ARV
CLIMATE POSITIVE CIRCULAR COMMUNITIES

ARV INNOVATION INTEL FOR IMPACT REPORT 2022

WP9 BUSINESS MODELS, FINANCIAL INSTRUMENTS, POLICY, AND EXPLOITATION

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[1] *ARV is a Norwegian word meaning "heritage" or "legacy". It reflects the emphasis on circularity, a key aspect in reaching the project's main goal of boosting the building renovation rate in Europe.*

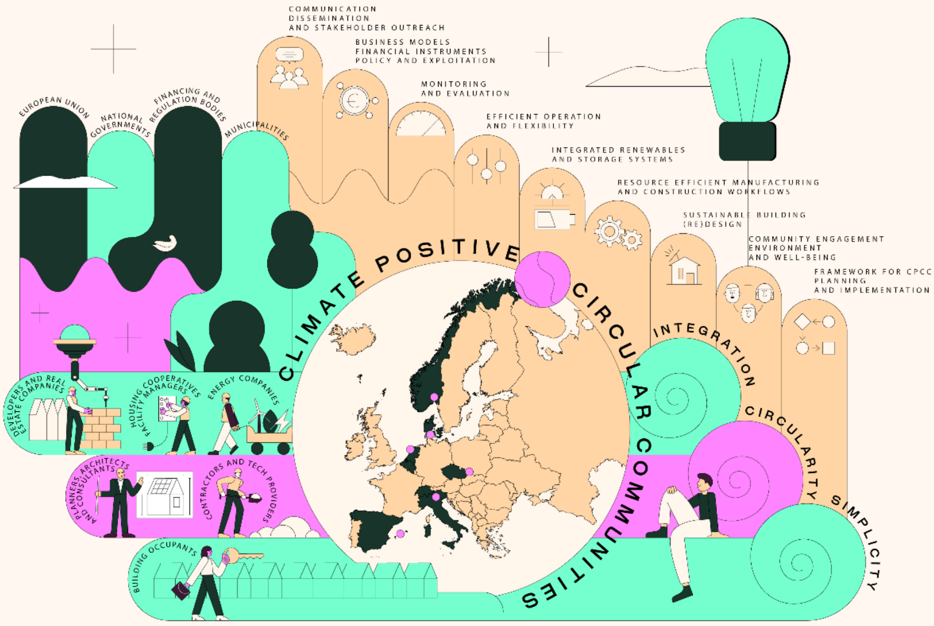
ABOUT THE ARV PROJECT

The vision of the ARV project is to contribute to speedy and wide scale implementation of Climate Positive Circular Communities (CPCC) where people can thrive and prosper for generations to come. The overall aim is to demonstrate and validate attractive, resilient, and affordable solutions for CPCC that will significantly speed up the deep energy renovations and the deployment of energy and climate measures in the construction and energy industries. To achieve this, the ARV project will employ a novel concept relying on a combination of 3 conceptual pillars, 6 demonstration projects, and 9 thematic focus areas.

The 3 conceptual pillars are integration, circularity, and simplicity. **Integration** in ARV means the coupling of people, buildings, and energy systems, through multi-stakeholder co-creation and use of innovative digital tools. **Circularity** in ARV means a systematic way of addressing circular economy through integrated use of Life Cycle Assessment, digital logbooks, and material banks. **Simplicity** in ARV means to make the solutions easy to understand and use for all stakeholders, from manufacturers to end-users.

The 6 demonstration projects are urban regeneration projects in 6 locations around Europe. They have been carefully selected to represent the different European climates and contexts, and due to their high ambitions in environmental, social, and economic sustainability. Renovation of social housing and public buildings are specifically focused. Together, they will demonstrate more than 50 innovations in more than 150,000 m^2 of buildings.

The 9 thematic focus areas are 1) Effective planning and implementation of CPCCs, 2) Enhancing citizen engagement, environment, and well-being, 3) Sustainable building re(design) 4) Resource efficient manufacturing and construction workflows, 5) Smart integration of renewables and storage systems, 6) Effective management of energy and flexibility, 7) Continuous monitoring and evaluation, 8) New business models and financial mechanisms, policy instruments and exploitation, and 9) Effective communication, dissemination, and stakeholder outreach.



The ARV project is an Innovation Action that has received funding under the Green Deal Call LC-GD-4-1-2020 - Building and renovating in an energy and resource efficient way. The project started in January 2022 and has a project period of 4 years, until December 2025. The project is coordinated by the Norwegian University of Science and Technology and involves 35 partners from 8 different European Countries.

EXECUTIVE SUMMARY

The ARV Innovation Intelligence for Impact report 2022 is the first of a yearly series of reports presenting the innovations that the ARV project have developed, designed, and tested to help establish Climate Positive Circular Communities in Europe. This report has the main objective to contribute to a speedy and wide scale implementation of CPCCs by putting on stage innovative solutions.

It is in the ARV ambition to produce innovative solutions that go beyond state-of-the-art and offer compelling approaches and technologies to policy makers, local change makers, and business professionals to advance the adoption of the CPCC concept. In this first edition of the Innovation Intelligence for Impact report, twelve innovations are presented. For the 2022 edition, the innovations were clustered in three solutions clusters – namely: knowledge solutions, engineering solutions and material solutions.

The report is an actionable tool for disseminating the innovative approaches of the implemented solutions within the ARV demonstration sites and processes. Considering this, the report has a strong connotation to provide information about the innovative solutions in an easy to understand, yet detailed manner. The solutions are presented in a standard format to allow a smooth reading, facilitating the comprehension, and hopefully sparking the interest of the reader to dive deeper into the subject matter.

The adoption of ARV innovative solutions by other changemakers is at the core of this report. A strong motivation of collating yearly the solutions demonstrated, is the willingness to take a period snapshot of scalable achievements to cross-fertilize the European built environment movement. The report will also be presented to the ARV Exploitation Board which is a group of high-level stakeholders capable of leapfrogging the innovations within their network and ecosystem of influence. By disseminating the innovations in this fashion, the ARV project strives for the report readers to internalize the learnings and bringing them to their communities, research groups, and think how to apply them to their local context.

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1. INTRODUCTION

As central features of human life, buildings furnish space in which to dwell, gather, labour, trade, make, learn, heal, and revel. Of all the things we create, buildings are the largest, and they generally persist for decades, if not centuries. How can we retrofit existing buildings and create new buildings to minimize energy use? How can we stop other, on-site sources of emissions? The aim of the *Innovation Intelligence for Impact Report* is to give stage to the ARV project innovations that are ready to be deployed and scaled to contribute to speedy and wide scale implementation of Climate Positive Circular Communities (CPCC). This report is the first of an annual series presenting the innovations the ARV project has developed, designed, and tested to help create CPCC in six different EU countries.

The successful implementation of CPCCs require innovative solutions on a wide range of technical and social topics. The ARV aims at providing solutions to nine thematic focus areas that present challenges and barriers to the implementation of CPCCs. The thematic focus areas are 1) Framework for CPCC planning and implementation, 2) Community engagement, environment, and well-being, 3) Sustainable building (re)design, 4) Resource efficient manufacturing and construction workflows, 5) Integrated renewable and storage systems, 6) Efficient energy management and flexibility, 7) Validation by monitoring, evaluation, and impact assessment, 8) Business models, financial instruments, policy, and exploitation, and 9) Communication, dissemination, and stakeholder outreach.

The mission of this report is to collate the ARV innovations achieved by the end of each year of the project, aiming at sharing broadly the innovations. It is in the ARV ambition to produce innovative solutions that go beyond state-of-the-art and offer them to policy makers, local changemakers, and business professionals to advance the adoption of the CPCC concept. In this first edition of the intelligence report, twelve innovations are presented. For the 2022 edition, the innovations were clustered in three solutions approaches – namely: knowledge solutions, engineering solutions, and material solutions. The reason why these clusters were selected is because the report wants to be an easy to navigate catalogue of innovations for the public, but also for subject matter experts. In this edition, these three clusters made sense for the innovations that came to realization in 2022. Nevertheless, in the next three editions of the report, the cluster may change due to the impact areas of the innovations themselves.

A glossary of terms used in this report is given in Appendix A.

2. OBJECTIVES

Awareness, Open access, Scalability.

The key objective of the report is to become a periodic lighthouse to facilitate a speedy scale-up of the ARV innovations by addressing, with innovative approaches, the nine thematic focus areas of ARVV that present challenges and barriers to the implementation of CPCCs. Hitherto, this periodic report wants to raise awareness amongst the built environment community of innovative solutions developed within the ARV project in an open access format, to transparently share results to scale the uptake of such innovations.

3. METHODOLOGY

The methodological approach is based on systematization of the results on development of the twelve innovations in the first year of the project implementation, with the aim of showcasing the first cluster of innovations that have been demonstrated. This aims to explore the possibilities of further exploitation of the innovations and its relevance for the replication and future perspective for applied used through the innovative business models.

As part of the Climate Positive Circular Communities Innovation Forum task, GDFA and NTNU have developed an innovation management tracker: ARV Innovation registry (see Figure 1). The Tracker not only paves the way to systematically support the annual report on ARV Innovation Intelligence for Impact, but also aims at empowering the ARV Consortium with an instrument to cluster innovations, learn from each other experiences, and discuss commonalities. The broader goal is to collect, analyze, and disseminate innovations to facilitate knowledge exchange and outreach with the ARV Exploitation Board to ensure early identification and to scale commercially viable innovations.

