Research Paper

GreenTech-Renovation

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Keywords

CO_2 Neutrality, Energy-Efficiency, Green Tech, Refurbishment, Climate Crisis, New European Bauhaus

Figure 1: The GreenTech demonstration project – a vacant school building on Kinkplatz, Vienna 7)

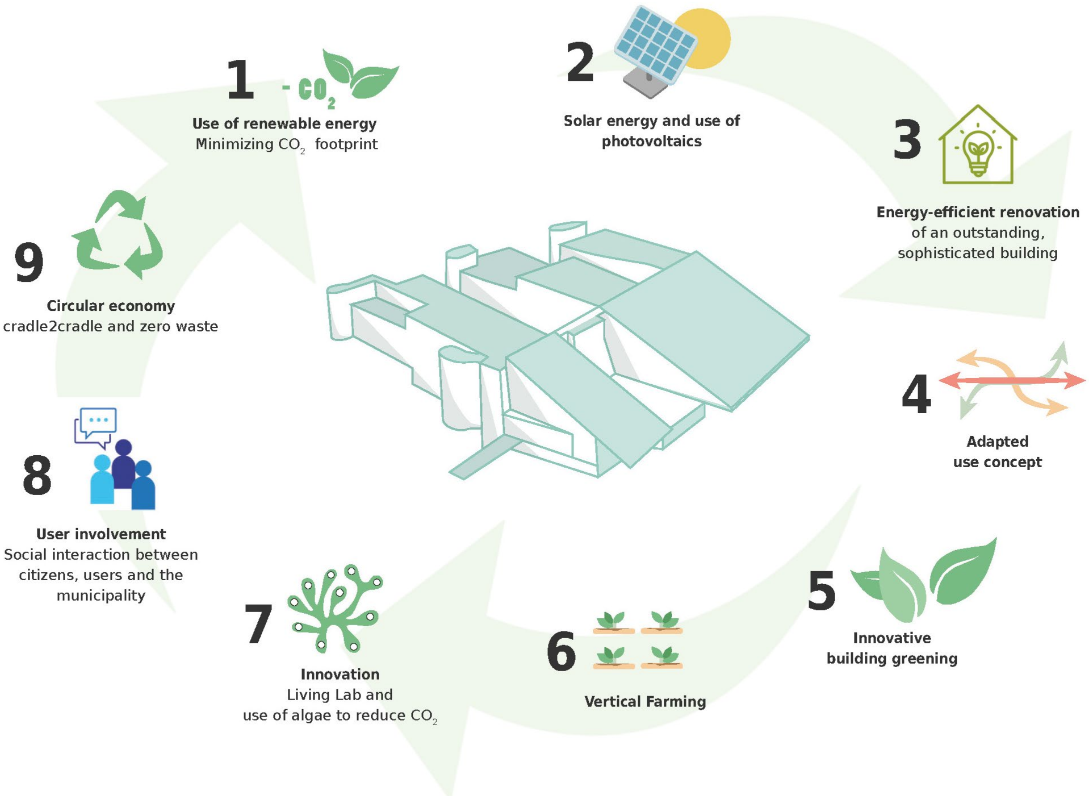

Figure 2: Diagram showing the 9 fields of research and action in refurbishment towards energy efficiency

Abstract

Status Quo and Challenge: Construction is responsible for approx. 40% of global CO_2 emissions from fuel combustion and 25% of GHG emissions as a whole. The transition to net zero buildings will succeed if, on one hand, safeguarding the existing is prioritized and existing structures are retrofitted and, on the other hand, new construction generates low to zero emissions. By adapting effective strategies and actions, we have the opportunity to not only improve the energy performance of buildings and increase the renovation rate of currently 1%, but also **to** ensure enhancing the quality of life in our urban areas and support citizens' health and well-being. Unique opportunities lie in refurbishment in terms of rethinking, redesigning and modernizing existing buildings into more energy-efficient and less material-intensive ones and sustaining economic recovery. The building sector can best follow the 10 principles of circular economy by prioritizing the refurbishment of existing buildings, especially the reuse of vacant buildings over further soil sealing and CO_2 emissions resulting from new construction. The challenges are high – especially for energy-intense building typologies, e.g., glass buildings for office and educational uses. The strategy and the focus of the research: FFG-funded GreenTech-Renovation[7]) serves as a demonstration project for energy-efficient renovations and the creation of a plus energy district. Innovative solutions for the energy-efficient renovation of architecturally valuable buildings with a high proportion of glass in accordance with the state of the art of technology and science are developed. A vacant school building in Vienna serves as a demonstration project, as many issues relating to sensible, energy-saving renovation can be exemplary addressed through this structure. The renovation of the school is to become a "case study" reference for this building typology and offer strategies for future projects, demonstrating scalability and replicability. Renewable Energies: The renovation will use renewable energies (solarthermics and photovoltaics, as well as geothermic probes and heat sources (e.g., environmental heat, ambient heat, waste heat or wastewater heat). For this purpose, a future-oriented building physics concept was developed with the aim of generating energy and absorbing CO_2 in order to boost RE potential to increase overall energy efficiency and reduce energy consumption. The results demonstrate that the building can become energy self-sufficient and even supply buildings in the vicinity with electricity from the PV on the roofs. A conscientious adaptation of use means to locate functions in a building based on the different thermal conditions within. In standard renovations, all spaces are treated equally and have to fulfill the norms comparable to new buildings. Correct use poses a central question in energy-efficient renovation, as it leads to targeted, efficient construction measures following the principles of circular economy, reduces material, CO_2 emissions and costs. The identification of suitable uses based on the spatial qualities lays the groundwork for minimal interventions rather than standardized renovations that often over-accomplish and damage the architectural quality. This approach represents a reversal of common practice. Greening, as a synergy measure, plays a connecting role in this project. Greening of roofs, façades and the site contribute to reduce urban heat. The international context and the replicability is established through the ENHANCE network (see figure 8) consisting of four universities (TU Delft, TU Vienna, DAstU , Politecnico di Milano, FH Technikum Wien, GrünstattGrau, an EU research center (EURAC), energy experts (IBO) and architects (Wessel de Jonge, Tillner & Willinger) and experts on participation and coordination (ÖGUT). The consortium cooperates with the New European Bauhaus (NEB) team in the context of the NEB lighthouse projects. The plan is to investigate innovative refurbishment techniques and energy-efficiency measures, shift to renewable energy sources and implement the five demonstration projects.

