lighting network.

- **The Modernisation Fund** – it is a new type of instrument to support investment in the modernisation of energy systems and energy efficiency improvements in some EU Member States for the period 2021-2030. It serves as a contribution to meeting long-term climate targets. The financial allocation assigned to the Czech Republic on the basis of emission allowances from the Modernisation Fund is a revenue of the budget of the State Environmental Fund of the Czech Republic, and its provision is decided by the Minister of the Environment. For the Czech Republic, this is up to 150 billion CZK. In January 2021, the government approved the ModFund (Modernisation Fund) General Programming Document. Funding will be provided to Member States by the European Investment Bank, with a 70/30 funding ratio in favour of priority investments. Further information is available at: https://www.sfzp.cz/dotace-a-pujcky/modernizacni-fond/vyzvy/.

8.3 International projects

- **Norwegian Funds** - The main mission of the EEA and Norway Grants is to reduce social and economic disparities in Europe and strengthen bilateral contacts and mutual cooperation. Sharing and exchanging experiences

and competencies between donors and beneficiaries is an important aspect that distinguishes these funds from the EU funds.

- **Horizon Europe** - Horizon Europe is the European Union's 9th Framework Programme for Research and Innovation for the period 2021-2027. It is the largest and most ambitious programme of its kind, with a budget of over €95 billion.

- **LIFE** - The programme is an integrated financial instrument of the European Commission. LIFE finances eco-innovation projects that require cooperation between science, industry and public administration, but also supports environmental management and information campaigns aimed at changing the attitudes and behaviour of target groups or protecting nature and biodiversity in the wild. The City of Prague is an eligible applicant under the LIFE programme. Public bodies can address the topics of floods and droughts, green and blue infrastructure, the implementation of adaptation and mitigation strategies in the field of climate, mobility, species and habitat protection, compliance monitoring and effective environmental governance.

  Information on LIFE itself is available at: https://www.program-life.cz/.

From the point of view of the implementation of adaptations, it is crucial to correctly set up adaptation financing and consolidate mechanisms of adaptation measures financing, evaluate the cost-benefit analysis of adaptation measures, and take into account the social price of carbon and the value of ecosystem services when planning city investments.

Furthermore, It is necessary to look for synergies in the area of financing adaptation measures, with projects focused on sustainable development, mitigation and environmental protection in general, as well as to consider the possibilities of using national and European programmes for financing climate change adaptation in the city and creating a city-wide pool of adaptation projects suitable for funding.

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Methodology for adaptation of school buildings to climate change in Prague

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