SOCIETAL ENGAGEMENT
WITH KEY ENABLING TECHNOLOGIES

CIRCULAR
ECONOMY

Report series on:
Mapping of Key Enabling Technologies Innovation Eco-Systems

CIRCULAR ECONOMY IN THE BUILDING AND CONSTRUCTION SECTOR IN ITALY:

TOWARDS SUSTAINABLE PRODUCTION AND CONSUMPTION

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1. Introduction

SocKETs brings together six European partners with the aim to test and develop methods and tools to align the development of innovations based on Key Enabling Technologies with societal values and needs. Socket will facilitate co-creation between industry representatives, researchers, policy makers, end-users, civil society representatives and citizens, and will develop tools for societal engagement in innovative technologies. Co-creation in SocKETs is intended as a form of collaborative innovation, in which ideas are shared and improved together toward the joint development of new value for society through innovation.

This report is part of a collection of case studies on co-creation and KETs based innovation developed by the project and is focused on circular by design processes in the building and construction sector, towards sustainable consumption and production.

It provides a first analysis of the innovation eco-system of this sector in Italy, including considerations on the innovation context, the barriers and opportunities for the introduction of new technologies, the key actors, relations and networks involved, and the relevant actions and interactions taking place. It aims to inform the design of a participatory process in which the most relevant technologies and innovations that could support the transition towards a circular economy in the sector are discussed.

This report is based on desk analysis and interviews with select stakeholders. The panel of interviewees is representative of most of key actors of the selected innovation eco-system, including 1 NGO, 4 R&I actors (both public and private), 2 business, 2 industrial stakeholders, and 2 policy actors. The panel is composed of 6 males and 5 females.

Both the desk research and the interviews highlighted that Key Enabling Technologies such as IoT and digital technologies such as distributed ledger technologies (e.g., blockchain), Artificial Intelligence, advanced materials and advanced manufacturing technologies, will be pivotal to enable the transformation of the building and construction sector towards circular economy.

2. Technologies and application scenario

The building and construction sector represents an interesting case study for both KETs-based innovations and for multi-stakeholder and public engagement processes, due to different reasons.

On one side, the building and construction sector is one of the primary sources of waste while the built environment is one of the major contributors to a city's pollution and GHG emissions. Increased citizens' request for sustainability, upcoming policies at national and EU level, such as the European Renovation Wave, and the possible change of perspective after the pandemic, will push the demand for innovative (even disruptive) solutions. In fact, the pandemic highlighted issues such as cities overcrowding, poor ventilation and low-quality heating in houses, need for cleaner air (both indoor and outdoor) and greener spaces[1]. The pandemic also rapidly changed working habits and stimulated a discussion at national level about the possibility to work away from offices[2]. This could push to

[1] https://newseu.cgtn.com/news/2020-07-12/COVID-19-and-the-city-The-future-of-pandemic-proofed-buildings-RCqRHMSn72/index.html

[2] https://www.forbes.com/sites/rebeccahughes/2021/02/15/could-remote-working-revive-italys-dying-villages/?sh=41573d7b7b7c

change the organisation of offices, buildings and even lead to a different urban planning, and this will probably require flexible solutions to reuse spaces.

On the other side, the sector in Italy still relies on traditional methodologies, it is highly fragmented, and the introduction of disruptive solutions will require deep changes across the whole value chain, and all the stakeholders will be affected. Moreover, innovation in the building environment also impacts people's everyday life and this requires alignment to their needs and concerns.

2.1. Opportunities and challenges

Both desk research and interviews underlined that a massive introduction of new technologies in the building and construction sector will be needed to address the main challenges (and drivers) for the sector, which can be synthetized in:

- Urban regeneration (regeneration of both buildings and urban spaces)
- Reducing material consumption and waste
- Reducing externalities (pollution, CO2 emissions, …)
- Energy efficiency and transition to renewable energy
- Comfort, quality, duration and security
- Buildings restoration, renovation and change of uses of existing buildings (e.g from residential or business, to community uses)
- Reducing soil sealing

In 2015 six levers that could advance the building sector towards a circular model were identified in (Ellen Macarthur Foundation, 2015):

- Shared residential space
- Shared and virtual office space
- Modularity and durability
    - selective deconstruction
    - selective maintenance
- Urban planning
- Industrial production and 3D printing
- Energy generation and use (i.e., energy efficiency and distributed production of renewable energy)

Few main global trends are linked to the drivers and challenges above:

- Decrease in the demand for new buildings and constructions, in particular in cities. At least in Italy, the building sector will likely suffer in the next period of a decrease in the demand for new buildings (both residential and offices), due to both the excess of buildings available, and the changes in habits and uses related to the impacts of the pandemic situation (e.g., reduction in office spaces, due to smart working.
- Limited availability of raw materials (sand shortage). This will drive the search of solutions for improved maintenance (duration) and recycling of existing buildings, and as well as use of use of novel materials
- The need to reduce the footprint of the building sector (waste management, biomaterials, energy efficiency, zero waste, land consumption etc).

Table 1 provides a connection between challenges in the building and construction sector, the possible innovation areas as emerged from the interviews and the connected technologies that could support the transition.

Table 1 Drivers and challenges of the building sector, connected innovation areas and technologies

BUILDING SECTOR DRIVERS/CHALLENGES	INNOVATION AREAS	TECHNOLOGIES
Urban regeneration, land use	• Urban planning, shared models, modularity and durability, selective deconstruction	• IoT, Satellite technologies, drones, and AI, advanced materials, advanced manufacturing systems
Reducing material consumption and waste	• Modularity and durability Selective deconstruction • Industrial (off-site) production • New materials	• IoT, blockchain and AI, also associated to BIM (Building Information Modelling) methodologies, Advanced materials (e.g. self-healing and self-sensing materials, recycled materials, etc…)
Waste management	• Traceability	• AI, robotics, blockchain
Reducing externalities (pollution, CO_2 emissions, …)	• Energy efficiency • New materials • Industrial production	• IoT, Advanced materials, Advanced manufacturing
Energy efficiency and transition to renewable energy	• Smart control • Deep optimization • New solutions for energy production and storage	• IoT, AI • Advanced materials
Comfort, quality	• Smart control	• IoT
Duration and security	• Predictive maintenance	• IoT, AI

2.2. Technologies

This section summarises the innovations based on Key Enabling Technologies that will be able to support the transition of the building and construction sector towards a circular economy model. Innovations emerged from the interviews are both incremental (e.g., improvement of materials) and radical (e.g., large diffusion of IoT solutions in buildings or related to products and waste traceability, advanced industrial manufacturing processes providing solutions for modularity).

Advanced manufacturing technologies will be a pivotal KET for the transition of the construction sector to a circular model, by enabling resource optimization and to design out waste (i.e. specify waste characteristics and use already during the product design phase). The trend towards design for disassembling, associated to modularity and dry construction technologies, will increase the industrialization of the sector and the use of **advanced manufacturing technologies** as well as **automated manufacturing systems**.

Interviewees highlighted how modular systems and dry construction technologies will allow to optimize the material consumption, since building parts can be produced off-site thanks to the information provided by the building digital project (off-site production allows to maximise resource efficiency and design out waste) and the on-site work is largely transformed into a sequence of assembly procedures. Moreover, this off-site production allows to combine the use of different materials (such as timber, concrete and steel) in order to provide the best performances with the least possible use of resources, by having

> "*the right material in the right place*" [interviewee].

Prefabricated and pre-engineered solutions may also improve the quality of the overall design and construction process (including higher accuracy in determining time and costs), while the wet construction techniques need excellent abilities to predict and control on-site activities and issues. Regarding on-site activities, prefabricated components are also easier to be assembled and ensure lower risk for construction site workers.