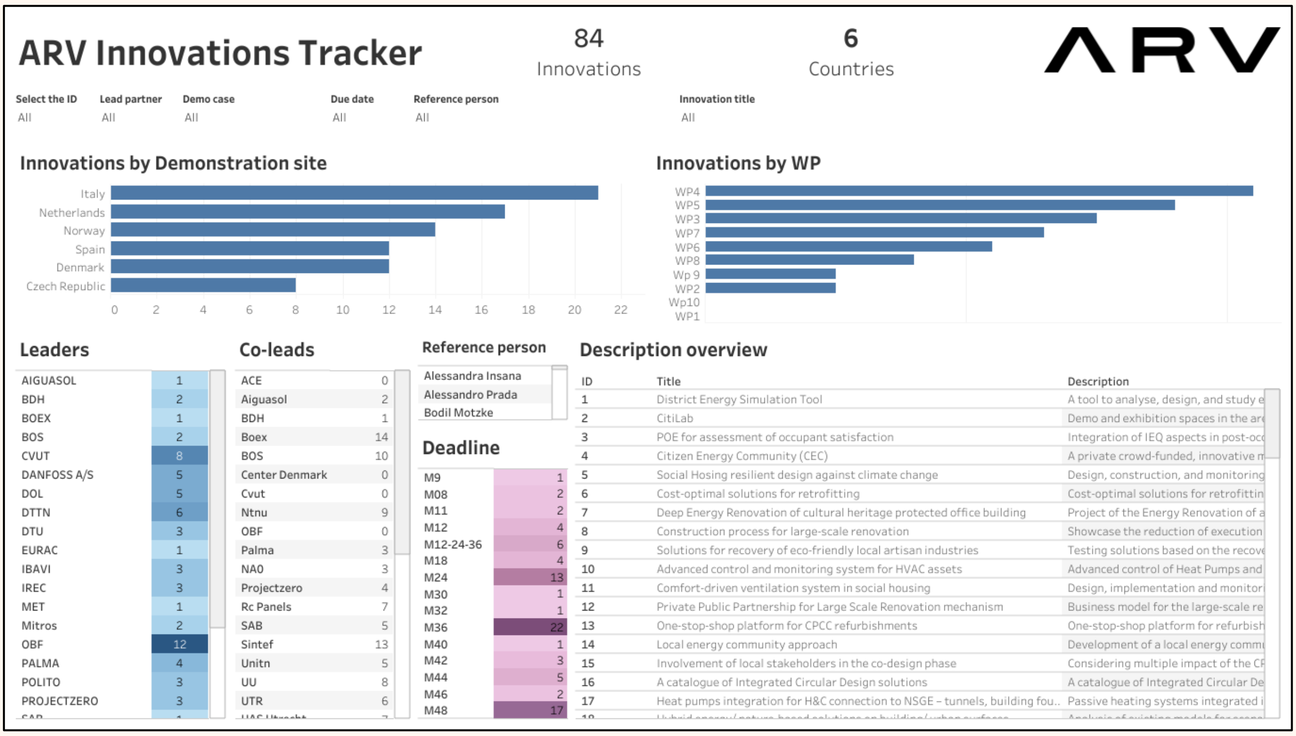


***Figure 1**. ARV Innovation tracker*

All key information about ARV innovations have been collected through the ARV Innovation registry survey, which is a living tool. The key information related to the current and expected readiness levels of the innovations and the overall level of the development, targets group and expected impacts and its exploitation pathways, will be collected through the ARV Innovation Registry bi-annually, according to the established innovation management approach (D1.3 Innovation Management Plan). For each of the ARV innovations, an Innovation Lead is appointed as the main responsible for developing and testing the innovation.

ARV innovations have the potential to be commercially exploited as products or services. The innovations will be commercialized with technology and system providers in the ARV consortium. In 2023, the first exploitation plan will be developed for the 15 innovations presented in this Report, in close cooperation with the ARV Exploitation board, which will be established in Task 9.5 as a vehicle for scaling the business models and financing instruments. The Exploitation Board will be composed of strong innovation clusters and financial sector players that will spread the green building and renovation concepts, to provide momentum to the 'renovation wave' that will be politically underpinned. The Innovation Clusters bring together key stakeholders from the whole value chain of CPCCs: knowledge institutes, tech and system providers, energy service providers, architects, real estate and building owners, municipalities and regional authorities, financial institutes, and different organizations working to promote sustainable buildings and communities.

As an important segment of the further exploitation and dissemination pathways of the achieved results, the ARV e-marketplace (Figure 2) will enable the aggregation of all the project results, innovations, technology providers, and service providers. The e-marketplace will include the necessary tools to streamline the process and deliver the necessary services and installations, and the financing mechanisms put in place will facilitate their uptake. The key results presented in the Innovation

Intelligence for Impact report will be further disseminated through the e-marketplace, beginning of 2023, and lead by Housing Europe.

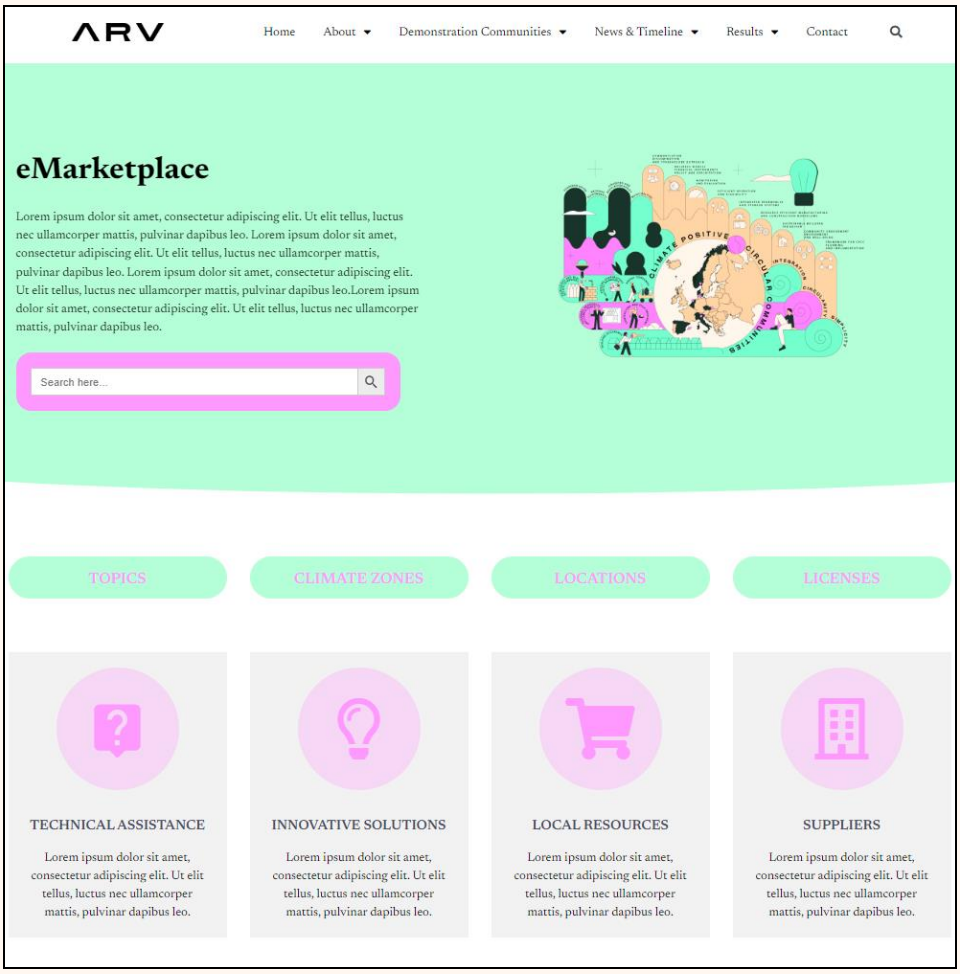


Figure 2*. E-marketplace as part of the ARV project website*

4. CIRCULAR INTELLIGENCE INNOVATIONS 2022

The completed ARV innovations of 2022 are composed by a wide range of technical and social expertise. Several innovations are characterized by an engineering component that produces an advancement in the technological level of a specific appliance. Another cluster of innovations revolves around production materials to ensure lower embodied carbon emissions of new buildings or retrofitted ones. For example, timber-based construction is an area where ARV in 2022 presents innovative solutions. Moreover, there is a strong component of innovative knowledge sharing. A few innovations are presented in the form of catalogues, compendiums, and decision-making processes.

According to the nature of the ARV 2022 innovations, they were clustered in three solutions approaches – namely: knowledge solutions, engineering solutions, and material solutions. In this chapter, all the twelve innovations are presented and subdivided into these clusters. The structure of each innovation follows a simple description section followed by three paragraphs where the lead authors respond to a few key, yet straight forward questions (e.g. *"How can it be applied? Why is it relevant?"* etc.). These structured approach of guiding questions aims at giving the report a guiding principle of simplicity yet with a rich amount of information.

Figure 3 offers a visual breakdown of the solutions subdivided into the abovementioned clusters.

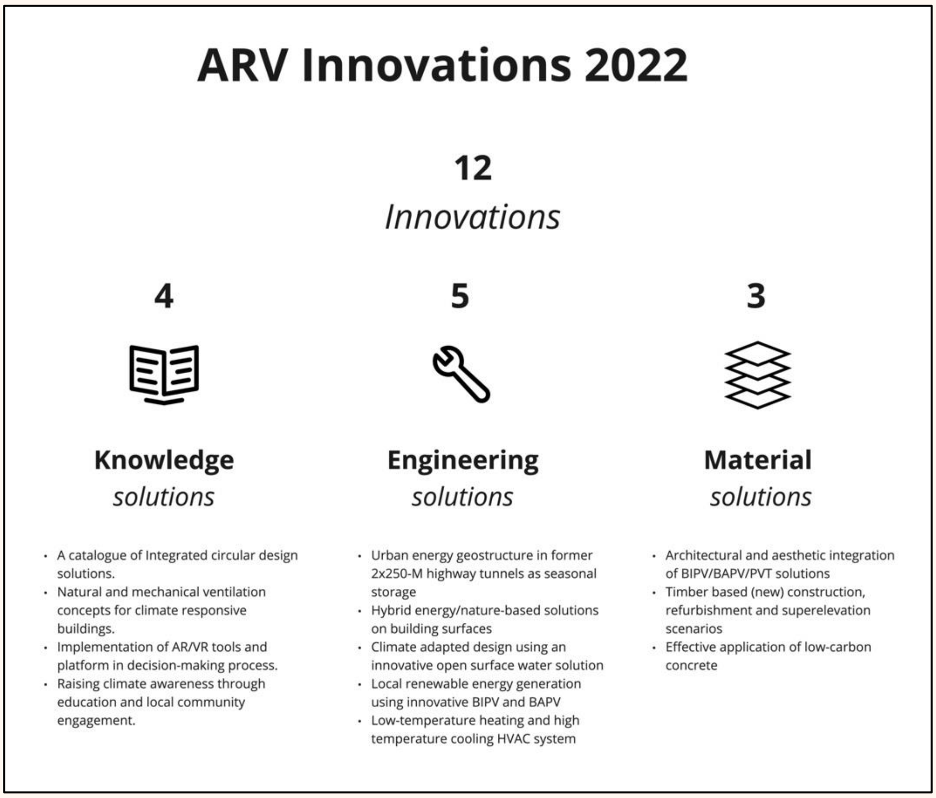


Figure 3. *ARV Innovations 2022 subdivided into clusters*

4.1. KNOWLEDGE SOLUTIONS

This chapter includes the innovations that are considered as “knowledge solutions”. These may be tools, methods, catalogues, and approaches to drive CPCCs strategy development, management techniques, collaboration mechanisms, knowledge sharing and learning, as well as knowledge capture and storage. The knowledge solutions strive to improve understanding, collaboration, and process alignment.