0. Introduction

The dynamics taking place in the big cities of Europe and the world pose a series of challenges and unprecedented demands. Most large cities worldwide have recently experienced the dramatic effects of the climate crisis. European cities face on top of that an unprecedented energy crisis with price explosions for gas and electricity which particularly affect lower-income households in older buildings. On the one hand, the population has increased in European cities due to better job opportunities, cultural networks and the location of social services. On the other hand, recent phenomena related to climate change and lately also to the war in Ukraine have been affecting the livability of human settlements and require mitigation and environmental solutions that have to be combined with the energy transition to renewables and the necessary refurbishment of existing buildings, especially all public buildings and the housing stock.

To meet the 1.5-degree pathway and the Paris goals, cities must reduce 55-60% of their net emissions by 2030. Cities in southern and central Europe have been impacted by Urban Heat Islands (UHI) phenomena, which are particularly critical in densely populated residential districts. Climate change impacts all building types (public, housing, office, industry) in several ways: New construction, as well as the operation of existing buildings significantly contribute to CO_2 emissions. As one of the major causes of carbon emissions, buildings therefore constitute a crucial field of action for mitigation and future reduction.

Modern tools of urban development, reconstruction and housing production after World War II have proven unable to face both challenges, leaving a huge stock of environmentally unsustainable public buildings (schools and offices), as well as post-war housing in vulnerable urban fabrics. However, even more contemporary standards applied to retrofitting have not sufficiently increased its environmental qualities. Since buildings are inertial objects, new construction and transformation is hardly reversible and the consequences of today's errors can last for decades. We urgently need innovation in the way we produce and (especially) transform the building stock to provide more livable and sustainable spaces. The energy transition towards renewables has to include all existing buildings and use state-of-the-science technologies, i.e., green tech. As made explicit by the current crisis of energy scarcity and in the provision of building materials, the circular economy (CE) is, in this sense, very useful to innovate and transform refurbishment and building in a more sustainable way.

The principles of reusing and recirculating materials can no longer be relegated to demonstration projects but have to be applied in every single project if the 1.5-degree goal is to be reached. This will be a daunting task for public buildings and the non-profit affordable housing production, which is already under economic pressure due to increased construction costs. Moreover, the scarcity of resources and building materials resulting from the COVID-19 crisis and, most recently, the dramatic increase in energy prices due to the Ukraine war have further raised the costs.

In this context, design and regulations can play key roles in reducing the dependency on fossil fuels and accelerating the transition towards CO_2 neutrality. By combining the refurbishment of existing buildings with energy-efficiency measures and a shift towards renewable energy sources and by following the cradle-to-cradle principles of a circular economy, this contribution offers a potential solution. Architectural design based on a circular economy can combine affordable design solutions with environmental goals and integrate green concepts in new construction and renovation while achieving CO_2 neutrality. Targeting the refurbishment of the existing building stock provides a huge chance to achieve the ambitious 1.5-degree goals while improving the living and working situation of the citizens. In addition, building regulations often hinder both ecological refurbishment and architectural innovation. If redrafted according to circular economy principles, they could stimulate sustainable developments and the integration of green measures.

Starting from these environmental, social and economic challenges, the applied research uses the "GreenTech-Renovation" demonstration project to investigate opportunities for refurbishment, innovation to improve green and environmental standards in building and renovation through CE, energy transition, and, ultimately, to enable better and more livable city quarters and buildings. A special focus lies on the shift of the energy sources towards renewables and the reduction of energy usage by thermally upgrading the buildings. The findings from the demonstration project will become replicable to similar building types (office, educational) and partially transferable to other buildings with high levels of transparency.

1. Status Quo, Problem Definition and Research Question

1.1 Existing Buildings in the EU will Constitute 80% in 2050

The EU Commission realized the urgency of focusing on the existing buildings even before the current energy crisis, which particularly affects uninsulated, older buildings dependent on fossil energy. Under the presidency of Ursula van der Leyen, the EU has set ambitious goals to jumpstart the renovation wave and accelerate the rate of energy-efficient refurbishment.