Example: resource-efficient construction systems, based on innovative advanced manufacturing techs
Dry prefabricated construction system that allows to create multi-storey frame buildings, made up by proper quantities of concrete, steel and wood elements, in order to guarantee best performances minimizing the use of materials, by exploiting the peculiarities of each material. The system allows intensive use of advanced manufacturing technologies and automated manufacturing systems, also in combination with BIM techniques, to optimize production based on (previous) design and (subsequent) construction phases. This off-site construction paradigm allows to reduce construction times, to fix the costs since the design phase, to guarantee design and construction flexibility, to design out production scraps, thus optimizing resource

With respect to prefabricated systems, some interviewees (from both the research and industrial sector) say that they could be easily employed in commercial or directional buildings and in manufacturing plants, which often need to change space configurations. They see more difficulties with the implementation of these construction techniques in residential buildings, one of them stating that "*being prefabricated, they don't allow for flexible and creative use*" [interviewee]. On the other hand, some stakeholders highlight the flexibility of use as a key characteristic of prefabricated materials.

Advanced materials will allow extension of the life cycle or will allow for an extended life cycle (e.g., self-healing and self-sensing materials), improve sustainability performances and energy efficiency (e.g., bio composites materials, ultra-performing), contribute to reduction of pollution and resource consumption (recycled materials). With respect to advanced materials, both the desk research and the interviews highlighted that there is a large and heterogeneous quantity of advanced materials. However, different experts underlined that "*we should always consider their whole life cycle with respect to the use they are intended to, in order to assess the actual convenience*" [Interviewee]. One

practical example are the materials for thermal insulation: Italian regulatory framework is now pushing for buildings with thermal insulation, but these materials have a limited duration with respect to the building, it is thus crucial to make balanced choices, considering both the environmental performances provided by the innovative material (for example in terms of energy efficiency) and its environmental cost throughout the whole life cycle (including end-of-life).

Advanced materials can also be produced using natural materials or secondary raw materials. One interviewee described how innovative mortars have been developed by using recycled plastic and glass to enhance mechanical and thermal properties. Recycled materials are also used in aggregates and in thermal insulating panels (with up to 100% recycled materials).

Example: high quality materials and components from CDW
The EU funded project Re4 (http://www.re4.eu/progress) produced aggregates, building blocks, tiles, insulation panels, timber beams, columns and weatherboarding from Construction and Demolition Waste and demonstrated both environmental and economic sustainability of its novel solutions.

Example: advanced mortars combined with secondary raw materials
Innovative mortars that incorporate recycled plastic and glass providing high mechanical and thermal insulation properties. These mortars allow to reduce thermal dispersion between the bricks they connect.

Example: multifunctional paints
Paints that combine high capability to reflect solar light with photocatalytic and self-cleaning properties. These paints are able to reduce the temperature in indoor spaces and the urban heat island effect, during the summer.

Artificial Intelligence will play a crucial role in accelerating the transition from linear to circular economy, as highlighted in a recent report by Ellen MacArthur and Google (Ellen Mac Arthur Foundation, 2019), because it helps solving complex problems and learns from data to make better decision over time. For example, AI could speed up the design of new advanced materials (e.g., for high performance applications) or it could contribute to increase the energy efficiency in smart buildings or smart cities. The report also underlines that "*AI is already showing how it can create value in realising circular material flows and in enabling enhanced valorisation of materials and products, by sorting post-consumer mixed material streams through visual recognition techniques. ZenRobotics, for example, works with cameras and sensors, whose imagery input allows AI to control intelligent waste sorting robots. These robots can reach an accuracy level of 98% in sorting myriad material streams, from plastic packaging to construction waste*".

Together with AI, other technologies such as **blockchain** could be profitably implemented to accelerate the transition to a Circular Economy (Kouhizadeh, Zhu, & Sarkis, 2020), for example in order to follow the entire materials life cycle and materials flows and enhance the cooperation along the supply and value chains, for example through industrial symbiosis (Tseng, Tan, Chiu, Chien, & Kuo, 2018), as well as increasing trust by supporting traceability, transparency and simplifying certification processes[3]. They are also being exploited in Renewable Energy Communities[4].

[3] https://www.mise.gov.it/images/stories/documenti/IBM-MISE-2019-INGLESE.pdf
[4] https://www.blorin.energy

IoT technologies can strongly contribute to the implementation of sharing models and energy efficiency solutions for smart buildings (and smart cities). Promising examples linking both sharing and efficiency of renewable energy solutions are the Renewable Energy Communities[5]. RECs are currently also being exploited in Italy[6]. IoT can also support the implementation of solutions such as the "digital twins"[7] for the smart buildings, e.g., as a way to improve performances or ensure better maintenance along the life cycle.

From the interviews, emerged that IoT solutions are currently adopted for efficient management of large estate assets or high-value (e.g., historical) buildings, but *"it could be potentially be used in the whole built environment, and not only for management optimisation, but also to monitor and modify users' behaviours (also through the development of mobile apps) and for predictive maintenance"* [type of stakeholder: Research]. With respect to maintenance, one interviewee [type of stakeholder: Research] underlined one Technology Transfer project that their organisation performed in order to allow a company to reuse production scraps and also to include sensors inside their prefabricated construction components, in order to monitor quantities such as tension state or deformation of each part.

Example: prefabricated component
Construction prefabricated components equipped with sensors, allowing to monitor the stresses and deformations occurring during each phase of the product life.

Another interviewed expert described the possibility to make IoT solutions and Artificial Intelligence work together to guarantee different levels of optimization. The first one is at a strategic level, which is connected to the need of Institutions and policy makers to optimize resource allocation over a selected area (e.g., a city, a district, etc…). The collection of big quantities of data (through sensors and IoT, but also satellite techs, automated vehicles and drones, as well as from territorial information systems) allows AI-based systems to identify areas needing intervention (e.g., from a social, environmental or other points of view) and optimize planning activities. The second optimization is at the building level, with respect to its components (materials, systems, etc…). The BIM methodology is becoming crucial to anticipate possible construction issues. It could also be associated with IoT technologies to monitor the building and to allow for consumption optimization (building automation), anomaly detection, and predictive maintenance. In addition, AI systems could improve optimization by learning from building and users' data and modifying functioning rules of automized buildings in order to reach selected targets. For the existing residential buildings (" *there is no interest in talking about new buildings since they are designed to be optimized and also because we should reduce new constructions and favour land consumption reduction*" [Interviewee]) the issue is making people investing in a building automation project. Interviewees don't see any issue or cultural barrier on the use of smartphones to interact with the functions of the building, since people are already used to mobile phone apps. The best results, however, could be seen in public or

[5] https://www.interregeurope.eu/fileadmin/user_upload/plp_uploads/policy_briefs/2018-08-30_Policy_brief_Renewable_Energy_Communities_PB_TO4_final.pdf
[6] https://italy.climate-kic.org/projects/geco-green-energy-community/ - https://www.enea.it/it/Stampa/news/energia-enea-nel-progetto-europeo-di-ricerca-sulle-comunita-energetiche/#uno
[7] https://www2.deloitte.com/us/en/insights/focus/industry-4-0/digital-twin-technology-smart-factory.html

commercial buildings and in manufacturing plants, where the same technologies allow for deep optimization with full systems control (with relative low costs). He said *"data is the added value that could make difference, also with affordable costs"* [Interviewee]. Associating interventions on the building shell to building automation could bring unexpected results.