4.1.1 A CATALOGUE OF INTEGRATED CIRCULAR DESIGN SOLUTIONS

This innovation is a catalogue of integrated circular and sustainable solutions for positive energy and low carbon footprint buildings which aims to be of help and support to all possible stakeholders (from designers to users), and especially to drive public administration and decision-makers to the proper choice of sustainable solutions for new buildings and refurbishment of existing ones, considering circular design practices integrated into Buildings 4.0 vision. Both physical solutions (building elements referring to envelopes – roof, façade, add-on – and ground – street, open spaces) and digital ones have been considered. They have been categorized as: Urban Green Infrastructure, Blue Infrastructure, Energy Systems, Shading devices, Building technologies, and Digital solutions. Each category is further divided into sub-categories, according to the type of solution considered. Each category answers to a specific climate-related challenge: Energy sustainability, Temperature regulation, Sustainable water management, Health and wellbeing, and synergies among them are highlighted as well. In fact, the proposed approach is based on challenges rather than objectives so to allow flexibility and continuous development of strategies and tactics as well as freedom in the choice of the specific solution to be adopted. Each challenge is further developed by specific objectives, which identify the urban transformation actions that can be implemented to tackle the challenges and that can change according to different locations and/or conditions. For each solution, the catalogue provides a brief description, the challenges it responds to, the objectives it can achieve, the performances it can guarantee, as well as the benefits, even if not strictly related to the challenges. Each solution refers to one or more case studies defined as best practices.

In particular, 28 physical solutions and 10 digital ones have been considered. A number of parameters are defined for each solution, organized as follows:

- Section A: definition, challenges, goals, performance, other benefits, SDGs, drawbacks, scale of application, use, regulations, and strategies;
- Section B: scientific data from conducted studies certifying the performance validity and order of magnitude of impact of the solution, with respective references;
- Section C: definition of best practice.

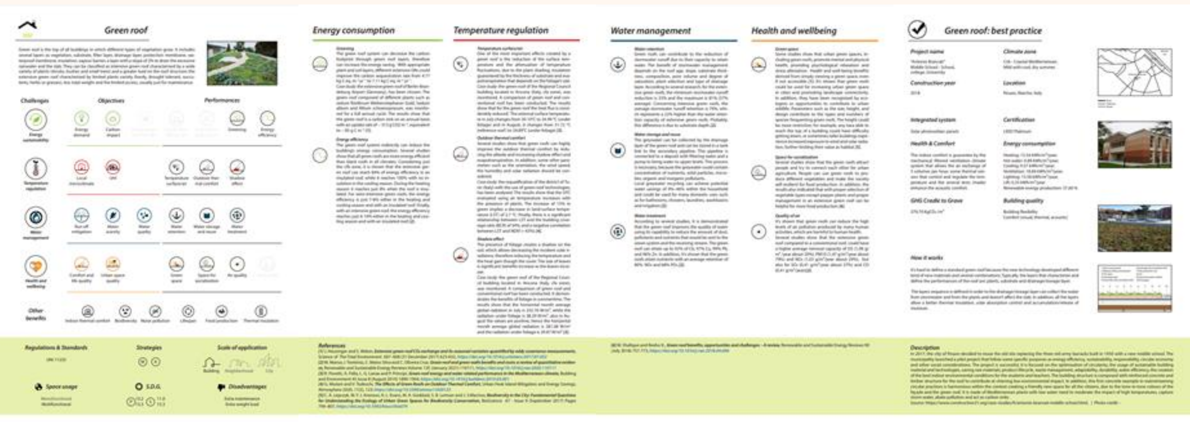


***Figure 4**. Example of a sheet for the Green roof solution*

Why is it relevant?

The performances of each solution constitute the due process to achieve the specific objective given in a design and planning procedure, driven by enabling processes of the built environment. As such, performances can be measured and controlled by practitioners. Designing through a climate sensitive approach relies on the understanding of the relationship between the built environment and urban climate, and on the management of parameters and interactions among them.

One of the main innovative aspects of the catalogue is the presence of information sheets on products, building systems, and technologies, mainly related to companies in the local production fabric, which can contribute to the implementation of the proposed solutions. In particular, the benefits and opportunities for companies to be present in the catalogue are:

- Local, national, and international visibility of their product/technology/system.
- Link to European projects within the Green Deal area.
- promotion and (in)training for the construction supply chain, public and private clients, and end users.
- Opportunities for synergies between construction stakeholders and the research world.
- Active contribution to the circular economy challenge and integration into Building 4.0 processes.

How can it be applied?

The catalogue presents a range of possible physical and digital solutions that can be applied especially in a SUSTAINABLE BUILDING (RE)DESIGN process, in particular (but not only) in the early concept design phase of new and existing buildings. Solutions are presented in general terms and real market products (particularly at a local/regional level) are listed. Depending on local environmental conditions and intended use of the building, pros and cons of each solution concerning environmental challenges are defined, with specific objectives and related performances. Especially designers and public administration technicians can refer to the catalogue so to guide their choice towards a local, circular, and efficient (re)design and planning process.

Future perspective

The catalogue is now available in a static version (pdf format), but in the near future, a dynamic version is envisaged through the creation of a website with a section accessible with an id and password where product information relating to certain solutions can be easily uploaded by the local companies. Moreover, this innovation defines a model that can be used also by the other partners of the ARV project towards a European catalogue of integrated circular and sustainable solutions for 4.0 buildings envelopes.

4.1.2 NATURAL AND MECHANICAL VENTILATION CONCEPTS FOR CLIMATE RESPONSIVE BUILDINGS

The purpose of the study on Natural and Mechanical Ventilation concepts for climate responsive buildings is to offer an overview on IEQ conditions created by different ventilation types, defining pros and cons of natural ventilation techniques in buildings vs mechanical ones. A framework on scientific evidence of papers comparing NV and MV in terms of comfort and well-being has been provided, in a perspective of high-performing and sustainable buildings' design (e.g., NZEBs, PEBs, climate responsive). The main hypothesis is that ventilation is firstly aimed to provide IEQ, with energy savings as a very important additional aim. For this reason, the following research questions were explored:

1. Which differences are present between IEQ conditions guaranteed by NV and MV?
2. Which ventilation techniques are more suitable at different climates, seasonal and outdoor pollution conditions, according to both IEQ and energy perspectives?
3. Which ventilation techniques are more suitable with different building types and uses?
4. Which are the research gaps in terms of effects of NV and MV on the IEQ, depending on the type of building, the ventilation technique and the comfort domain considered?

Several papers concerning recent scientific literature were grouped and analyzed:

- In terms of type of building considered.
- In terms of comfort domain analysed.
- In terms of type of ventilation recommended.
- In terms of outcomes in both the field of comfort and the field of energy consumed.

By a methodological point of view, a systematic review was performed, using AND/OR Boolean operators in a search on the Web of Science database. The following figure reports the detailed search string used. PRISMA flow diagram was used in the systematic review process.

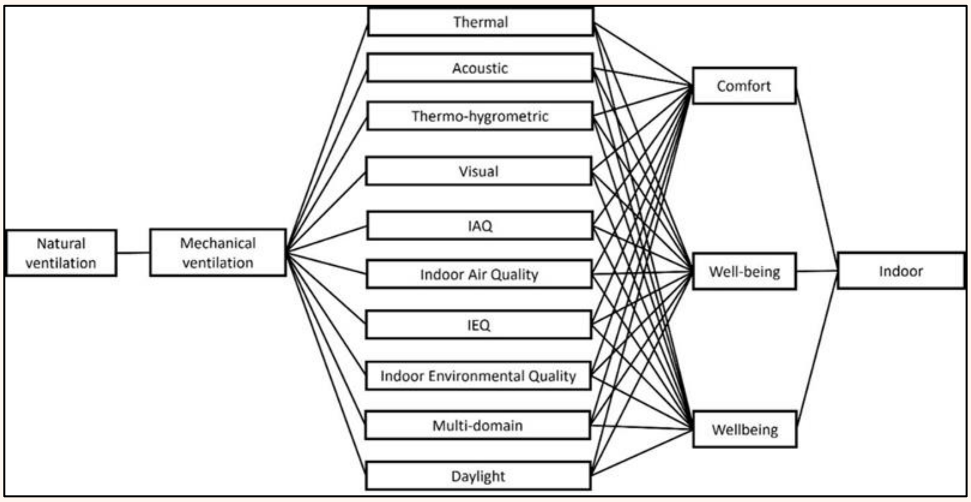


***Figure 5**. Detailed search string used for the systematic review with AND/OR Boolean operators*

Even though ventilation design is often aimed at ensuring adequate IAQ, thermo-hygrometric comfort seems to be the main ventilation behaviour driver for occupants. Especially in non-residential buildings and after the COVID-19 pandemic, the approach in ventilation studies has slightly changed to a health-based driven, rather than a comfort- or energy- based one. In general, present research strongly highlights that hybrid ventilation is the most recommended solution, to guarantee both energy savings and proper IEQ conditions, when not achievable with natural ventilation alone. This is particularly true in extreme or polluted climates, where windows' openings alone could lead to poor indoor conditions, and/or highly occupied or healthcare environments, where NV alone might be not sufficient to maintain an adequate level of IAQ and healthy conditions. The literature analysed also suggests that, when possible (e.g., residential environments, smaller offices) the hybrid solutions should also consider the necessity of control by occupants, allowing to switch to a total manual system if required. Proper design of ventilation is encouraged, promoting the use of numerical modelling such as CFD analyses, to ensure IEQ and avoid issues such as short-circuiting of supply and exhaust air and draught sensation by occupants.

Why is it relevant?

The outcomes of the study can be useful for understanding the main research gaps in the field and to guide designers in the best choice to ensure comfort and well-being in NZEB and PEB design, also with attention to proper ventilation of indoor spaces. In fact, ventilation is a key factor in the field of sustainable climate responsive design, as energy savings strongly depend on ventilation techniques. In this framework, the choice of proper ventilation type (to be energy-driven or IEQ-driven) cannot be made regardless of indoor comfort and well-being. The use of either NV, MV or HV is highly dependent on the climate, the outside pollution, the building type, and the season. In this sense, the ventilation system could be coupled with sensors and smart home solutions, being able to switch from one typology to another, whenever the indoor and outdoor conditions allow or require it. Moreover, warning sensors might be useful to advise occupants on the indoor pollutants and CO_2 concentration when NV is used.

How can it be applied?

The outcomes of the study can be exploited by policymakers, to further expand and update ventilation standards and guidelines considering both energy consumption and indoor well-being. The development of such guidelines is fundamental for engineers, architects, and planners, to help them in conscious and contemplated choices during the design process. In particular, the study can be applied during the early concept design phase of the building (re)design to properly define the building shape and devices for ventilation and night cooling techniques towards energy saving and human well-being.

Future perspective

Studies addressing the topic of well—being related with the comparison of NV and MV would be beneficial for human-cantered indoor building design. Moreover, literature, standards and guidelines would benefit from studies on ventilation exploring comfort with a multi-domain perspective. Ventilation is clearly and directly connected with thermo-hygrometric environment and IAQ, but recent studies agree on how all the comfort aspects interact (e.g., noise-IAQ, emissions of pollutants with higher sunlight, psychological aspects). For this reason, comfort studies coupling subjective surveys with objective measurements, and correlating the comfort perception in terms of the four domains with each other would be necessary. Moreover, some environments such as healthcare facilities would need further research in terms of comfort related with comparison of different ventilation techniques.