80% of the buildings that will exist in 2050 are already built. In the EU, more than 220 million buildings, representing approximately 85% of the building stock, were built before 2001 and will mostly still be standing in 2050. They are also unprepared for the ongoing and future changes in our climate, such as increasing temperatures and extreme weather events. Buildings are responsible for about 40% of total energy consumption in the EU and 36% of greenhouse gas emissions from energy. Building renovation is crucial to tackling this energy use and emissions, to meeting the EU's 2030 emission reduction target and to becoming climate neutral by 2050, as well to increasing resilience to climate impacts.

Today, renovation reduces energy consumption of the buildings by only 1% per year. Deep renovations that improve the energy performance of a building by at least 60% are annually carried out only in 0.2% of the building stock and in only a fifth of the cases, is energy efficiency significantly improved. [1])

In Austria, the entire demand for new construction could be integrated into the existing unused building stock. A creative reuse process could reintegrate many vacant buildings into the real estate market. The most ecological measure, therefore, is to always prioritize reuse rather than demolish and rebuild. Unfortunately, this is not the way the construction industry works. Traditionally, institutions as well as private clients follow fixed budgets for a project based on new construction and sale or lease. In this model, the calculations of their business model do not follow life-cycle costs. In a new business model, the costs have to be calculated for the entire lifespan of a building.

The building sector contributes to approx. 40% of all CO_{-2} emissions worldwide. This includes new construction, as well as the operation of the existing buildings. When it comes to the emissions resulting from operating, especially heating and cooling, the older buildings fare much worse than the newer ones from the last decade, which were built after stricter energy consumption regulations had been implemented in 2012. The Energy Efficiency Directive 2012, especially the Energy Performance of Buildings Directive [2]), revised in 2018, will help reach the building and renovation goals set out in the European Green Deal.

1.2 The Problem of Soil Consumption

New construction activity generally entails the consumption of soil (soil sealing), a precious and non-renewable resource, which is high, e.g., in 2020 an additional 57 km^2 were sealed in Italy and an additional 39 km^2 in Austria. This is a worrying trend that should be stopped and the focus shifted towards refurbishment or substitution and, when possible, soil desealing. A second issue connected to the theme of refurbishment regards the age of the building stock. In Austria, 13 ha of soil are sealed daily for new development, while the volume of new construction could be accommodated in the vacant stock. A trend reversal is underway and the government has set ambitious targets to drastically reduce sealing and stimulate refurbishment. In both Austria and Italy, the biggest part has reached over fifty years of age. Although often very energy-intensive, those buildings contain a large amount of “embedded energy” in terms of materials and energy embedded in its construction that should be taken into account.

1.3 Energy-efficient Refurbishment of Existing Buildings to Reach the 1.5 Degree Goal and CO_2 Neutrality

In order to sustainably improve the ecological footprint of the building sector, the perspective has to widen from the creation of new, energy-efficient buildings and focus on the refurbishment of the existing building stock. Although passive houses and plus energy houses are great contributions, especially in colder climate zones, these ambitious, new buildings are unfortunately not the norm but the exception. Furthermore, they cannot compensate the generally low energy standards of the mass of existing buildings and will by far not suffice to achieve the net zero target. The rate of refurbishment per year is far too low, currently at only 1% per year, while the energy efficiency is often hardly improved.[3)] The planning and building regulations in place in most of Europe and worldwide do not yet consider the urgency of improving existing city quarters and individual buildings. Since the climate crisis is now accompanied by an energy crisis, the urgency has increased, as older buildings use considerably more energy, rarely use renewable energy sources and are more susceptible for overheating in summer since they are located in more densely built-up urban areas with less green space.

1.4 Measure Embodied Carbon in Existing Buildings and Include Stored CO_2 in Calculations

When addressing these complex challenges, therefore, it is best to act on a city and community level in coalition with public or private building owners. Before considering the demolition of an existing building to replace it with a new one, e.g., with higher density, the embodied carbon has to be measured and considered in the approval process. Every building owner has to measure the embodied carbon of their existing buildings and the manufacturers of materials have to provide the numbers for it. Combined with a CO_2 tax, this will be an effective counter-strategy to the current practice in which tear down and build new predominate – in the EU and in countries outside the EU with more constrained budgets.

2. The Path to a Circular Economy and Energy-efficient Refurbishment

2.1 Application of Circular Economy Principles to Buildings and Renovation

The best and all-encompassing step towards a CE is to stop teardowns and instead reuse the existing buildings. The 10 Rs of circular economy describe perfectly how to deal with construction and their most effective implementation is the reuse of existing buildings.

1. Refuse	e.g., asbestos, oil-fired heating systems	6. Refurbish	Renew and upgrade
2. Rethink		7. Remanufacture	Refabricate
3. Reduce		8. Repurpose	Find new uses
4. Reuse		9. Recycle	
5. Repair		10. Recover	

Figure 3: The ten “Rs” of CE

The City of Brussels has taken the right steps in that direction by implementing the Circular Economy Action Plan for the Brussels Capital Region (BCR) that foresees a transformation from a linear model as existing in 2019 towards a circular model in 2040. The pathway there is voluntary for all buildings by 2025, regulatory for public buildings by 2030 and for all buildings by 2040. This means that the City will not permit the demolishment of an existing building unless a refurbishment has been investigated and proven to be unfeasible. [4)]