Almost all interviews highlighted the importance of reusing and sorting materials from Construction and Demolition Waste. One interviewee focused on the need to look at urban areas needing regeneration intervention as "mines" (urban mining). To this extent it would be crucial to be able to retrieve and map information about materials contained in buildings and infrastructures. This would allow to maximize on-site reuse and recycling, starting from the design phase. However, while it would be relatively easy to set up open platforms to share and manage this kind of information, it could be relatively difficult to gather details on material contents before demolition. Nowadays, the best option for material recovery is selective deconstruction. Technologies such as RFID, IoT, blockchain and AI could improve this process, by enhancing materials and components sorting and tracing, but interviews highlighted that they should also be used to solve (and optimize) logistics issues that could emerge. In fact, one interviewee underlined that selective deconstruction "*needs large spaces inside the construction site to store the different materials in containers (one for each EWC[8] code), thus it is easier in large construction sites, but becomes difficult when talking about renovation interventions inside urban areas such as city centres*" [Interviewee].

Both desk research and interviews highlighted challenging opportunities for the building and construction sector and, in general, for the built environment related to the massive introduction of KETs-based innovations. Most of the interviewees pointed out that the most urgent and relevant innovations are those that will enable the largest possible diffusion, in order to maximize positive effects on both inclusiveness and sustainability. The different stakeholders share an optimistic perspective also on the potential economic effects that could be activated by the introduction of KETs-based innovations and new business and social approaches related to these innovations. However, due to the possible disruptive effects on both economy and society, specific issues need to be discussed in order to anticipate and prevent possible negative impacts or barriers, but also to ensure that benefits are maximised and diffused throughout society. In particular, the interviewees underlined the importance to ensure inclusiveness and equal distribution of benefits and opportunities.

3. Context of the innovation eco-system

The building and construction sector is one of the most resource and waste-intensive economic activities in Europe (ECSO, 2019). Buildings are also responsible for about 40% of the EU's total energy consumption, and for 36% of its greenhouse gas emissions from energy, since most of the existing buildings are not energy efficient, rely on fossil fuels for heating and cooling, use old technologies and wasteful appliances (EC, COM(2020) 662).

In Italy, similar data emerge from EU and national reports (ECSO, 2020). Moreover, the sector in Italy went through a strong crisis after 2008, which lead to a total turnover decline of 20.5% between 2010 and 2019 and a decline in the number of people employed of about 26% in the same period. However, the sector showed some positive development in the past few years. According to the European Construction Sector Observatory: "in 2019, the volume index of production in the narrow

[8] European Waste Codes

construction sub-sector increased by 3.6% between 2015 and 2019, and by 2.0 index points (ip) between 2018 and 2019. This increase follows a growth in investments particularly targeting dwellings (+7.5%) in urban areas, non-residential construction and civil engineering (+6.6%) and the narrow construction sub-sectors (+7.1%) between 2015 and 2019, which translated in an annual growth of 2.8 ip, 3.3 ip and 2.1 ip respectively" (ECSO, 2020).

A report by Italian industry Fassa Bortolo and Symbola Foundation (Fassa Bortolo, Fondazione Symbola, 2019) associates the quite positive trend of last years is mainly due to policies aiming at increasing seismic safety (about 80% of private homes were built before 1990, which means nearly 10 million buildings) and energy efficiency through building renovation, in order to "improve towns and cities by making their air cleaner, heating and air-conditioning cheaper and reducing energy consumption by up to 30-40%". After analysing 100 Italian business stories associated to innovation in the building and construction sector (most of which focusing on quality and sustainability), the authors highlight that "*if properly used, urban regeneration is a resource that could become an engine for recovery for the entire economy. In 2017, 87.6 billion euros were spent on extraordinary maintenance, against the 41.4 billion spent on new constructions. Of the 167.1 billion euro of production in constructions, 124 was spent on building renovation*".

Based both on data and business experiences, the report claims that "*It is time for a new approach to construction, one that uses new technologies and skills to support building renovation, energy efficiency, seismic safety and urban quality improvement*".

3.1. Main values and principles

The Building and Construction sector in Italy is still characterized by a linear approach. Almost all the interviewees highlighted that steps ahead have been made in the field of energy efficiency, but they underlined that a major part of the way towards a circular economy in the sector is still to be covered, in almost all the other aspects (ranging from the implementation of ecodesign principles, to the reduction of resources consumption, the extension of product life cycle, and proper use of waste and secondary raw materials).

Circular Economy needs a radical change of perspectives in both consumption and production in order to be effectively implemented, as going from linear to circular also means transforming scarce or competitive relations into cooperative ones. In fact, in order to better design resources cycles, it is useful to think about the whole systems and follow cascades (that can be – for example – referred to successive uses of the same product or material through different applications, but also to successive use of the same materials across different industries). This is one of the reasons for the "value chain" approach of the New EU Circular Economy Action Plan (European Commission, COM(2020) 98).

One interviewed expert underlined that

> *"circular economy is too often connected to recycling, which should be instead the last option. Better approaches, such as reuse, sharing and service-as-a-product should be promoted as new business models, because when there is an increased producer responsibility on end-of-life then there is also increased potential possibilities for reuse"*. [Interviewee]

Circular economy is expected to provide benefits that are operational as well as strategic, on both a micro- and macroeconomic level. The WEF identified it as trillion-dollar opportunity, with huge potential for innovation, job creation and economic growth. However, the implementation of circular economy aspects requires changes in manufacturing value chains and as well economic models.

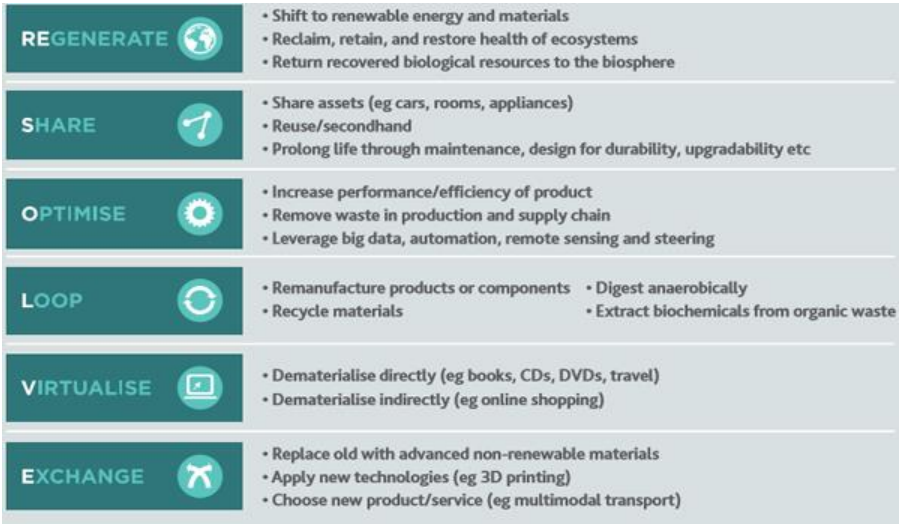

Figure 1 ReSOLVE framework

A useful guide both to analyse a system and to address its transformation into a circular one is provided by the "ReSOLVE" framework (see **Error! Reference source not found.**) and the work done Ellen Macarthur Foundation (Ellen Macarthur Foundation, 2015). The ReSOLVE framework is a list of six actions that can be exploited to transform a linear system into a circular one: Regenerate ("shift to renewable energy and materials, reclaim, retain, and regenerate health of ecosystems, and return recovered biological resources to the biosphere"), Share ("maximise utilisation of products by sharing them among users, reusing them throughout their technical lifetime, and prolonging their life through maintenance, repair, and design for durability"), Optimise ("Increase performance/efficiency of a product; remove waste in production and the supply chain, leverage big data, automation, remote sensing, and steering"), Loop ("Keep components and materials in closed loops and prioritise inner loops … this means remanufacturing products or components and as a last resort recycling materials"), Virtualise ("Deliver utility virtually"), Exchange ("Replace old materials with advanced non-renewable materials, apply new technologies, choose new products and services"). It is worth noting that different sectors could benefit the most by combining various actions. In the case of the building and construction sector the greatest impacts are expected in **share and loop**, followed by **optimize, exchange and virtualize**.