The exploitation of night cooling allows to further exploit natural ventilation during night-time, when lower temperatures are present, using the delay in the heating process of massive elements. Therefore, comparative comfort studies with and without this technique would allow to assess the comfort benefits during morning hours, further encouraging designers and stakeholders to exploit this design technique. Eventually, other innovative passive solutions have been proposed in the last years, including the use of internal cladding for improving the thermal inertia, the coupling of massive elements with the smart use of shadings, use of compact form to reduce the heat loss through the envelope area, organization of spaces, air quality control through proper selection of materials in air-tight buildings. The use of these techniques should be explored in terms of indoor well-being, when coupled with MV and NV systems.

4.1.3 IMPLEMENTATION OF AR/VR TOOLS AND PLATFORM IN DECISION-MAKING PROCESS

Visualization techniques, particularly Virtual Reality (VR) and/or Augmented Reality (AR) will be used during the development of the ARV demonstration projects to better communicate results of different scenarios analysis to different types of stakeholders, to facilitate citizen engagement, promote education and training for sustainability. The development of VR and AR applications are targeted toward several distinct stakeholders (city planners and policy makers) and citizen user group types (school children, common public, inhabitants and infrastructure users, service personnel).

Why is it relevant?

The growing development of image-based techniques provides simulation tools to be used for visualization and research purposes. Augmented Reality (AR) and Virtual Reality (VR) are two visualization and presentation tools which provide a greater sense of realism in scenarios one wishes to evaluate. These tools overcome logistical challenges as they can provide real-view (AR) and full-scale visualization (VR) of different scenarios, in which diverse building and urban elements can be easily changed. Research for different disciplines constantly show that users gain a better understanding of the problems when using VR. Indeed, AR and VR tools are promising tools to better communicate and evaluate different solutions to specific problems, as well as to channel users' input and experiences facilitating their active engagement.

Two objectives of the ARV project involve: (O2) to demonstrate a replicable framework for efficient design of CPCC, and (O3) to demonstrate community engagement platforms for awareness raising, occupant insight and well-being, and co-creation. AR and VR are relevant tools for contributing to these two specific objectives. These tools can be used to visualize different solutions in full-scale, immersive and realistic scenarios that can serve to: streamline the evaluation process and decision-taking of stakeholders (O2), and to raise awareness among citizens to engage them in the co-creation of new CPCC (O3).

How can it be applied?

AR tool: The development of the AR visualization application is greatly advanced, and a prototype is already finished. The AR tool will be applied for the Oslo demo, more specifically to the Voldsløkka school, in which three building elements will be on focus: wall. glass, and use of photovoltaics (PV). For each of these elements, there are subcategories showing different materials which provide the users information about the greenhouse gas emissions of each material. This ensures focus on the education of citizens, including school children, on energy-related issues and promote their engagement in the development of CPCC.

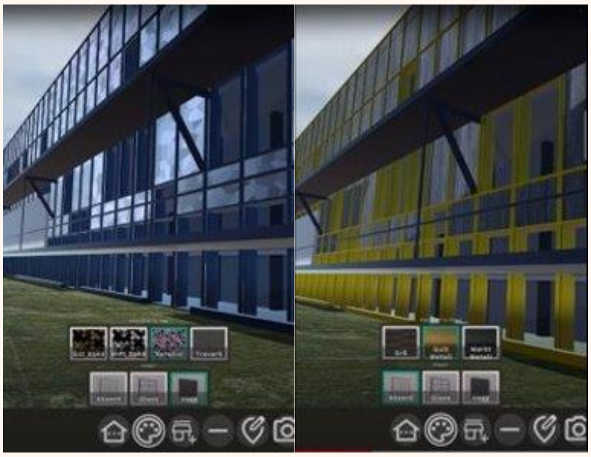


Figure 6. *Screenshots of the AR tool for the Oslo demo depicting the visualization of the Voldsløkka school with the possibility to change the building elements.*

VR tool: The development of the VR tool is currently focused on the Palma demo (Llevant Innovation District), specifically on the Neighbourhood Scale Retrofit. There will be 2 display levels: *i*) The entire framework of the project, in which the target areas of the district will be highlighted allowing a 360° vision with free movement: and *ii*) The environment of each action, in which a street will be selected and modelled in 3D with maximum realism to be used in VR. Both of these display levels will allow to visualize in full-scale and high realism the defined priority areas of the Llevant Innovation District. This will provide a better understanding of the stakeholders (city planners and policy makers) for decision making.

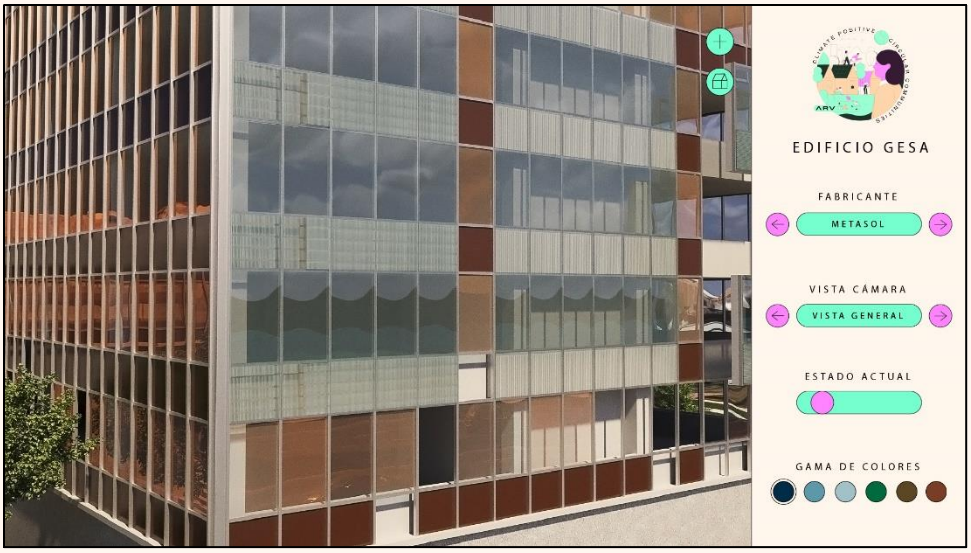


Figure 7*. Illustration of a building to be used in a VR scenario for the Palma demo (work in progress).*

Future perspective

The AR tool will be tested in an already defined experimental design, in which both experts (city planners and policy makers) and lay people (citizens) will use the AR application on site, i.e., the Oslo demo. Their opinions and evaluations of both the app (as technical tool) and the new insights and level of understanding they have had from the app (information about greenhouse gas emissions between different materials) will be evaluated to further develop the tool, in collaboration with living lab approach to citizen engagement.

For the VR tool, the priority areas for the Llevant Innovation District (Palma demo) are already defined, and the information is collected. The data collected will be used to further develop the VR tool with the 2 display levels mentioned above. The VR model will be tested and is expected to support design discussions and meetings with stakeholders in collaboration with the living lab approach to citizen engagement.

4.1.4 RAISING CLIMATE AWARENESS THROUGH EDUCATION AND LOCAL COMMUNITY ENGAGEMENT

Description

Raising climate awareness among citizens entails a multi-faceted approach, where making use of educational facilities for sustainability teaching of pupils and citizens is particularly pertinent. At Oslo Voldsløkka school, the aim of the engagement activities organized in Living Labs, is raising awareness among secondary school and the cultural school pupils, as well as among their parents and the wider community found in the neighbourhood. The focus of the activities is the energy transition and circularity, including solutions regarding energy technologies and building materials. Voldsløkka school will establish a physical demo-space for engaging the pupils into activities of different types, including learning, co-creation and becoming young green ambassadors. The demo-space will be developed in cooperation with the pupils. The activities planned at the school also aim at involving the local community. They will be invited into using the neighbourhood and buildings actively, e.g., through exhibitions, and open events on energy and circularity. In the search for innovative approaches to raising climate awareness among the youth (who are digital natives), AR or VR tools will be actively explored.

Why is it relevant?

Citizen's perspectives, especially that of young people, are often missing in sustainable neighbourhood transformation. Youths lack the mobility that most adults have in the city, and they often tend to be more limited to the area directly around where they live or go to school. Young people also lack the connections and access to decision makers that many adults and professionals have through work and social engagements. At Voldsløkka, the aim is direct participation strategies towards young people. Young people`s perspectives and experiences will be gathered so that they can be actively included in the context of deep energy renovations and the deployment of energy and climate measures by the construction and energy industries. Education, learning, and awareness raising are relevant to create and operate a built environment. The activities will have a strong focus on circularity and how community engagement can contribute to small- and large-scale circular pathways. Raising climate awareness among young people is also a pre-requisite for the future of societies. The outcome of engaging with the pupils and the local community is expected to raise awareness about sustainable behaviour, particularly energy efficient solutions. The goal is establishing energy efficient behaviour as part of the community`s everyday life.

How can it be applied?

The programme and tools developed for the specific activities for raising climate awareness targeting young people and their families, can offer the possibility to be implemented in an educational context in classrooms as well as within the wider community, as methods for teachers. They can also be an inspiration to other ARV LLs as well as other projects targeting youth, for example within other schools in the Oslo Municipality, though in a modified manner and adapted to the local context.

Future perspective

When asked what would make the European Year of Youth[2] successful, the most stated response from youths was 'if decision-makers listened more to the demands of young people and acted on them' (72%). Youth involvement in climate mitigation topics is crucial. Raising climate awareness by creating and operating a climate positive circular community through dialogue and co-creation with the youth in the community and making use of educational facilities and curriculum, represents an exciting opportunity to engage the youth segment in Europe. The programme and tools for the specific activities for raising

[2] https://youth.europa.eu/year-of-youth_en

climate awareness targeting young people will be planned out in the first half of 2023 and implemented/adapted in phases going forward.

Living labs as innovation environments will open up for participatory urban planning, in which the focus will be on the collective, allowing local communities to understand the challenges and opportunities related to a specific neighbourhood. This in turn will allow creating active processes together with stakeholders and decision-makers, aiming to achieve mutual learning and engagement that can be used in all future community projects. However, if we are to consider living labs from a strictly ethical point of view, where participation is an essential part of a democratic process, it is important to underline that living labs primarily should be for the good of the community that we are working with. Upscaling is an added advantage and not a prerequisite.