Figure 4: Brussels Capital Region –a circular model by 2040

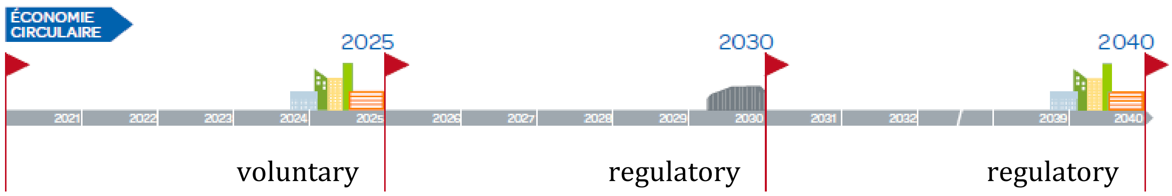

Figure 5: The path to the circular model in the Brussels Capital Region by 2040

The recommendations are to investigate first the feasibility of a retrofit or a retrofit addition. Due to a lack of investment in the past, public buildings, especially schools, have very low energy-efficiency standards. In the current energy crisis, this leads to high costs for public bodies and severe financial problems for communities and cities. Effective energy-saving measures that can be taken immediately are, e.g., to reduce standard temperatures on all thermostats – mandatory in public buildings. “Reduce” is one of the 10Rs of CE and is currently applied in many communities and cities across Europe but should become permanent.

For future refurbishment projects, the insulation of buildings with cradle-to-cradle certified materials, recycled materials and an energy hierarchy to prioritize renewables will have to become mandatory.

2.2 Renovation Wave – The Role of Architecturally Valuable Buildings

When focusing on construction and renovation, it becomes clear that a large positive impact can be generated by a renovation wave following the principles of circular economy. In the chapter “Leading the third industrial revolution,” the official website of the EU mentions that 35 million buildings could be renovated by 2030 and 160,000 new green jobs could be created in the construction sector by 2030 [5]. Buildings with an architectural and societal value represent a particular challenge, as they are part of Europe's cultural heritage and provide an identity to their surrounding neighborhoods, and therefore require special attention when being renovated. However, architecturally valuable buildings from the past 70 years are often not yet protected by monument status and therefore endangered by speculation. At the same time, dating from a period when we knew less about how to build energy-efficiently, they mostly show high energy consumption and related CO_2 emissions. Improving the energy efficiency of architecturally valuable buildings is a complex challenge, given the fact that conventional efficiency-enhancing measures cannot be used if the building’s integrity is to be respected. Monument authorities across Europe are increasingly faced with post-war monuments but have no long-term experience with technical solutions. Being aware of the value of the cultural heritage, they lack solutions on how to protect them.

The adaptive reuse and redesign of existing buildings produces architecture with a particular cultural significance that – as a consequence – is also sustainable in nature. This is not only due to the evident contribution to a circular economy and the improvement of their technical performance, but these two factors are multiplied by the prolongation of their lifespan as a result of their enhanced cultural significance and appreciation.

2.3 A Special Case – Architecturally Valuable Buildings with High Levels of Transparency

Many transparent buildings from the past 70 years are worthy of monument protection but have not yet received this status despite their high architectural quality. They offer a beautiful exterior appearance and light-filled, airy interior spaces. Glass is a highly intelligent and flexible material, and often transports the leading idea of making visible and transparent what is happening inside. Due to the effects of climate change, especially Urban Heat Islands (UHI) in urban areas, these buildings face serious comfort challenges and require considerably more energy for cooling. The explosion of energy prices in 2022 due to the Ukraine war has reinforced the necessity for energy-efficient renovation. Actually, over the whole year they are far from being climate-neutral and with the climate crisis forcing clear, new priorities, which are translated into the 2030 and 2050 climate goals, these buildings have to be refurbished – and this can be

Left: Fig. 6: Industrial Hotel Berlier, under renovation, Dominique Perrault, Right: Fig. 7: Bibliotheque National de Paris

done within the frame of the Davos Declaration of Baukultur [5)] and the New European Bauhaus mission.

The following group of European buildings was identified based on similar age, characteristics, high transparency, potential for energy-efficient renovation and willingness of the owners to implement the research findings in the refurbishment. The timing to act is perfect, since many of these buildings will require renovation of the building skin and replacement of the technical equipment in the next few years. Alternative energy sources can then be integrated and synergies with nature-based solutions explored.