Experts' interviews highlighted that in the last years the building and construction sector was mainly focused on recycling materials, which is a crucial part in this transition, but in the next years there will also be an increasing attention on reducing resources consumption, thus observing the hierarchy of circular economy actions, by improving the eco-design practices as well as the reuse of materials and components by improving selection and traceability.

A large part of the virtualization process is now a reality in the field since BIM (Building Information Modelling) is now mandatory for large public construction projects (and will be mandatory for every kind of public work since 2025). Virtualization will improve all the value chain and allow a stronger cooperation between involved stakeholders.

Table 2 shows how new practices and technologies could enhance the adoption of a ReSOLVE framework in building and construction sector.

Table 2 The ReSOLVE framework for the transition of the building and construction sector towards circular economy.

Steps	Good practice	Technology
REGENERATE	• Shift to renewable energy • Prioritizing renovation with respect to demolition or new constructions	Advanced materials
SHARE	• Share spaces, also by selecting flexible construction solutions in order to rapidly adapt to different needs • Reuse components	Techs for traceability (IoT, blockchain)
OPTIMIZE	• Use BIM projects to share information on design in order to optimize use of resources (prefabricated solutions) • Exploit the properties of each material and combine materials in order to reduce overall consumption • Monitor through sensors in order optimize management and maintenance • Optimize industrial production	IoT, AI, Advanced/automated manufacturing systems
LOOP	• Use modular and dry construction techniques in order to be able to reuse components (in particular in commercial building and manufacturing plants, which often change configurations) • Reuse components in new/renovated buildings • Recycle production scraps and construction and demolition waste to produce new materials to be used along the value chain or in different production chains (sectors)	Advanced manufacturing systems Advanced materials IoT
VIRTUALIZE	• Digitalization of building information and design to share information and optimize each phase (design, production, construction, maintenance, end-of-life) • Use sensors and machine learning to collect data for monitoring and optimization activities	IoT, AI, Automated manufacturing systems
EXCHANGE	• Substituting primary (virgin) raw materials with recycled materials. • Substituting wet construction techniques with dry ones, allowing to maximise circularity	Advanced materials Advanced manufacturing systems

A list of principles for building design addressing circular economy issues has been provided by the European Commission (EC, 2020), with target on specific stakeholder groups, i.e., Building users, facility managers and owners; Design teams (engineering & architecture of buildings); Contractors and builders; Manufacturers of construction products; Deconstruction and demolition teams; Investors, developers and insurance providers; Government/ Regulators/ Local authorities. However, SocKETs interviewees highlighted notice that a crucial principle to be considered is that the transition towards a circular economy should naturally include all the citizens, at least for two reasons: the first one is that the built environment characteristics affect their everyday life, the second one is that both technological innovation and transition towards sustainability need to be inclusive in order to be diffused and thus effective.

3.2. Market description

Both desk research and interviews converge on the general conclusion that a diffused introduction of KETs-based innovations and their capability to enable a deep transformation in the building and construction sector towards a circular economy model will produce unprecedented economic benefits (in addition to environmental and social benefits), also beyond the specific sector.

Looking, for example, at the impacts of Italian financial incentives for renovation works in 2017, Fassa Bortolo and Symbola Foundation found that they "led to the investments of over 28 billion euros, and created more than 418,000 direct and indirect jobs, improving the construction entrepreneurial system and reducing energy consumption, pollution and household bills" (Fassa Bortolo, Fondazione Symbola, 2019). They also found that "between 2014 and 2017, more than 34,000 companies in the construction sector, 20.8% of the total, invested in green products and technologies", meaning that at least part of the Italian industrial system is interested by the benefits associated to these technologies.

A national report of the Italian Parliament (Camera dei Deputati, 2020) analysing the impacts of incentives policies for building renovation, shows that in 2008 new constructions represented the 41.7% of the Italian market and extraordinary maintenance only the 39.1%, while in 2019 new construction fall to 24.5% and extraordinary maintenance increased up to 50.3%. However, this report also points out that more than 65% of incentives for building renovations and 75% of incentives for energy efficiency were used in the North of Italy, highlighting a huge gap between the north, the centre (with 20% and 15% respectively), and South (14% and 10%, including Islands). The report also provides a first evaluation of the potential impacts of new incentives established in 2020 (i.e., Superbonus). It estimates a domain of 6 million buildings that could be potentially involved, gathering 19 million of houses. In relation to renovation works related to the seismic risk reduction the potential total of works is evaluated in about 1000 billion Euro, while the total potential works of energy efficiency are evaluated in about 600 billions Euro. The National Association of Buildings Constructors (ANCE) estimated 6 billions of potential direct economic benefits in 2021.

SocKETs interviews highlighted that the main part of recent investments are related to energy efficiency interventions and that there are still missed opportunities also on the resources efficiency side. The sectoral analysis conducted by Ellen MacArthur Foundation in the building and construction sector (Ellen Macarthur Foundation, 2015) highlighted significant waste and very short cycles. This way of producing and wasting costs Europe trillions every year, including actual resource costs and externalities such as pollution and CO_2 emissions. For example, structural waste in the building sector have been found across the whole life cycle (construction, utilisation, usage, and end of life), and also

in the urban planning (see **Error! Reference source not found.**). The analysis showed that "*in the built environment, the average European office is used only 35–40 percent of the time, even during working hours. This includes offices on expensive inner-city land.* ***Retrofitting existing buildings*** *can profitably reduce energy consumption by 20–40 percent.* ***Passive and zero-net-energy houses*** *are already making money in several market segments but remain a minority among new buildings.* ***Modular construction techniques*** *can reduce total construction costs 30–60 percent*". Moreover, it underlined that **construction and demolition** account for 25-30% of all waste generated in EU, which is often unattractive because contaminated with "*paints, fasteners, adhesives, wall-covering materials, insulation, and dirt*". For these (and other) reasons the New Circular Economy Action Plan for EU identifies the "Construction and Buildings" sector as one of the key product value chains (European Commission, COM(2020) 98).

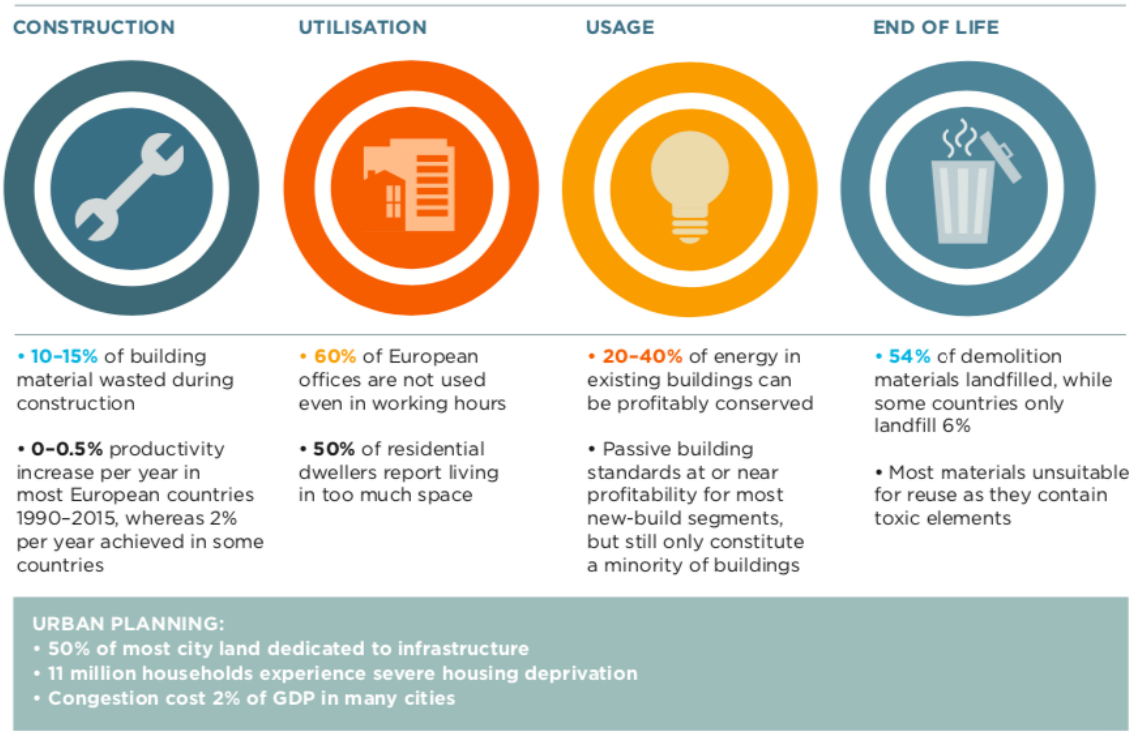

Figure 2 Structural waste in the built environment. (source: Ellen MacArthur Foundation, Deutsche Post Foundation, McKinsey Center for Business and Environment, Growth within: a Circular Economy vision for a competitive Europe, 2015)