4.2. ENGINEERING SOLUTIONS

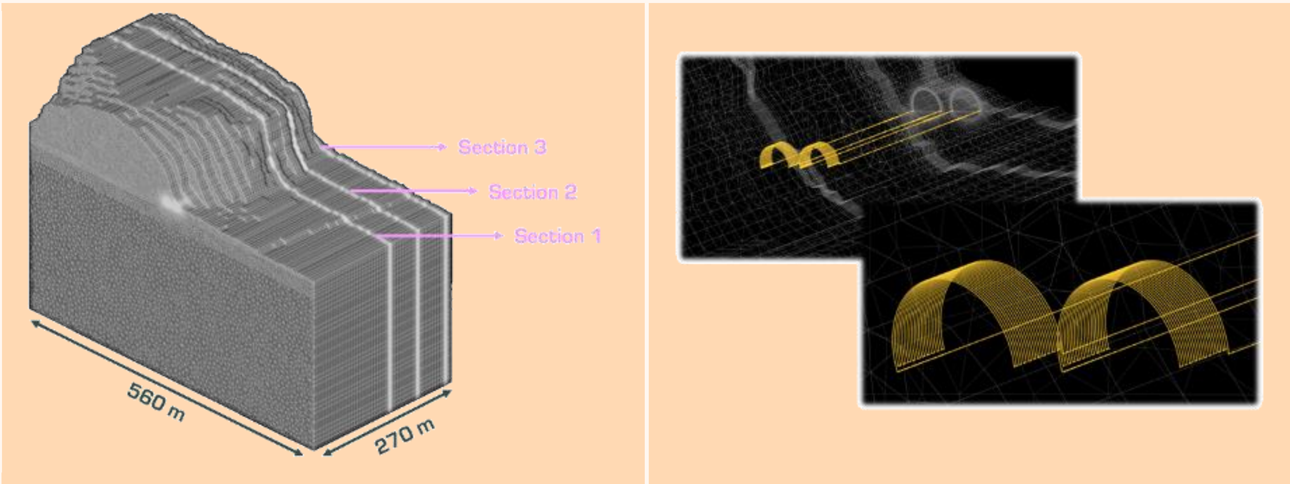
This chapter includes the innovations that are considered "engineering solutions". In principle these innovation involves to some extent the deployment or advancement of solutions that have to do with mechanical, electrical, plumbing, and construction innovations.

4.2.1 URBAN ENERGY GEOSTRUCTURE IN FORMER 2X250-M HIGHWAY TUNNELS AS SEASONAL STORAGE

Description

The concept of assigning a double role, both structural and energetic, to structures in contact with the ground – so-called energy geostructures - has been spreading in the last years for contributing to the production of clean, renewable thermal energy. In particular thermal activation of tunnels has shown great energy potential and recent full-scale projects have demonstrated the feasibility of such technology. However, so far applications have been related to new tunnelling projects, whereas possibilities of implementation in the existing heritage of tunnels have not yet been traced. The innovation is related to the study, design, and testing of a system to retrofit and thermally activate an existing tunnel (in operation or abandoned) for an energy purpose not envisaged originally. The system includes a network of pipes capable of transporting a heat transfer fluid.

A prototype of such a system is being investigated by means of preliminary numerical analyses with the final aim to install it in the Piedicastello tunnels within the Trento demo. The tunnels, today abandoned and devoted to an exhibition hall, will be turned into a heat exchanger with the ground and with the internal environment for road de-icing and/or heating and cooling purposes of an adjacent building to test the potential of the identified solution in a realistic operating environment. To this aim, pipes will be fixed at the intrados (1) and inserted in radial holes (2). A preliminary numerical model of solution (1) (see Figure 8) has successfully investigated i) the optimal installation distance from the tunnel mouth, ii) the optimal heat carrier fluid velocity and iii) thermal performance (thermal power and energy produced).



(a) (b)

***Figure 8**. Illustration of (a) the numerical model and (b) close-up view of the heat exchanger system configuration in Section 2 located at an average distance of 65 m from the tunnel mouth.*

What challenge does it solve?

Climate change mitigation and adaptation strategies are urgently needed in a world that is becoming extremely vulnerable face to the evident signals highlighted by recent extreme weather events. To meet the target of climate neutrality in 2050, the energy transition path needs to follow steps that necessarily include a substantial increase in the use of clean and renewable energy in the sector of heating, cooling, and domestic hot water (HC-DHW). Residential, service and industry sectors combined, their HC-DWH energy share accounts for about 50% of the total primary energy use in 28 EU Member States. Limiting the statistics to the residential sector, the HC-DHW energy supply is covered by coal, oil and natural gas sources for a share of more than 70% in Europe. Not only the fossil fuel consumption contributes to the environmental harm, but also it creates an overreliance on interregional supply infrastructures and world economic stability.

The innovation described above represents an efficient technology able to exploit low enthalpy geothermal energy, i.e., a local, renewable energy source with low environmental footprint that would reduce these negative impacts. This energy source provides a massive potential and offers the additional advantage of being pervasively distributed, stable with respect to atmospheric conditions, and cost competitive. In this context, ground source heat pumps (GSHP) technology, based on the thermal coupling between the building and the ground, which is exploited as a heat source or sink to provide thermal energy for the direct HC-DHW use, plays a key role.

The system offers the opportunity to re-use an existing tunnel, built for different reasons (generally transport), also for the exchange of heat with the ground/inner air and, consequently, to heat or cool housing units, providing the buildings base load, or other potential users, such as stations, as well as for the de-icing of roads and highways, through a sustainable and renewable energy system. It also contributes to the achievement of the minimum percentage thresholds for energy supply from renewable resources for the production of domestic hot water, winter and summer air conditioning established by legislation for new buildings and the renovation of civil/building works.

How can it be scaled?

The prototype will demonstrate the feasibility of exchanging heat with the surrounding ground through the geostructure, namely the tunnel, for serving a specific building and/or infrastructure. However, metro tunnels and other types of underground structures very often exist in or close to urban centres. Therefore, the technology is optimal for a local harvesting and for widespread distribution of thermal energy at both single space and district scales and could be integrated in low-temperature district heating and cooling networks. Additionally, aging and decay of existing road and railway tunnels which are getting old all around the world is requiring maintenance and repair works to guarantee the continuation of service in safe conditions. The opportunity offered by the refurbishment can be seized to renovate the tunnels heritage not only from a structural point of view but also under a sustainable standpoint.

Future perspective

The technology potential may be even enhanced by coupling it with other renewable energy-based systems, such as for instance solar collectors. This coupling can lead to interesting applications such as Underground Thermal Energy Storages (UTES). The integration of solar panels for hot water production with the geothermal loops can provide thermal storage abilities to the system and can be used as a thermal source for low-enthalpy energy storage in the ground. This innovative integrated system would allow to buffer differences between thermal supply/demand at a local level, which is particularly attractive due to the inherent asymmetry nature of intermittent renewable energy sources. Tunnels could thus benefit from a smart and sustainable approach and be retrofitted for transforming them into energy generators having positive impacts in terms of social and economic activities.

4.2.2 HYBRID ENERGY/NATURE-BASED SOLUTIONS ON BUILDING SURFACES

Description

In the current scenario of urban development and climate change, the design of urban surfaces can play a key role in enhancing the environmental quality of urban areas and their climate resilience. The innovation focuses on the evaluation of the application of Nature-based Solutions (NbS) and energy systems on the urban surfaces, their potential integration, and the generated synergic impacts. The analysis, which starts at the building scale, is also broadened at the district scale, as the strategies proposed to tackle issues related to urbanization and the correlated effects of climate change are more effective at this scale. Furthermore, the analysis of the surrounding district is also relevant for the design of the interventions at the building scale, as there is a mutual influence of these two. Building on the experience in the Trento demo case, this will allow to draft some guidelines for future interventions in urban districts.

Why is it relevant?

Cities are experiencing an increasing number of extreme events (e.g., heat waves, flooding, or droughts, etc.) due to the effect of climate change. Moreover, urbanization is threatening the service that ecosystems bring to human well-being in built environments. NbS can play a significant role in the control of the urban heat island effect, in the regulation of water flows, or in the provision of buffer zones that can reduce the effect of flood events on the built environment. The application of NbS on building surfaces, such as in the case of green roofs or facades, offers several benefits both at city and at building level. At a city scale, they also contribute to increase the urban vegetation, consequently promoting urban biodiversity, to pollution capture and air quality improvement, and to noise control. At a building scale, NbS can be used as passive technique for energy saving. Besides the environmental aspects, NbS also produce social benefits, encouraging the fruition of urban areas, inducing a physiological wellbeing, and improving the image of the city.

On the other hand, the diffusion of renewable energy system on urban surfaces, mainly through the application of solar active systems, represents a key solution for meeting the growing energy demand of cities, supporting their commitment toward becoming carbon neutral, and for the energy self-reliance at the local scale.

NbS and solar active systems can work in synergy and benefit one from another, providing habitats for certain species and enhancing plant diversity, but also increasing the efficiency and useful lifetime of PV panels thanks to the reduction of their operating temperature. Examples are bio-solar or multifunctional solar-green roofs or multifunctional façade systems integrating building greening and PV. Finally, NbS also include solutions for urban agriculture, and hence might contribute to reduce the environmental impact of food supply in cities, hence diminishing the energy embodied in food transportation and the related ghg emissions.

How can it be scaled?

The proposed innovation aims to draft some guidelines for the definition of urban surface uses, applicable at multiple scales. Indeed, being based on local data and site-specific analyses, these might be replicated in a wide variety of urban context and different scales. The use of urban surfaces – in particular the synergies between NbS and energy systems – needs to be considered as leading the development to multiple opportunities, to improve the existing urban environments and support not only environmental, but also social and economic resilience. In particular, it is key to recognize and consider the cumulative impact of energy and NbS solutions – but also other integrated solutions - when applied on several surfaces in the urban environment. This will also require the integration of considerations about the definition of urban surface uses in both building codes and masterplans to move from the building to the city scale, hence increasing the impact of such solutions.

In order to succeed in transforming urban areas from a "cost" to a "resource", it is also necessary to be able to calculate the economic value generated according to the allocated function and thus be able to compare this value with other economic values generated by alternatives. For example, the maximisation of the cumulative and positive effects of the application of NbS on urban surfaces becomes an ecosystem service whose value can be estimated by means of the Total Economic Value (TEV) methodology[3].

Future perspective

As urban planning plays a key role in promoting the notion of urban surfaces as resources in the view of urban sustainability and climate resiliency, the development of such solutions and related guidelines should become part of the urban planning practice. Particular focus should be placed on how to integrate different urban surface uses to avoid inefficiencies and competition, and to foster synergies. To achieve this, an integrated management of all the surfaces in urban areas, both public and private owned, will be key. Additional potential benefits are the reduction of land consumption, the provision of previously inaccessible urban areas, the transformation of urban areas from "cost" to "resource", the maximisation of cumulative and positive effects on the urban microclimate.

4.2.3 CLIMATE ADAPTED DESIGN USING AN INNOVATIVE OPEN SURFACE WATER SOLUTION

Description

The Regulatory plan of the Voldsløkka area in Oslo requires that the school courtyard is to be developed as a park with a variety of vegetation at different heights and with permeable surfaces and natural surfaces covering at least 30% of the outdoor flooring. A strategy for local and open surface water management was recommended for the area to avoid the rainwater runoff damaging buildings, properties, and infrastructures and creating inconveniences to the local residents. The requirements set in the Regulatory plan are implemented in the landscape design of the school courtyard by making use of different types of vegetation and surfaces to optimize the local storm water management and at the same time create a varied and appealing outdoor environment.