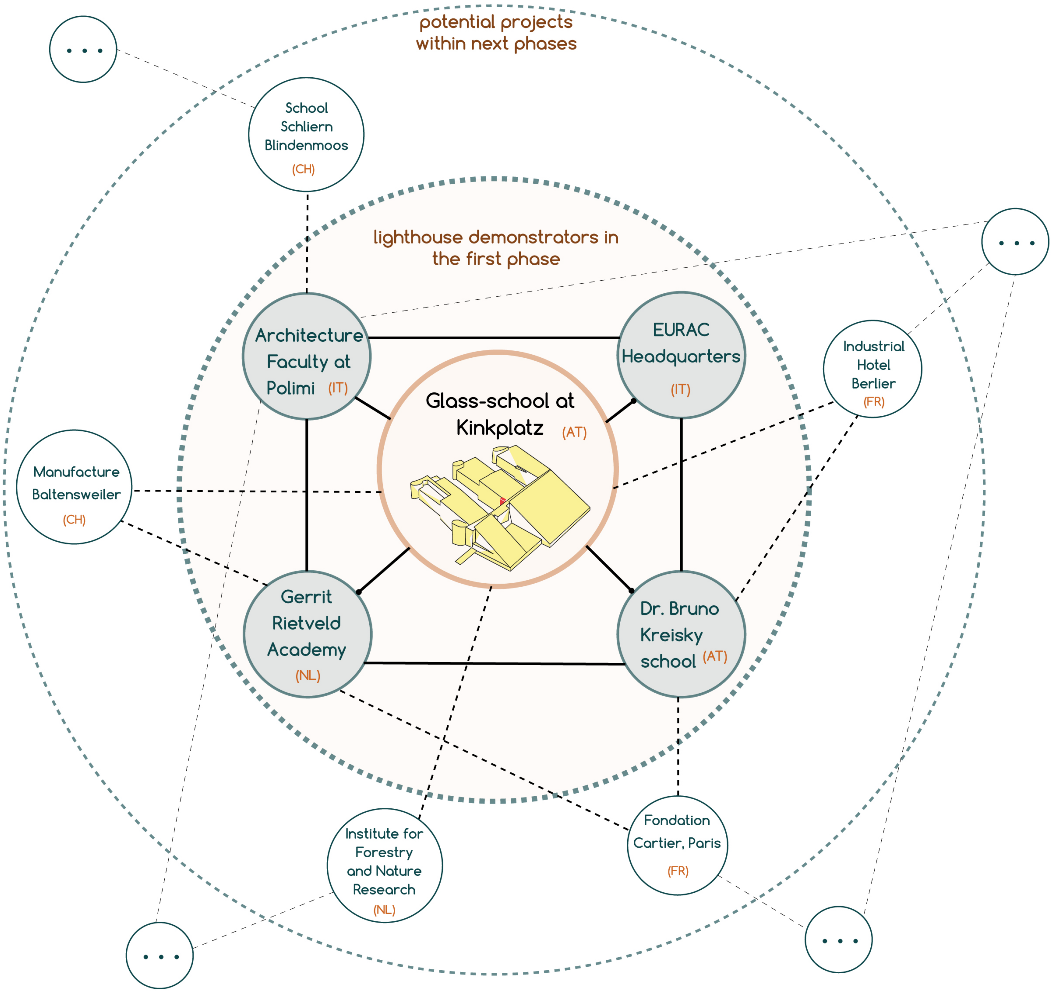

Figure 8: Diagram – demonstration project GreenTech-Renovation as the nucleus of a group of comparable buildings – lighthouse demonstrators in the first phase of the NEB, potential projects within next phases.

3. Excellence – A New Dimension Introduced by the NEB

In 2021, one lighthouse initiative to jumpstart this wave was the New European Bauhaus (NEB) initiative. When introducing this initiative, Ursula von der Leyen stated, “I want Next Generation EU to kickstart a European renovation wave and make the Union a leader in the circular economy.” The innovative aspect of this interdisciplinary initiative lies in its equally high environmental and economic ambitions while equally aspiring to become a new cultural project for Europe. The reference to the renowned Bauhaus from the beginning of the 20th century demonstrates the importance of quality in design combined with innovation in technology, building materials and techniques [6)]. The New European Bauhaus acknowledges the relevance of beauty, sustainability and inclusion equally and coincides with the following strategies:

Beautiful: Development, prototyping and validation of architecturally valuable solutions for energy-efficient renovations with a special focus on cultural heritage and the wider development of climate-resilient city quarters. Sustainable: Deployment of highly innovative, energy-efficient renovation solutions for buildings with a high proportion of glass, such as building-integrated PV, green façades, vertical farming, etc. Inclusive: The aim is to extract the elements that contribute to beautiful, inclusive and sustainable built environments through a holistic, bottom-up approach.

Aiming to make Europe climate-neutral by 2050, the European Commission (EC), with the New European Bauhaus (NEB) initiative, has added a cultural identity dimension to the economic, social and environmental measures of the European Green Deal. The EC has initiated a fundamental shift by making the New European Bauhaus a cooperative cultural project which involves all relevant stakeholders and proclaims architectural quality and design thinking among its guiding principles. The European policy framework [7)] has already started to pay more attention to quality aspects by focusing on priority themes (such as the circular economy, climate adaptation, cultural heritage, the renovation wave, innovative public procurement, biodiversity and nature-based solutions) to improve the life conditions in urban areas set out in the Urban Agenda for the EU. By adapting effective strategies and actions, we have the opportunity to not only improve the energy performance of buildings and increase the renovation rate of currently 1% but also to ensure enhancing the quality of life in our urban areas and support citizens' health and well-being. The COVID-19 crisis has clearly demonstrated the importance built-up areas and their surroundings, i.e., public spaces, play in our daily life, as well as the unique opportunities that lie in refurbishment in terms of rethinking, redesigning and modernizing existing buildings into more energy-efficient and less material-intensive ones and sustaining economic recovery. The building sector can best follow the principles of the circular economy, the 10Rs, by prioritizing the refurbishment of existing buildings, especially the reuse of vacant buildings over further soil sealing and CO_2 emissions resulting from new construction.