At national level, the **Construction sector confirms as the main source of special waste** (43% of special waste in 2017 came from constructions and demolitions), especially in the northern area (producing 60% of the total waste from this sector, while southern areas produced 23% and central areas 17%) which is still increasing its waste production in this sector (ISPRA, 2019). The share of construction and demolition waste, which is prepared for reuse, recycled or materially recovered, is calculated in accordance with EU Decision 2011/753/UE and was 75% in 2017, beyond the 70% objective set by Directive 2008/98/CE (Fondazione Sviluppo Sostenibile, FISE Unicircular, 2019). However, the lack of end-of-waste criteria and a confused national regulatory framework discourage the recovery and recycling activity and the growth of the associated market of secondary raw materials. Interviews conducted by SocKETs highlighted that a major part of these materials are not reused or recycled, thus they eventually end their life in a landfill.

A national Report on Recycling activities in Italy identified 11 barriers for the effective reuse and recycle of construction waste. Among them:

- Scepticism from end users with respect to products derived from waste, mainly due to knowledge on their characteristics and to procedures to be applied
- Lack of transparent and affordable data on the effective waste production
- Lack of recycled materials options for construction materials
- Lack of specific criteria to evaluate environmental compatibility of recycled materials
- Inadequate materials separation and selective deconstruction practices.

The availability of a large and heterogeneous quantity of recycled materials emerged from SocKETs interviews. Experts underlined that there have been research activities on recycled materials for at least two decades, but other barriers (such as lack of knowledge about certification systems or scepticism) prevent the sector from doing massive use of secondary raw materials. The Green Building Council in its recent position paper (Green Building Council Italia, 2019) highlighted the need for qualification procedures for recycled/reused materials and the fact that in Italy different certifications allowing to know the recycled content of products, equipped with different criteria and verification and communication methods, thus confusing and discouraging operators.

Finally, in order to accelerate the transition towards a circular approach, the interviewees notice that there is the need to overcome business fragmentation and increase cooperation along the value chains. Circular economy allows for industrial symbiosis and for new supply and production chains to be developed in order to maximise the sharing and loop activities (as previously identified in the ReSOLVE framework). This could be strongly supported by the introduction of technologies such as Advanced manufacturing systems, IoT, AI, as underlined in section 1.1.2.

3.3. Policy frameworks, normative and regulatory regimes

This section provides a description of the main policies and laws emerged from the interviews. All the interviewees agreed on the crucial role played by the regulatory and policy frameworks to support or obstruct innovation and its adoption in the building and construction sector.

The most relevant European initiative that will involve the building and construction sector in the next years is the The New European Bauhaus, defined by the European Commission as “an environmental, economic and cultural project, aiming to combine design, sustainability, accessibility, affordability and investment in order to help deliver the European Green Deal”, having sustainability, aesthetics and inclusiveness as core-values. This SocKETs case study could bring a contribution to this European initiative, thus improving the final impacts of the projects.

Interviews underlined that many advancements in the building and construction sector towards circular economy were recently driven by European policies or regulations, such as those reported in Table 3.

Table 3 Relevant EU policies and regulations emerged from the interviews

EUROPEAN GREEN DEAL	The EU Green Deal has been defined as the new Growth Strategy for Europe, inspired by the need to tackle climate change. It provides a roadmap "with actions to boost the efficient use of resources by moving to a clean, circular economy and stop climate change, revert biodiversity loss and cut pollution".
RENOVATION WAVE	In the framework of the EU Green Deal, the EC planned to set a new strategy to boost renovation of the built environment, aiming both at boosting the energy renovation rates of buildings in EU and tackling the issue of energy poverty. It will also focus on skills and employment strategies and on strengthening the use of digital tools and smart technologies.
ENERGY PERFORMANCE OF BUILDINGS DIRECTIVE (EPBD)	Together with the Energy Efficiency Directive, the EPBD aims at having a high energy efficient building stock by 2050. the EPBD is going to be revised in the context of the Renovation Wave.
NEW CIRCULAR ECONOMY ACTION PLAN	The new action plan includes a Strategy for a Sustainable built environment, the revision of the Construction Product Regulation, the revision of material recovery targets set in EU legislation for construction and demolition waste and its material-specific fractions.
EU INDUSTRIAL STRATEGY	The strategy for EU industry includes the goals of the EU Green Deal and will support the creation of lead markets in clear technologies. In this framework, it supports the sustainability of construction products and the improvement of the energy efficiency and environmental performance of built assets, which are essential for the transition towards climate-neutrality.
RENEWABLE ENERGY DIRECTIVE (RED II)	The RED II established new target for Renewable Energy Sources consumption by 2030, setting targets for each country and asking them to specify energy policies to meet these targets in their national renewable energy action plans. Provided a new definition of "Renewable energy communities", giving greater power to citizens for self-generation and consumption of electricity.
EU CONSTRUCTION PRODUCT REGULATION (CPR)	The EU CPR provides harmonized rules for the marketing of construction products in the EU, starting from a common language in assessing performances.
EU CONSTRUCTION AND DEMOLITION WASTE PROTOCOL	The CDW (voluntary) protocol addresses some of the main hurdles to the recycling and reuse of CDW, such as the quality assurance of the secondary products, by encompassing five objectives: Improved waste identification, source separation and collection; Improved waste

	logistics; Improved waste processing; Quality management; Policy and framework conditions.

The European Construction Sector Observatory (ECSO) analysed the state of play of circular economy in the building and construction sector in Europe and in particular highlighted that the CDW regulatory framework needs further development and reinforcement at European level (ECSO, 2019).

At National Level, a majority of the policies underlined by the experts in relation to the possibility to introduce KETs-based innovations to drive the sector towards circular economy (see Table 4) are referred to incentives for renovation.

Despite huge incentives encouraging buildings renovation, interviewees highlighted that there are two main issues in national regulatory framework regarding regulatory unpreparedness and fragmentation. Regulatory unpreparedness emerges for example in association with end of waste criteria to be applied in order to allow the reuse of waste and scraps as secondary raw materials: in this case, even if the technology allows to reuse or recycle specific types of materials, regulatory updates are still missing, even though they are strongly requested to the Government for years and by almost all the different stakeholder groups. Regulatory fragmentation exists between different levels (i.e., at national, regional, sometimes at municipal level) and between different Regions or Municipalities. An interviewee provided the example of a 1927-law on mining activities, which assigns the responsibility for the regulatory framework of hydrocarbons extraction to the national legislator, while the decisions referring to quarries are asked to Regional authorities. Another interviewee pointed out that in some cases, different Municipalities, in the same Region, have different approaches with respect to some demolition materials: "*in some cases you are allowed to reuse them directly in the construction site, in other cases you are obliged to commit them to dedicated platforms or landfills*" [Interviewee].