The school's green areas are organized and planned in two main groups with different designs, to facilitate natural protection of the vegetation, green areas at the plot edges, and green island in the middle, as shown in Figure 9. The central green areas are developed as islands surrounded by "channels". These "channels" are the features that ensure an efficient stormwater management on the school grounds. The terrain around the channels is planned so that rainwater flows towards the islands, as shown in Figure 10. The channels are covered by metal grates below of which rain beds are placed. On the rain beds, a flower meadow with Norwegian, wild, perennial meadow plants is placed. The stormwater is collected by the channels and redirected to the islands, where it is absorbed led deeper down towards the crushed stone reservoir below. The system islands-channels are designed in such a way to clearly show the water flows and the mechanism of storm water management employed in the school site.

[3] https://en.wikipedia.org/wiki/Total_economic_value

Figure 9. *Landscape design of the Voldsløkka project. Original image by ØSTENGEN & BERGO AS, edited by Nicola Lolli (SINTEF).*

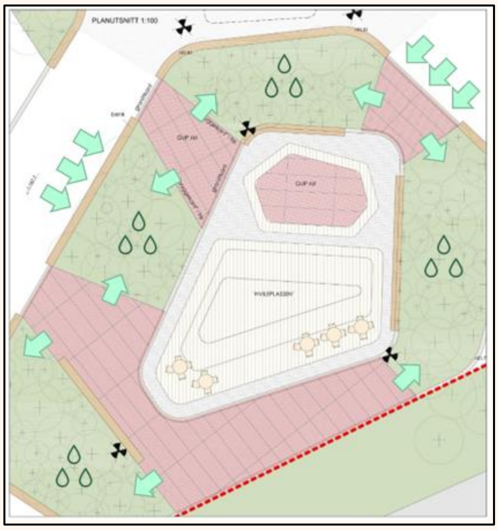


Figure 10. *Scheme of storm water management in one of the project's "islands". Original image by ØSTENGEN & BERGO AS, edited by Nicola Lolli (SINTEF).*

Why is it relevant?

The City of Oslo's work on stormwater management is a critical initiative for the city to become climate resilient. Numerous measures have been implemented since the Stormwater Management Action Plan was considered at political level in 2019 (proposition 291/19)[4]. Oslo Municipality promotes the use of

[4] https://www.klimaoslo.no/article/follow-up-of-the-climate-strategy/

open, local surface water management to contrast the damage to buildings and infrastructure produced by poor rainwater management. Such a problem is exacerbated by climate change, which in the Nordic will lead to more rain and sudden heavy rainfall. By opening closed streams and rivers and using green roofs and draining surfaces instead of asphalt, rainwater flows are slowed down and the risk of flooding reduced. The demonstration of this innovation in the Voldsløkka project aims at showing how technological solutions for effective local storm water management can be designed and implemented by integrating educational purposes and without sacrificing the aesthetic of a natural environment within city borders.

How can it be scaled?

This innovative storm water management system will be fully operative from August 2023. It will be used to demonstrate the effectiveness of such solutions and its technical limitations (durability of materials, growing rate and health of vegetation, effectiveness of stormwater outflows over time) in relation to the replicability potential in other geographical areas.

Future perspective

The City of Oslo is expected to develop and complete thematic maps for stormwater and urban flooding and a Stormwater Management Guide, in 2023. The City of Oslo's property enterprise is working actively to develop and implement effective stormwater solutions on municipal land. There are currently 15 construction projects in which stormwater management has been integrated through the use of green roofs and other naturally based solutions. Work is underway on the development of a stormwater management communication strategy with the aim of strengthening the communication work relating to stormwater management from 2022.

From 2022, new or revised instruments will be introduced to strengthen the efforts towards The City of Oslo resiliency and robustness against climate change. The aim is to consider by a larger extent current and future natural events which are being exacerbated by climate change. This strategy will consider an increased effort for the preservation and development of blue-green structures, further development of the Green Inventory, and the strengthening of risk and vulnerability analyses in planning processes, with a particular focus on ground conditions. The criteria for stormwater management and blue-green structures are of particular importance for ensuring climate adaptation. Since 2021, these criteria are also used in area regulations. The regulations concerning the blue-green factor set out minimum requirements for nature-based solutions in connection with land use.

4.2.4 LOCAL RENEWABLE ENERGY GENERATION USING INNOVATIVE BIPV AND BAPV

Coloured PV panels are installed on the roof and façade of the school building in the Voldsløkka project to provide an overall energy production of 230 000 kWh/year. This is equal to 2 kWh/m^2 per year of excess electricity production, making the school a plus-energy building. The design of the PV modules layouts is defined by the PV modules orientation in relation to the sky, the orientation of the school building longest facades, and the Regulatory provision regarding the appearance of the PV façade. The building N-S orientation is not optimal for PV production, as the longest facades are facing either East or West, thus not taking advantage of the higher insolation on South-facing facades. In addition, the Regulatory provision requested the school façade not to resemble that of an office building, meaning that solutions that entail large and monotonous surfaces with PV panels were not accepted. The challenge is therefore to combine the limitations given by the not-optimal building orientation, the need for variety of the façade appearance, and the highly ambitious energy goal for the building. The choice of using different shades of green and black for the PV panels, and the rotation of their vertical axis (as shown in Figure 11) is given by the necessity of avoiding a uniform and monotonous look of the façade.

***Figure 11**. West façade of the school building. Original image by KONTUR and SPINN Arkitekter, edited by Nicola Lolli (SINTEF).*

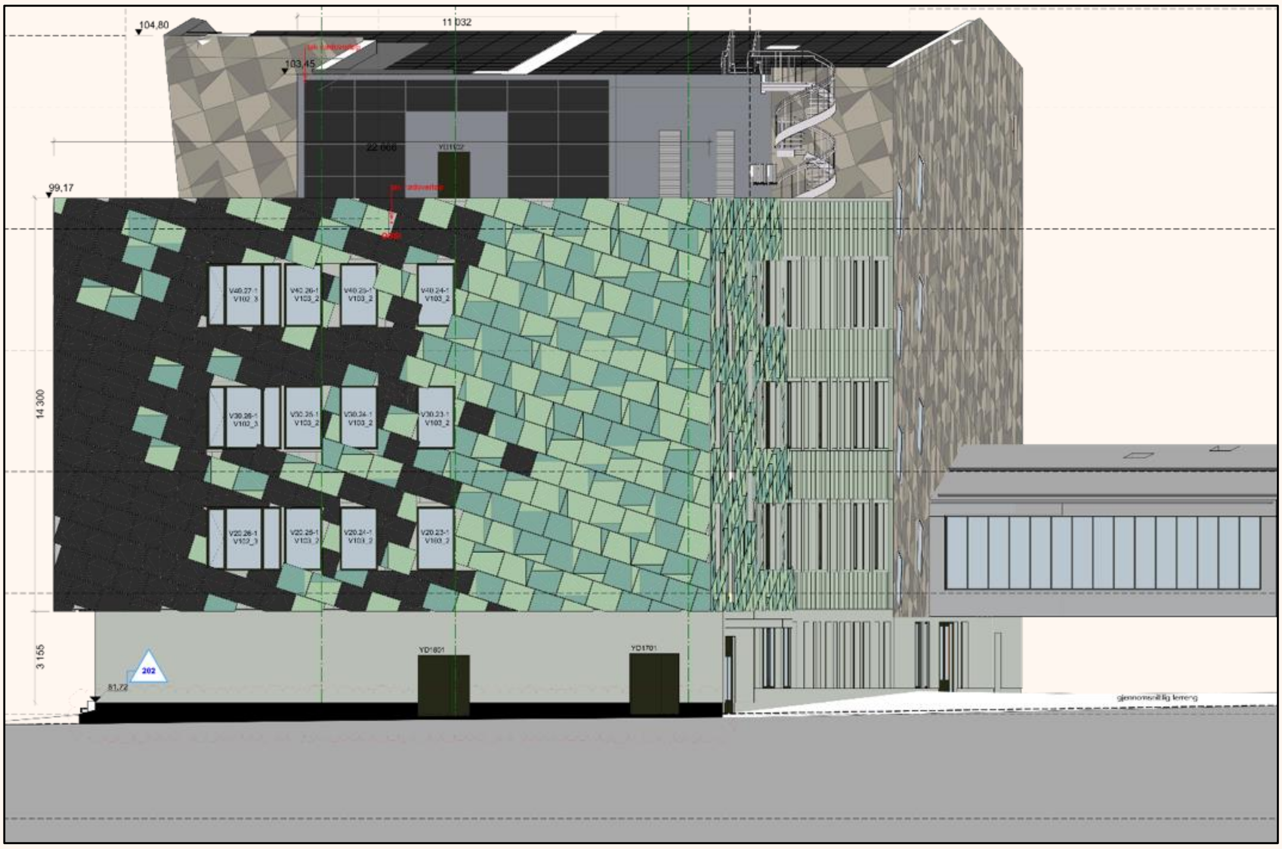


***Figure 12**. South façade of the school building. Original image by KONTUR and SPINN Arkitekter, edited by Nicola Lolli (SINTEF).*

Why is it relevant?

The aim of the school building project is to deliver excess electricity to the grid in order for the school to be a plus-energy building. This can be achieved by making use of large quantities of standard black PV modules on the facades, at the expenses of aesthetic expression and architectural quality of the building. The challenge is therefore, to show that it is possible to deliver such an excess of electricity and at the same time propose an appealing architectural expression for the building facades. This is obtained by using combinations of black and bi-coloured PV panels which are oriented by a circa 20-degree angle on the horizon. The rotation of the panels reduces the space for allocating the PV modules due to the panels cuts around windows and at the façade border. To achieve the planned energy target for the building, parametric design tools are used in order calculate in real-time the allowed amount of PV modules at varying angles of the panels' orientation. The corresponding electricity production is thereafter calculated for the various orientation and resulting number of modules.

How can it be applied?

***Figure 13**. Picture of the mounted BIPV-modules on one of the Voldsløkka facades. (Photo by Bodil Motzke, Oslobygg)*

The PV panels are mounted on an aluminium profile system which is composed of a main system with vertical element spaced every 600 mm and a secondary system, with horizontal elements aligned to a 20-degree angle from the horizon. Where the secondary profile system partially overlaps with the windows behind, glass panels are installed instead of PV panels. These glass panels match the colour variations used for the PV panels. The number of total glass panels is circa 15% of the total number of PV panels. The ratio of the green-coloured modules and black modules is as such: circa 25% of the modules on the west facade and circa 40% on the south façade are black. All other modules come with two different shades of green, in such a way each PV panel consists of two different, green-coloured parts. Two different combinations of the bi-coloured panels are used, as shown in Figure xx. These panels are installed either in an upright position or rotated by 180 degrees. This is to make the impression that 4 different panels are installed on the façade. An equal number of panels of each of these two-colour combinations is installed on the facades.

Future perspective

The application of such a design demonstrates the feasibility of large PV-integrated facades to meet a plus-energy building target and at the same time provide an appealing and dynamic architectural expression.