4. GreenTech-Renovation

Demonstration Project for the Energy-efficient Renovation of Architecturally Valuable Buildings with a High Proportion of Glass – A Vacant School Building

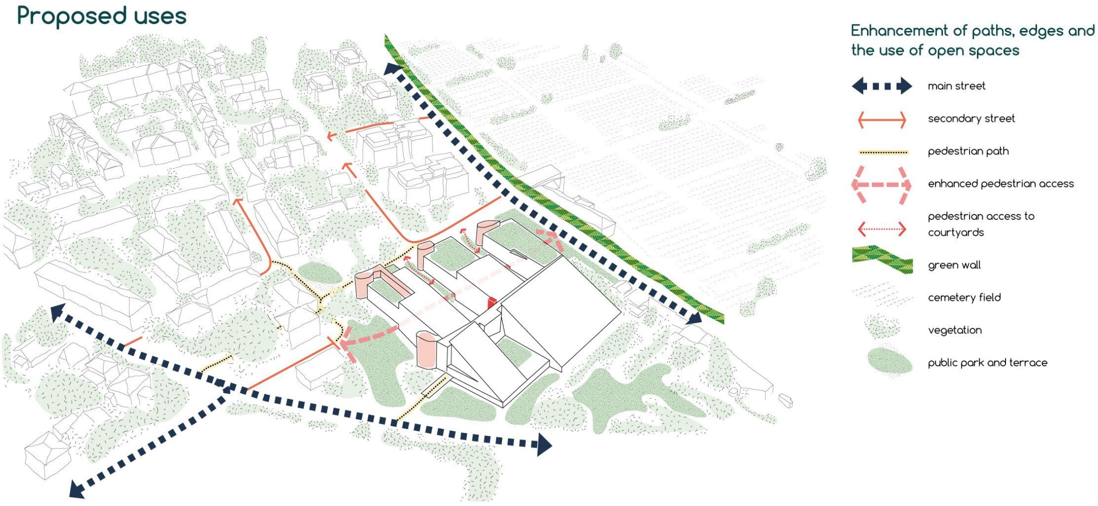

Figure 9: The former school on Kinkplatz in its context, a residential neighborhood in the outskirts of Vienna

The focus of the research [8)] was to find innovative solutions for the energy-efficient renovation of architecturally valuable buildings with a high proportion of glass in accordance with the state of the art of technology and science. Helmut Richter's School on Kinkplatz served as a demonstration project for this research work, as many issues relating to sensible, energy-saving renovation can be exemplary addressed through this structure. The renovation of the school is to become a "case study" reference and pilot project for energy-efficient and ecological renovation for this building typology. A valuable basis for future projects will be provided by the solutions developed in variants. The renovation strategies were prepared and structured in such a way that they can be used in further renovation projects for buildings from the second half of the 20th century.

International reference projects were analyzed in order to supply usable, structured data. The renovation concept was developed holistically based on this, but the measures for the various sub-areas of the building were broken down into individual components. Through this division in the sense of a "pattern language" into areas, parts and components, findings from sub-areas, e.g., the glass façades and roofs, deliver valuable, applicable data for follow-up projects.

Measures for increasing energy efficiency and the use of renewable energies

The energy-efficient renovation will take place using renewable energies (e.g., solarthermics and photovoltaics, as well as biomass/biomethane in a sustainably generated and available scope) and heat sources (e.g., environmental heat, ambient heat, waste heat or wastewater heat). For this purpose, a future-oriented building physics concept was developed with the aim of generating energy and absorbing CO_2 in order to boost RE potential to increase overall energy efficiency and reduce energy consumption and thus maintenance costs. The main goal was a transformation from the use of gas towards renewable energy sources. The research proved that 66 geothermal probes are feasible and can be installed in the west and in the two courtyards. Together with the brine / water heat pumps, this is more than sufficient for the entire heating and cooling of the building.

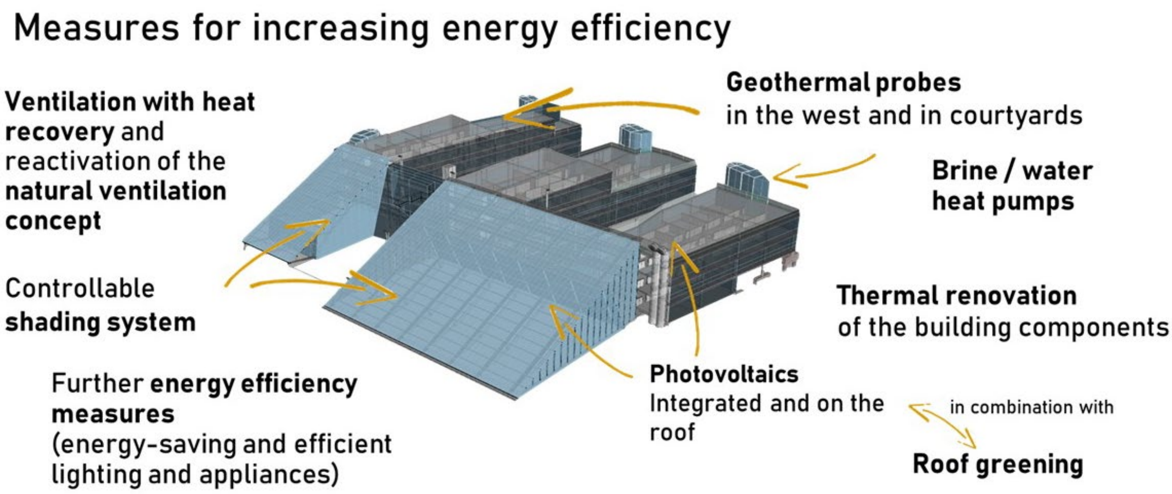

Figure 10: The former school on Kinkplatz – diagram for increasing energy efficiency, FH Technikum Wien