A further issue emerged from almost all the interviews is the scarce application of existing laws, as in the case of Minimum Environmental Criteria (connected to the Green Public Procurement), which are defined by law for specific products and sectors, but still missing practical implementation in many public tenders. Most of the interviewees suggested to enhance commitment and improve formation of public functionaries to address this point.

Italy has also standardised a **good practice for selective deconstruction** (UNI, 2020), supporting the planning and realization of buildings disassembly designed for the recovery of materials and components. Moreover, a standardisation process is going on both at national (UNI) and international (ISO) level, to define a series of standards that will provide: common definitions, principles, domains and frameworks (ISO/TR 59004); business models and strategies for business transition towards a circular economy (ISO/TR 59010); principles and indicators to measure the level of circularity of different organisations (ISO/TR 59020); good practices for the circular economy and suggestions of strategies for their implementation (ISO/TR 59031). These standards are not limited to a specific sector but will be crucial also to the building and construction sector (and for the built environment in general).

Table 4 Highlights from the National regulatory framework

WASTE REGULATORY FRAMEWORK	the Italian regulatory framework gathers both national and regional laws
POLICES (AND INCENTIVES) TO SUPPORT BUILDINGS REGENERATION	• Home purchase and/or renovation fund: since 2019 the renovation/restructuring bonus allows 50% tax deduction for renovation on private properties • Eco-bonus: scheme for energy efficiency renovations (until the end of 2021) allowing for a tax deduction up to 65.0% for renovations and interventions on the building envelope, aimed to improve energy performance • Superbonus 110%: a fiscal measure (until December 2021, even if several organisations advocate for longer duration) providing a tax credit amounting to 110% to households for energy efficient and seismic related renovation • Earthquake Bonus (Sisma Bonus): a scheme allowing for a tax deduction (until the end of 2021) from 50.0% up to 85% (if the interventions improve the property by two risk classes) for works carried out for making an earthquake-proof dwelling • Funds for social housing in earthquake areas: resources allocated to the regions hit by the seismic events of 2016-2017 for the financing or co-financing the construction of housing to be used for permanent leasing with social rent

Finally, there are some specific issues of interest emerged from the interviews and deserving discussion between stakeholders:

- Green public procurement (GPP)
- Extended Producer Responsibility
- End of Waste
- Life Cycle Assessment
- Sustainable finance and EU Taxonomy
- Material recovery targets
- Certification, labelling and circularity indicators

Few interviews also highlighted the need to address regulatory issues regarding the production and management of citizens' data (workers, users, etc.), that will be allowed by the introduction of applications such as those based on IoT, AI, Advanced manufacturing systems.

All the stakeholders pointed out that the discussion on regulatory framework is essential both to guarantee rapid implementation of innovations and new business models and to guarantee high levels of environmental and social sustainability.

3.4. CSR, open innovation and co-creation practices

Very few stakeholders cited examples of Corporate Social Responsibility practices related to the building and construction sector and its connection with innovation or circular economy issues. With respect to co-creation practices, however, at least one example was proposed for the building sector and it is referred to some decades ago, when the term co-creation was not in use but participatory processes with mutual learning activities were already experimented in architecture.

One of the experts cited the Village Matteotti in the industrial town of Terni as a paradigm of participatory process in architecture by Giancarlo De Carlo, in the beginning of '70s. De Carlo involved steelworkers and their families in the planning activities, through meetings, interviews, debates and exhibitions. He finally assumed the role of educator as well as designer and builder. Every phase of the project was considered together with the users, who were directly involved in all phases of construction. The village was built on users' requirements, such as separating pedestrians and vehicles, providing private and public green areas, having social spaces.

A recent example of Social Responsibility is provided by an interviewee [type of stakeholder: Industry]. He described the Foundation "Prossima Generazione Valle Camonica", putting together the local authorities and industrial stakeholders of Camonica Valley, with the goal to regenerate abandoned industrial areas and enable new business activities to grow, in the form of B-corp. This should lead to the creation a "Benefit Valley", combining business profit to positive impacts on society and environment at local level.

One example of good practice is the Centoc'è project, in Rome, which built a smart community to involve citizens in an urban regeneration process and to elaborate circular economy models at urban scale. It developed activities such as living labs or world café, but also a virtual community. A further example is the campaign Civico5.0 (https://civicocinquepuntozero.it/chi-siamo/), which is dedicated to people living condominiums with the aim to provide news, information, good practices about energy efficiency and technologies enabling the sharing economy.

One interviewee highlighted also the Sand Network[9], developed in 2018 in Milan, as a good practice regarding cooperation between different actors along the value chain and aiming at enhancing the possibilities for industrial symbiosis. The aim of this network is to push the local building and construction business ecosystem towards circular economy, by introducing innovation and making different group of businesses or business functions working together on common objectives.

Different experts highlighted that ICT technologies, (where needed) in combination with IoT, could support new opportunities for participation, such as citizen science activities. For example, citizens could help in signal structural damages in buildings and infrastructures, or to collect data about buildings (such as data about systems, materials, construction period, etc.).

[9] https://retesand.it

3.5. Actors of the innovation eco-system

Innovation in the building and construction sector involves several actors. Different interviews highlighted that the "circular by design" approach is a holistic design approach, thus forcing actors from very different backgrounds to work together already at the very early stages of conception and design.

For this reason, the primary stakeholders of the innovation ecosystem (those who are directly involved in the work to develop of new technologies, applications and approaches) include a large part of the building and construction value chain. In particular, interviewees highlighted few stakeholders having specific roles in the innovation process:

- Construction, materials/chemicals, manufacturing, tech (ICT-IoT-AI) companies: providing the products that constitute the building and all its systems. They are affected by almost all kind of innovation that could be relevant to buildings sustainability.
- Professionals and associations of professionals (e.g., Architects, Engineers, etc.): designing the building and its systems, they also supervise the construction phases. They can take active part to the innovation development or simply participate by setting requirements.
- Research organizations, research centres: providing knowledge to generate innovation and supporting both the technology and the knowledge transfer towards companies and professionals
- Utilities companies: in some cases, they invest in R&D and/or take part to technology development. The services they provide can have a crucial role in solutions for building automation.

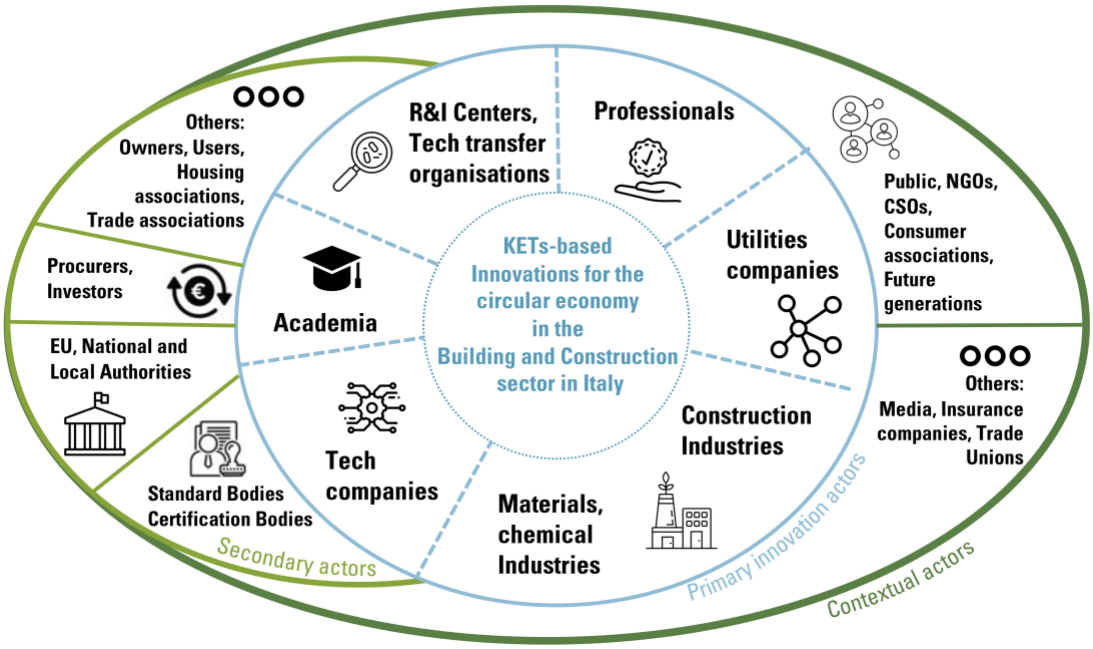

Figure 3 Innovation ecosystem of KETs-based innovations for Building and Construction sector in Italy