4.2.5 LOW-TEMPERATURE HEATING AND HIGH TEMPERATURE COOLING HVAC SYSTEM

Description

Low-temperature heating and high temperature cooling HVAC system (LowEx) is a concept designed to maximize the effectiveness of ground source heat pump systems. The individual components of the system are not novel in themselves. However, the novelty is in how they are designed to work optimally together. The coefficient of performance (COP) of heat pumps is mainly determined by the temperature difference between the cold source and the emitting temperature. COP shows the ratio between useful heat and compressor power as input energy. By minimizing the temperature difference between the sources, the COP is maximized. Therefore, the system is designed to operate with supply temperatures of the HVAC system very close to the desired room temperature. To enable this, the system utilizes a combined radiant heating and cooling system allowing for temperature differences between the room design temperature and the fluid, as low as 5 K. This is done with a novel heating and cooling system that delivers low temperature heating and high temperature cooling, using the same infrastructure coupled with the ground source heat pump. In this way, the high performance of the heat pump results in energy needs as low as 3 to 10 kWh/m^2 year and greatly reduces the compressor power peak. The LowEx system is integrated by using the existing infrastructure, thus saving cost and embodied energy from material use.

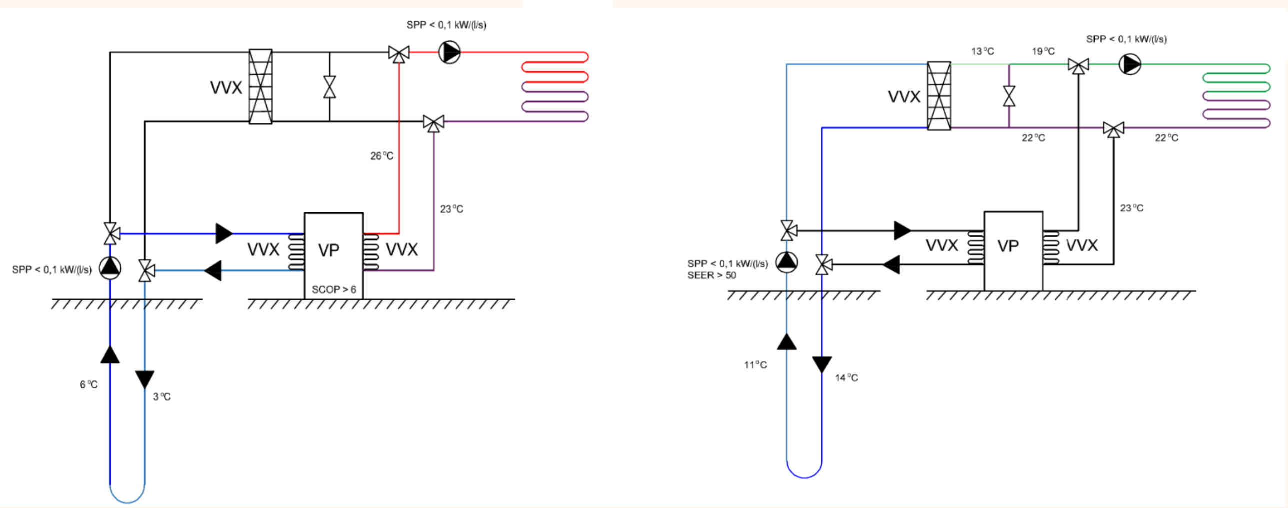


***Figure 14**. Schematic of the LowEx system, in winter operation (left) and summer operation (right). Source: Tor Helge Dokka, Skanska Norway.*

What challenge does it solve?

By reducing the energy needs for heating and cooling, the local renewable energy production can be used for addressing other buildings end-uses (lighting, ventilation, appliances) which are less dependent on seasonality, thus reducing the yearly mismatch between the PV production and the buildings' energy use. The LowEx system is integrated by using the existing infrastructure, thus saving cost and embodied energy from material use. The same can be said about the use of a common system for heating and cooling, resulting in less need for piping and heating and cooling emitters. The use of high temperature cooling makes it possible to utilize free cooling from the energy wells to a much larger extent than in traditional systems, because cooling from the wells can be directly utilized even when the temperature of the water from the borehole rises towards 19 °C.

How can it be scaled?

The system works well for both small and large buildings. Due to beneficial temperature levels in the hydronic system of HVAC, the heat pump system performance will increase. The more efficient the building envelope is, the more efficient the LowEx system will be. With lower demand, the lower temperature difference between the emitter and the room can be, thus increasing the heat pump performance. The system is well suited for all new energy efficient buildings and in deep renovation processes. However, the system requires installation of radiant heat tubing, which could be challenging in some renovation projects.

Future perspective

In the Oslo demo project, the LowEx system will be demonstrated, followed-up, and evaluated. Building energy flexibility is recognized as important property of the future. Flexibility enables a building (or group of buildings) to shift its energy demand in time, either as response to external signal from the grid, or to optimize its self-use of locally produced electricity. The way the LowEx system integrates its heating and cooling system into the building construction, enables efficient activation of the building thermal mass. This makes the building well prepared to be an active asset in the future energy market.

4.3. MATERIAL SOLUTIONS

This chapter includes a description of solutions related to the use of materials in an innovative way, to reduce the greenhouse gas emissions from buildings, to enhance the architectural qualities, to save energy, to increase the renewable energy generation, to enhance user satisfaction, etc.

4.3.1 ARCHITECTURAL AND AESTHETIC INTEGRATION OF BIPV/BAPV/PVT SOLUTIONS

Description

The aim of this activity is to explore the ongoing process of integrating technical systems in the vertical building envelope, with particular reference to solar thermal and photovoltaic solutions. The experimentation of new solutions – accompanied in Europe by new standards on integrated building envelopes developed by the scientific community and partnerships between the PV industries and the glass sector – has had important repercussions aesthetically and architecturally, resulting in a new generation of architectures representative of green deal challenges. Since the turn of the century, energy efficiency objectives in Europe have conditioned architectural concepts from a morphological point of view, starting from the surface-shape relationship of buildings, and today the new forms of integration between building and energy production systems are creating opportunities for developing a new aesthetic, technological and construction language.

In the context of the project, this thesis was developed as part of the ecosystem of the Autonomous Province of Trento, where the companies in the building sector are strongly oriented towards the development of industrialized products and off-site solutions for architecture, with particular reference to the engineered wood components sector. Therefore, the aim was to experiment, within the ARV project, with plant-systems integration in an industrialized building envelope system produced in a factory. Incorporating a prefabricated envelope system and an industrialised product makes it possible to demonstrate the relationships between the various components, including the systems (PV, HVAC, etc.), the wall-window node, and the technologies for predictive monitoring by analysing the design of the assembly-disassembly processes.

The innovation refers to a prefabricated PVT (solar photovoltaic thermal technology) module ready to be integrated into the building envelope as an active façade system. The design of the prefabricated building solution guarantees efficient assembly/disassembly in external walls, easy maintenance, and possible integration of plant systems, thanks to fast and plug-in connections. At the same time, it guarantees air/wind tightness and water resistance, offering considerable adaptability to the various structural configurations of the façade. The PVT module is made using additive manufacturing processes, such as digital fabrication and thermoforming methods. Aesthetically, a unique coloured glass hides the solar technologies without filtering or blocking UV rays assuring both the solar and technological functions.

Preliminary energy analyses have been carried out by the Department of ENERGY (DENERG) of Politecnico di Torino, through numerical models, in order to evaluate the behaviour of PVT technologies. Several full-scale mock-ups of the module have been produced to analyse the technical solutions and start testing the physical module's behaviour.

What challenge does it solve?

1/ Driving the production process of the BIPV envelope system in off-site industrialised architectures makes it possible to analyse, with greater control, the possible strategies for integration of the various plant systems and transparent or opaque envelope components, with adequate verification of performance compared to standard on-site construction practices. It will be possible to develop plug-

and-play solutions capable of simplifying the assembly and disassembly phases of the various plant components with more circularity-oriented maintenance criteria.
2/ The design of a BIPV technological envelope to be produced as an industrialized component in the factory will facilitate the logic of economies of scale in planning the final cost of the product, an aspect that today constitutes a deterrent to experimentation in many European countries.

How can it be scaled?

1/ The PVT solutions can be adapted to both the new construction market and the redevelopment of the existing building stock through modifications of the envelope layers. This customization is more feasible if the component production processes are industrialised.
2/ The PVT solutions starting from different market and design needs, can either be a repeatable "wall module" to define an envelope system or be integrated within the window system.

Future perspective

The immediate aim is to complete the ongoing validation process by testing the system in the open field, in order to increase the Technology Readiness Level. Thanks to these processes inside the ARV project, it is desirable to accelerate the shift of the BIPV/PVT market from today's dry construction system towards a system of three-dimensional industrialized components belonging to Industry 4.0 patterns, which increasingly involve the construction sector.

4.3.2 TIMBER BASED (NEW) CONSTRUCTION, REFURBISHMENT, AND SUPERELEVATION SCENARIOS

Description

This innovation concerns the development and implementation of two timber-based scenarios, respectively intended for new and existing buildings, in the framework of the ARV Trento demo, namely the neighbourhood of Piedicastello. Both scenarios will enhance the use of wood as a circular construction-renovation material combined with forefront sustainable and energy saving technologies, nature-based solutions and compound performance and comfort monitoring systems. Moreover, the scenarios allow the direct involvement in ARV of design and construction companies from the local timber value chain.

The first scenario consists in the construction of a new wooden-based positive energy building located in demo area 4, which is currently used as a car parking lot. Considering the actual configuration of the surrounding area, the new building has been preliminarily conceived as an EV charging hub with integrated services (2 floors in elevation + 1 underground) which could prove useful to multiple users (i.e., commuters, tourists, etc.) and generally to Piedicastello community and residents.

From a structural perspective, the building will be based on a load-bearing timber frame consisting of timber pillars, glulam beams and wooden floors. The underground floor has been planned as a concrete basement to be used as a plant and storage service room, also including geothermal probes linked to the geothermal structure tested by Politecnico di Torino in demo area 3. The building envelope will generally consist of prefabricated walls, while the southern side will be covered with innovative prototype walls whose performance will be monitored over the project lifespan: green wall, ventilated wall, BIPV wall, transparent BIPV wall, cool wall, super-insulated wall. The building will be completed by a smart control system for real-time performance monitoring and management.

The second scenario concerns the architectural renovation and energy refurbishment of existing buildings by use of timber. In the framework of ARV, this scenario has been conceived to be applied within demo area 2 of Piedicastello, a residential area including ‘60-‘70s quite homogeneous and medium-rise apartment buildings. The scenario consists of testing the prefabricated wooden-based panel – called “Renew Wall” - produced by Fanti Legnami, a local construction company involved in ARV as a linked third party of Habitech-DTTN.

“Renew Wall” stems from a previous 36-months local research project which delivered a lab and real environment tested prototype, certified by European Technical Assessment (ETA). This technology is a modular system and wooden-based retrofit kit conceived to be easily applied on existing buildings. It is composed by an insulated wood-based panel already integrated of windows, shutters, and a controlled mechanical ventilation machine with heat recovery. The panel can be completed by customizable finishings, thus increasing the architectural and aesthetic appeal. Thanks to the reduced time of works and the limited impact, building occupants can continue to live in their apartment over the renovation.