The installation of photovoltaics is feasible on the three flat roofs as well as on the two south-facing slanted glass roofs. The insulating glass panes from 1994, which have lost their thermal qualities, will be replaced by glass with integrated PV cells. The total production of electricity was calculated to be 350,000 KWh/ year, which is more than double the electricity consumption when the building was last used in 2017 (see Figure 10). Combined with efficiency-enhancing measures, the electricity use can be reduced and the excess electricity sold or integrated into an energy community with the residential buildings in the neighborhood. Since the residential buildings have different hours of intense usage as the educational and laboratory and office building, this will work well.

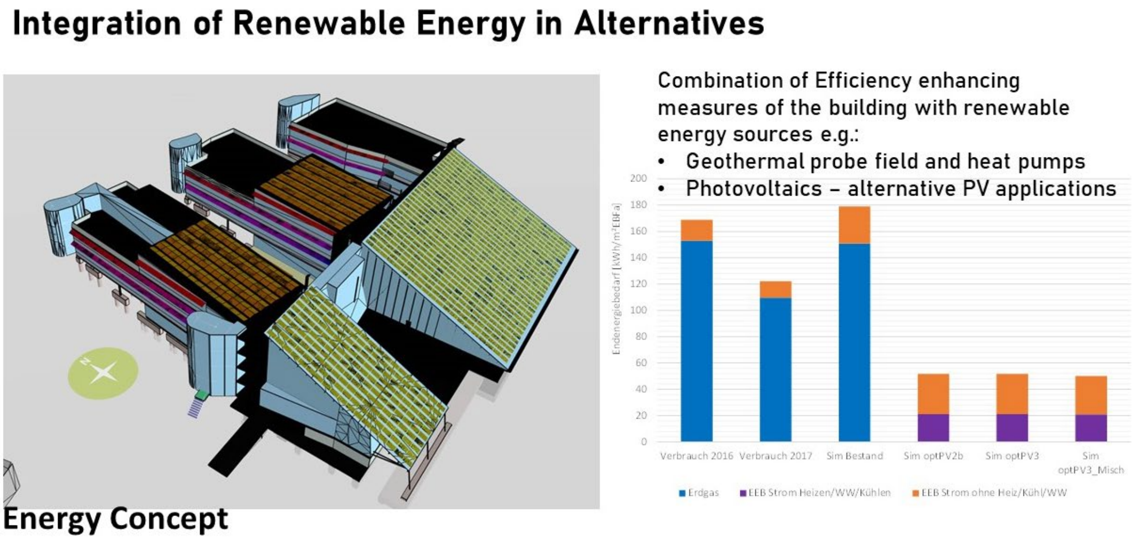

Figure 11: Diagram for integration of renewables, PV, potential reduction of energy usage, FH Technikum Wien

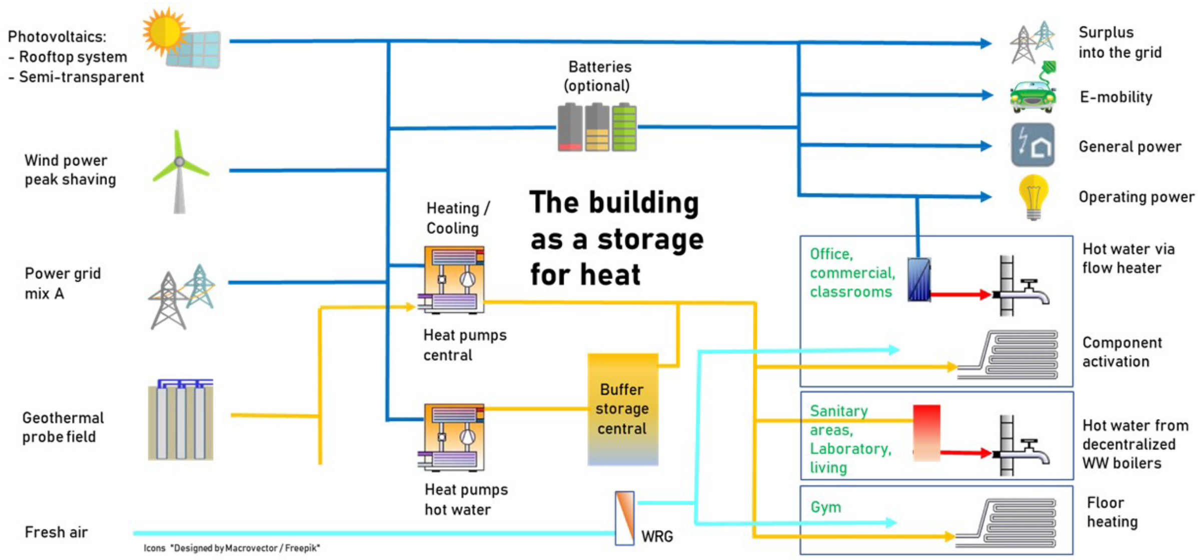

Figure 12: The former school on Kinkplatz – diagram for the building as a storage for heat, FH Technikum Wien

Adaptation of Use

Correct use poses a central question in energy-efficient renovation, as it leads to targeted, efficient construction measures. In the analysis and planning phase, the following essential questions were asked: What are the architectural qualities of the building? Which use best corresponds to these qualities and is suitable?