Other relevant stakeholders emerged from the interviews, are:

- Industrial and sectoral associations (e.g., construction associations)
- EU, National and regional authorities (regions and cities), territorial districts
- Funders and investors (e.g., banks and foundations),
- Regulators, Standard bodies, Certification bodies
- NGOs, CSOs, Housing association, consumer organizations
- Trade unions
- Insurance companies
- Building owners and users
- Media

Even if not directly connected to the innovation development, public authorities and policy makers are seen crucial for most of the interviewees. One of them said:

> *"Construction sector has always had a huge inertia with respect to innovation. I always visualize it like an enormous elephant made by billions of ants. But, if few ants move in the right direction, then the whole elephant will move. Public authorities play a key role to stimulate the first ants. If they are an evaluation criteria or minimum requirements to access public tenders, then innovation and sustainability will represent a competitive advantage".* [Interviewee]

Public authorities are seen as an enabler by almost all the experts. They have the possibility to support innovation giving competitive advantage both through regulation and Green Public Procurement. On the other side, their inertia or wrong choices have the effect to stop innovation.

The key role is assigned to designers, since they make the most relevant choices. An industrial stakeholder synthetized that

> "*the construction companies realize what is prescribed by the project and usually professionals are also responsible for the coordination of on-site operations*" [Interviewee].

In this perspective, the role of professional associations (mainly architects and engineers) is thus crucial to provide them formation and updates about innovative solutions, best practices, regulatory framework, and so on. This is crucial for small (or individual) professional studios, which usually don't dispose of resources (mainly in terms of time and people) to follow the last updates. In some cases, a generational gap has been also highlighted, with new generations of professionals generally more open to new construction paradigms and materials, digitalization, innovation and sustainability.

Since most of the "products" are designed to last several decades after their construction or renovation, as highlighted by different interviewees, the list of actors that will have a stake on the product during its life cycle is broaden than what could be expected in other industrial sectors. This is also one of the main reasons for the importance of collection and availability of information about materials, systems and components: this kind of knowledge will allow future generations to intervene on buildings and infrastructures in a more efficient way with respect to what we are able to do nowadays.

A "special" stakeholder is, thus, represented by future generations as described by Feige et al. (Feige, Wallbaum, & Krank, 2011). Even if they cannot take part to the innovation process, they should be

one of the main targets of the transition towards a circular economy, in particular in a sector where products are designed to cross generations.

SocKETs experts interviewed in the first phase of the project, in order to identify the relevant information and issues for this case study, include:

- 1 NGO from civil society, dealing with environmental issues and social issues connected to them
- 4 different R&I actors:
    - the Architecture, Built Environment and Construction Engineering Department of a University
    - an R&I District, born to develop Innovation in the building and construction sector, with specific focus to seismic security and environmental sustainability and with partners representing the whole building and construction value chain
    - a private research centre, dealing with materials, technologies, and design, working on both R&I and Technology Transfer (mainly to SMEs) activities
    - a (large) public research centre, which is the national reference point for new technologies, energy and sustainable development
- 2 different business stakeholders:
    - a professional designer studio, gathering both Architects and Engineers
    - an innovative start-up dealing with R&I, Technology Transfer, training and dissemination, with specific focus in the fields of advanced materials and digital technologies (IoT, AI, big data analysis, etc), also applied in the construction sector
- 2 different industrial stakeholders:
    - an industry producing materials for building and construction, dealing with both natural and innovative materials and solutions, and working with a deep implementation of advanced manufacturing processes
    - an industrial association of building and construction companies
- 1 policy actor:
    - a certification agency, dealing with buildings energy certifications and environmental labelling.

4. Societal and ethical aspects

Since KETs-based innovations may bring disruptive changes in everyday life and the circular economy itself aims at changing society, it is crucial that both the innovation and the transition towards sustainability ensure inclusiveness and social desirability. For this reason, interviewees were asked to start reflecting on the ethical and societal aspects connected to the expected large diffusion of emerging technologies in the building and construction sector as well as throughout the built environment.

4.1. Ethical and social conditions and implications

SocKETs interviews highlighted that shifting of the building and construction sector towards the circular economy implies the adoption of a new paradigm. This deep change is not limited to the main stakeholders of the building and construction sector: it involves cities, people, relations and activities. The most evident impacts are those on the environment, however there are also relevant societal and (some) ethical issues emerging from interviews.

The interviewees highlighted a series of implications. Most of them are connected to environmental issues, but they also include relevant ethical and societal aspects:

- Reduction of waste from the building and construction sector, towards (near) zero waste approaches
- Incentives and green public procurement, which emerged as crucial points to overcome economic barriers for innovative solutions, but also to demonstrate (through public investments) their performances and the possibilities they add for all the actors along the value chain
- Waste traceability, together with end-of-life regulations to facilitate the reuse of components and recycling of secondary raw materials will not only reduce environmental impacts, but will also improve legal aspect connected to waste management
- The need to improve standards in terms of circularity (including energy consumption, use and recycling of building materials), also through the adoption of certifications and labels (such as Level(s), LEEDs, and many others, even too many according to interviewees)
- Improving safety standards, both for workers and end users
- Innovation and sustainability call for a strong communication towards citizens but also between different stakeholders
- The need to increase public awareness with respect to innovation and quality
- The opportunity to develop urban labs to test new solutions (smart cities)
- The possibility to introduce new models of funding for restoration actions (incentives, sharing public-private, etc)
- Switch to collaborative modes, sharing economy models/sharing of assets
- Diffusion and inclusiveness of changing opportunities: an innovation enabling a small enhancement for a huge number of people/cases should be preferred with respect to a spectacular innovation accessible to a niche of people
- Complexities related to the data such as property, value, use of data, where data are stored, consumption associated to large data centres.
- Large use of sensors and processors (not only in large supercomputing facilities but also in edge-to-edge computing) is connected to large consumption of materials and also critical raw materials (European Commission, COM(2020) 474),such as rare earth elements or lithium, with environmental but also geopolitical implications
- "All the technology brings wellbeing to citizens who can afford it and probably in few years a large part of technologies will be available for a large part of citizens, at a certain point they will become the only products available on the market" [Interviewee]
- Public housing as a way to test and diffuse innovation.
    - "*In the past, public housing represented the opportunity to test new solutions. This should be reconsidered since connecting investments in public housing renovation to the experimentation of innovative solutions for sustainability could bring large impacts from the technological, economic, societal and environmental point of view*" [Interviewee].

- The digitalization of buildings design through the BIM approach, introduces the IPR issues about the property of the data and the design project itself.

All these issues deserve further and deep reflection with citizens and stakeholders, during the development of the Italian case study.

4.2. Public and stakeholder awareness

The general public started to have awareness about energy efficiency thanks to national laws setting legal obligation to energy labels for buildings and providing lot of resources to encourage energy efficiency as well use of renewable energy production systems in private buildings. The easy-to-understand energy label allows the user to recognize a better investment when purchasing (or renting) a house.