What challenge does it solve?

Both scenarios offer an alternative to as-usual construction and renovation works and address the issue of building environmental impact. Timber-based interventions allows to exploit the advantages of off-site manufacturing, including the design and delivery of accurate and optimized structural components that only needs to be assembled and installed on site. Compared to business-as-usual solutions, this leads in principle to a reduced and more predictable construction/renovation time, combined with limited impact and inconvenience of works on end-users, such as building occupants, and the surrounding environment (i.e., use of scaffoldings, less noise and dust produced, etc.).

Moreover, both scenarios enable to address sustainability in a comprehensive way, combining wood well-known features as a construction material (CO_2 sequestration and storage) with optimized energy performance, thermal comfort, nature-based solutions and RES integration – the latter in relation to the new building.

Furthermore, new building’s structure, which is based on square modules, enables to deal with long-term re-usability and possible redesign aspects. Modularity coupled with a flexible layout for the internal space of the building could prove a useful resource for future configurations of the hub and its functions and for adding new parts in both directions and in principle also in elevation.

How can it be scaled?

The new building scenario presents relevant scalability potentials related to its abovementioned modularity, thus allowing for adaptation to different urban environments, especially when it goes to tertiary and commercial areas.

In addition, the innovative façades which will be tested in the southern side allows to compare different thermal and energy performance and to selected case-by-case the most appropriate solutions depending on the conditions, usage, and context of the installation.

Scalability at a district level is also possible in relation to Piedicastello regeneration plan which has been recently approved by the Municipality of Trento for the northern side of the district, the so-called “Italcementi” brownfield. ARV new building and testing activities could inform the design and construction of new buildings in that area, which has been partially planned for commercial and tertiary activities.

The refurbishment scenario has also good potential to be scaled at a district level, especially within residential areas including a high number of inefficient private and/or social housing buildings. This condition could take advantage of offsite manufacturing and prefabrication to produce standardized and optimized wooden renovation kit on a large scale, taking advantage of the abovementioned ease of installation of wooden components. A combination of this sustainable solution with existing fiscal incentives for refurbishment could also encourage the increase of the renovation rate for buildings in a certain area.

Future perspective

As for the new timber construction scenario, the early concept design needs now to be fine-tuned and finalized to start the construction and implementation stage. Attention will be paid in parallel to the urban regeneration developments concerning the replication area in the northern side of the district. Concerning the renovation scenario, a detailed analysis of business-as-usual vs. wooden solution is currently ongoing and could be prove useful to start working, in parallel, to the set-up of the One-Stop-Shop innovation related to district-scale sustainable renovation works in Piedicastello.

4.3.3 EFFECTIVE APPLICATION OF LOW-CARBON CONCRETE

Description

Low-carbon concrete with 40% lower embodied emissions than the current standard has effectively been applied in the Voldsløkka demo site in Oslo. The low-carbon concrete class A used in Voldsløkka typically has CO_2-emissions of 220-240 kg/m^3, depending on use. Whereas a typical concrete has an emission-factor of 400-410 kg/m^3. Concrete is used in the parts of the building adjacent to the ground.

What challenge does it solve?

Besides water, concrete is the highest consumed material in the world. It is used to produce and build the vast majority of the world's buildings, bridges, roads, dams, and several other constructions. Cement production alone is responsible for approximately 8% of the worlds CO_2 emissions. Reducing the amount of the emissions related to cement and concrete production will have a major impact on global CO_2 emissions. The emissions related to building in concrete stems, to a very large degree, from the production of the cement (as the critical ingredient in concrete) and has a large potential for emissions-reductions. In addition, construction techniques and optimization of amounts of concrete used in various structures can reduce emissions through the simple fact that less material is used. In the Voldsløkka school both these emission-reduction pathways have been utilized to reduce the CO_2 footprint. So-called low-carbon concrete, with CO_2 emissions 40% lower than standard concrete has been used. In addition, concrete has only been used in critical parts of the structure, replacing it with wood-structures in other parts of the building load-bearing structure.

How can it be scaled?

Of all materials used for construction, concrete is the one that is used the most. It goes without saying that the replacement of only a small fraction of the total amount of concrete used worldwide can cause mayor CO_2 emission reductions.

Future perspective

In general, there are several technical challenges with concrete where high amounts of cement are replaced by supplementary cementitious materials (SCMs). With reduced cement content and increased other additions, the early strength and, depending on the composition of the binder also long-term strength development will be reduced. Furthermore, some durability properties might be reduced while others will be increased. Usually, resistance to alkali silica reactions as well as chloride ingress is increased for properly cured concrete with low carbon binders. On the other hand, resistance to carbonation in buildings and frost-salt scaling in infrastructure concrete may decrease and remains a challenge. High replacement of cement with SCMs and decreased amount of cement in low carbon concrete also has an impact on the workability (flow properties) and handling of the concrete. Hence, it is often necessary to increase the number of chemical admixtures to guarantee similar workability and strength development. Still, for low carbon concrete type A, with about 40% CO_2 reduction potential compared to a reference concrete many of these challenges are solved. Today, the SCM used in these types of concrete on the Norwegian market is fly ash (from coal fired power plants). However, the amount of available fly ash will decrease in the future and cement producers are starting to look at alternative SCMs to replace cement. In a recently finished research project (NEWSCEM[5]) promising alternatives have been found. In the second phase of this project (ZeroCarbCon[6]) the aim is to develop novel CEM II/C products (50% replacement of Portland Cement) for use in building and infrastructure concrete. Research is needed to understand these novel binders with these new types of SCM to gain similar good results as today with fly ash from coal incineration plants.

The Norwegian Concrete Association has published a carbon classification system for concrete (NB37) which the concrete industry has used for several years. Good results have been obtained in practice with low carbon concrete type A according to this classification (approx. 40 % lower CO_2 than reference), and the market demand for this material has increased. The more difficult part is to implement low carbon concrete type "Pluss" and "Extreme" with even lower CO_2 emissions (50-60% reduction).

A remaining challenge is to increase the demand further by building up competence through information campaigns, manuals, and guidelines for a common and easy understanding of how to use and apply these types of concretes.

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[5] https://www.ntnu.edu/kt/research/concrete/projects/newscem
[6] https://www.ntnu.edu/kt/research/concrete/projects/zerocarbcon

CONCLUSIONS

The report presents twelve interesting and innovative solutions. Some of the solutions are not innovative on a global scale per se. The innovative part lays in the specific context and the precise environment and framework where the innovations are applied. All innovations presented are aiming at scaling buildings with high performance in energy and reductions in greenhouse gas emission. Some innovations promote the idea of retrofits to address electricity and fuel waste with better insulation and windows, efficient lighting, and advanced heating, ventilation, and cooling systems. Others focuses on nature based solutions and carbon sinks. Also, the combination of high energy efficiency with high user satisfaction and architectural qualities, are important aspects.

Overall, all solutions improve the system to enable the transition to Climate Positive Circular Communities. As we look forward, an urban regeneration transformation is undeniably possible. Already, economics favour energy efficiency in buildings and nature-based approaches over linear and fossil fuel-based approaches in many places. A renovation wave shift away is underway in Europe, albeit not fast or widespread enough. The speed of transformation is the issue at hand. We must curtail and supplant 19th and 20th-century forms of construction and renovation while ensuring that the future of Climate Positive Circular Communities clean is equitable and empowering for all.

The ARV Innovation Intelligence for Impact report 2022 has assessed an extensive but not exhaustive set of ARV innovations enabling CPCCs in the ARV demonstration sites, as presented here. The ARV partners continue to add to this compendium as we review and quantify the potential of solutions to stop emissions and/or support sinks in the built environment, as well as broader urban societal transformations that also have climate benefits. In the three years to come the updates of the report will tap upon practices and technologies that are nascent but look to have promise, pending further development and investigation. The ARV Innovation Intelligence for Impact report 2022's assessment of solutions will continue to be a living project for the next four years. The future report and analysis depend on the availability of critical inputs—namely robust data, reviewed research and on-site implementation by the ARV partners. The synthesis provided in this report is only as inclusive and robust as the information being synthesized by partners.

The report acknowledges those limitations and encourage research on an increasingly broad solution set, especially innovative solutions emerging from real life experimentations and implemented within the ARV demonstration communities. In the future reports, we will examine other climate solutions. All aim at solving urban regeneration issues that are systemic in nature and challenging to quantify, such as resisting the development of new fossil fuel infrastructure, increasing overall urban density, or reducing consumption through sharing, repair, and re-use. The ARV Innovation Intelligence for Impact report 2022 recognizes the limitations of the scope of our solutions here, too. A broad aperture for solutions is vital, and ARV continues to evolve approaches that support it.

In conclusion, the report strives to be a useful resource for scaling CPCCs and to showcase economic viability and potential into the commercialisation and wide adoption of these solutions.

FUTURE UPDATES

This deliverable will be updated in Month 24, 36 and 48 (December 2023 second version, December 2024 third version, December 2025 fourth version) of the ARV project. Each version will present the innovations achieved during the respective ARV year.

REFERENCES

ARV D1.3 Innovation Management Plan (2022), final version V.03 (confidential)

eMarketplace · ARV (greendeal-arv.eu) (Assessed 25 November 2022)

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APPENDIX A – GLOSSARY OF TERMS

Table A.1 *Abbreviations used in the report.*

Abbreviation	Description	References
BAPV	Building Adapted Photovoltaics	https://en.wikipedia.org/wiki/Building-integrated_photovoltaics
BIPV	Building Integrated Photovoltaics	https://iea-pvps.org/key-topics/international-definitions-of-bipv/
CPCC	Climate Positive Circular Communities.	See ARV Deliverable D2.1 for a detailed definition of CPCC
Dissemination	Making the results of a project public (— by any appropriate means other than protecting or exploiting them, e.g., scientific publications)	https://ec.europa.eu/info/fundingtenders/opportunities/portal/screen/support/glossary
Exploitation	The utilization of results in further research activities other than those covered by the action concerned, or in developing, creating, and marketing a product or process, or in creating and providing a service, or in standardization activities.	https://ec.europa.eu/info/fundingtenders/opportunities/portal/screen/support/glossary
NbS	Nature based Solutions	https://research-and-innovation.ec.europa.eu/research-area/environment/nature-based-solutions_en
NZEB	Nearly Zero Energy Buildings	https://energy.ec.europa.eu/topics/energy-efficiency/energy-efficient-buildings/nearly-zero-energy-buildings_en
PEB	Positive Energy Buildings	https://www.sustainableplaces.eu/positive-energy-buildings-definition/
PVT	Photovoltaic Thermal hybrid solar collector	https://en.wikipedia.org/wiki/Photovoltaic_thermal_hybrid_solar_collector
SCM	Supplementary Cementitious Materials	https://www.cement.org/cement-concrete/concrete-materials/supplementary-cementing-materials

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