In the research project, the building was examined for appropriate usage possibilities. The proposed approach, based on the spatial qualities and the technically feasible, sensible measures to find intelligent and suitable uses, represents a reversal of common practice. Efficient, minimized structural interventions open great savings potential in material usage, CO_2 emissions and costs. GreenTech-Renovation shall become part of the Bauhaus Initiative and thereby a lighthouse project for the European Union.

Greening, as a synergy measure, plays a connecting role in this project.

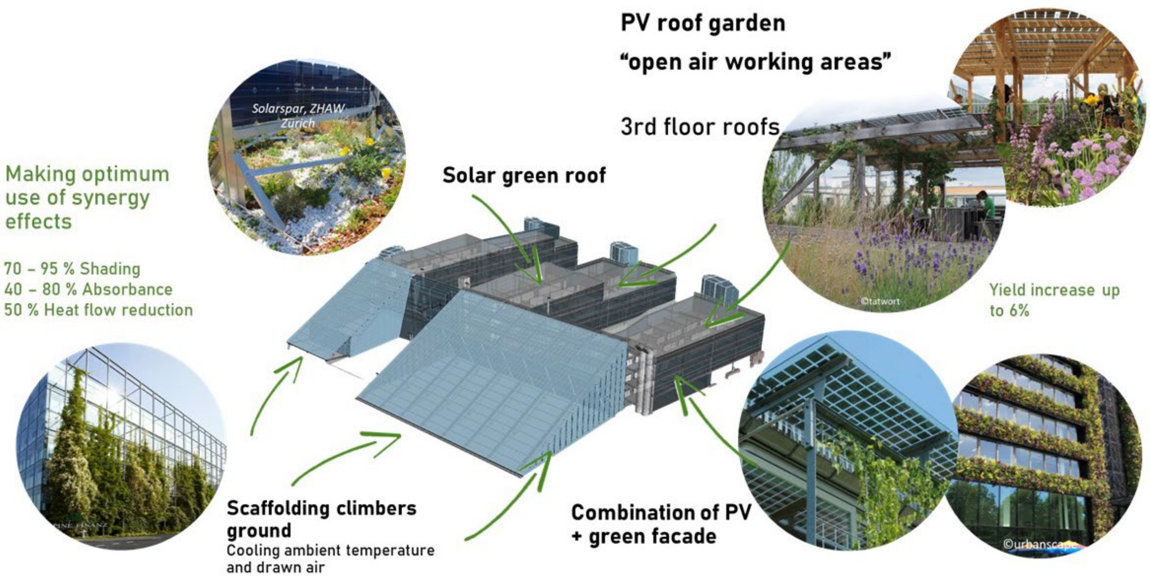

Figure 13: The former school on Kinkplatz – diagram for the integration of greening on façades, roofs and on the site

4. Conclusions and Outlook

The paper has illustrated some of the challenges, trends and potential solutions for the success of the renovation wave. The first important conclusion is the necessity to shift away from new construction and soil consumption to refurbishment of the already oversized built stock. All these examples head towards the principles, now officially endorsed by the new EU regulations, of the circular economy, integrating the ten "Rs" of CE in the refurbishment of the existing built stock. The focus was laid on a special challenge in this context - architecturally valuable buildings with high levels of transparency from the last 70 years, because these buildings consume high amounts of energy, their refurbishment using renewable energy is more difficult and rare, with a need for demonstration projects.

5. Footnotes

1) https://ec.europa.eu/commission/presscorner/detail/en/qanda_20_1836.

2) www.eur-lex.europa.eu. directive: energy performance of buildings 2010/31/EU, version 26/02/2021.

3) Renovation quote 1% shall be tripled, following the model of the"Green New Deal", Der Standard, 14.2.2021

4) CE Action Plan RENOLUTION.brussels, Bruxelles Environnement leefmilieu Brussel.

5) https://davosdeclaration2018.ch/davos-declaration-2018/.

6) www.europa.eu, New European Bauhaus.

7) The European policy framework - such as the **Renovation Wave** (in regard to double the annual renovation rate of building renovation), the New **Circular Economy Action Plan** (in regard to the entire life-cycle of products), the **Zero Pollution Action Plan** (in regard to healthy indoor environments), the **Bioeconomy strategy** (in regard to managing natural resources sustainably), the **European Skills Agenda for sustainable, competitiveness, social fairness and resilience** (in regard to green and digital skills).

8) The FFG-funded research project is a project initiated by architects Tillner and Willinger, which includes the expertise of theoretical as well as applied research. In cooperation with the following research institutions:
IBO – Austrian Institute for Building Biology and Ecology
Andreas Vass, Hubmann Vass Architekten, Prof.Franz Graf, EPFL Lausanne
TU Wien, Vienna University of Technology, Institute of Architectural Scienc es, Structural Design and Timber Engineering

FH Technikum Wien, University of Applied Sciences Technikum Wien
GrünStattGrau, Research and Innovations GmbH with the vertical farm institute

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