> *"Thanks (mainly) to the national laws about building energy labels and the great incentives to energy efficient renovations even my grandmother knows that the building may have a coat (as a thermal insulation system)"* [Interviewee]

Increased awareness on the possibility to increase well-being and reduce energy bills is raising interest by the general public to energy efficiency renovations. Also increased general interest to environmental issues is contributing to diffuse a new perception on the need to increase building energy performances. But this raising awareness process is a slow process, and a lot of people still have reluctance to invest on renovation, maybe because it is still seen as a cost rather than an investment.

A similar perception emerges with respect to innovation. On one side, in recent years there is a raising perception that innovation could help the building and construction sector, however different experts underlined the scarce attitude of people (including some stakeholders) to recognize quality and to evaluate the added value of innovative solutions.

A crucial aspect emerging from almost all interviews is the lack of awareness of citizens and stakeholders about the performances and quality of advanced materials, in particular those containing recycled materials. Experts underlined that small and micro construction companies show skepticism about performances of advanced materials embedding production scraps or waste, while end users are mainly concerned about possible toxicity of materials they will be in contact with. In order to overcome this kind of cultural barrier, one expert state that

> *"We should stop to call them 'waste materials', we should call them 'secondary raw materials', as alternative to virgin raw materials. The trust toward a product is essential."* [Interviewee].

5. Cultural aspects

<u>Business culture</u>

The interviews highlighted that the building and construction sector in Italy tends to be quite conservative in terms of innovation and use and application of new technologies. There are very few innovation and tech intensive companies working in the field. One of the main reasons is that the field is mainly made of small and micro businesses, and this usually impedes the access to (funds and) the most advanced technologies. The business culture of these small and micro businesses prevents (or represents a strong barrier to) clustering and growth, and in some cases sees quality and

sustainability more as barriers (costs) rather than competitive advantages. In this condition, the introduction of technology is often a request of the single customer.

> One expert said that *"the most critical phase is the work in the construction site. Here we find that a major part of these small businesses still works in an artisanal way and are anchored to a model based on manual unskilled labourers, since this offers competitive prices compared (in the short term) to more advanced construction systems".* [Interviewee]

Associated to this issue, there is also a limited connection between the actors of the sector and limited information and education initiatives. All the experts agreed that the sector would benefit from:

- Continuous interaction between the stakeholders in order to develop cooperation models that could make them work together in rethinking the whole process
- Regular information made available throughout the innovation ecosystem, about technologies, methodologies, new products, regulatory issues, opportunities, etc… experts also agree that these should be mainly provided by public authorities and by associations (trade unions, trade association, etc…).
- Professional education for all the stakeholders involved in order to increase awareness on different aspects, including (but not limited to): new technologies and innovation, regulatory and legal, economic and market, environmental and safety aspects. The lack of education on recent updates leaves small (micro) businesses out of the innovation process. It is also crucial for each stakeholder to gain consciousness about its role in the value chain and the possibilities to collaborate with other actors to improve both its job and the whole sector.

> *"Professional education is a crucial aspect but is often underestimated, in particular with respect to sustainability issues and innovative solutions, but also with respect to regulatory framework and good practices."* [Interviewee]

The professional education should not be limited to private organizations (industries, construction companies, professionals, etc…) but as well to policy makers and local authorities, in order to avoid the risk of regulatory unpreparedness.

> *"Scarce formation in public authorities leads to unused instruments such as Minimum Environmental Requirements. If public authorities are not aware about the possibilities provided by latest innovative solutions, then there will be an issue of regulatory framework preparedness".* [Interviewee]

<u>Need for a culture of quality and sustainability</u>

Interviews highlighted that we should invest on education and communication actions in order to make people recognize the value of an increased quality and sustainability in buildings. They connect this lack of interest (which sometimes is also scepticisms) towards new solutions to increase quality and sustainability as a cultural issue.

> One expert said "*Architecture is Ethics, because it should be by definition connected to the environment <<to reach harmony>> and providing answers to people's needs. We lost this idea of Architecture during the latest decades of the XX century, when the idea that houses for the masses should only be designed to be cheap became a kind of general principle".* [Interviewee]

Experts underlined that in recent years the diffusion of the energy labels allowed for example citizens to rapidly recognise the value of reduced energy consumption and this is increasing the demand for

this kind of solutions. They suggested a similar approach in order to highlight the circularity of buildings, even if it is made by a series of different issues (reduced consumption of natural resources, maximization of reuse, optimization of consumptions, etc…). In the case of innovative materials (e.g., nanomaterials) or materials including recycled parts (e.g., materials from waste) people are often sceptical about the actual quality and worried about possible toxicity and negative long-term effects on health. Sometimes this is due to difficulties in finding but also understanding the information about innovative solutions. *"The information supporting the material is crucial both for the workers and the end-users".* [Interviewee]

However, a need for a diffused culture embracing general sustainability and innovation aspects emerged. This would also support the dialogue between stakeholders and the general public. SDGs and European Directives helped in developing a debate on sustainability of the built environment inside the society, at different levels, but a strong communication is still needed for every kind of innovation activity in order to inform and motivate people. For example, during the last five years people are more conscious about environmental issues and their connection with health, they are asking more actions to reduce pollution, outdoor but also indoor.

In recent years there has been an increased consciousness both in the private and the public sector that innovation can bring sustainability, increase wellbeing, but also support productivity (thus increase gains). This kind of consciousness should be also transferred to citizens that should be aware that innovation bringing quality and sustainability, should not be seen merely as a cost since the advantages (from the economic point of view, but also in terms of wellbeing) can be more than the initial investment.

Generational issues

There is a generational diversity in stakeholders' approach. Younger people are more open to innovation, in terms of materials as well as in terms of attitude to change processes and approaches. Older people tend to think "*I've always done in this way, I will keep my habits*" [Interviewee], even when change is prescribed by law and also in the case of professionals. A similar inclination can be found in younger end-users.

From competitive to collaborative systems

Linear economy pushed the stakeholders (but also citizens) in a permanent competition to grab resources and to lower prices, also to the detriment of environment, safety, wellbeing, etc. Similar cultural approaches permeated the whole society. Interviews highlighted how, in contrast to linear economy, circular economy needs a holistic approach, with strong integration between systems and collaboration between different actors.

For example, the digitalization of buildings design through the BIM approach and the possibility to share the information since the very early stages of a project, allows the different stakeholders to cooperate in order to maximise the opportunities and the efficient of the whole project.

In a similar way, the sharing (e.g., of energy production equipment in energy communities) of assets, information and services could bring people to build a new community dimension connected to their neighbourhood.

6. Interest in co-creation and SocKETs activities

Almost all the experts showed interest in multi-stakeholder and public engagement activities, since they expressed a strong need to strengthen the integration between the different stakeholders along the value chain and to push for cooperation throughout the whole innovation ecosystem. The main peculiarities regarding the interest in taking part to co-creation processes and in particular to SocKETs activities refer to the business and industrial stakeholders and to the research stakeholders.

Business and industrial stakeholders

Interest in participating in public engagement and co-creation activities, is mainly motivated by the possibility to promote the characteristics of their innovative products to other stakeholders and to enhance people awareness on the importance of employing sustainable and high-quality building and construction systems. Also, the possibility to become a testimonial raised the interest in participation, as well as having the possibility to collect a list (database) of good practices.

Further motivations are the possibility to network with other stakeholders to develop results that could be taken by the national Government as input for regulatory improvements, expanding knowledge about good circular economy practices from other fields (or other countries) that could be imported in the building and construction sector, interact with operators from other sectors that could exchange scrap materials with the building and construction sector.

> *"A good example of dialogue between stakeholders was the CIRCE project, allowing to exchange knowledge and best practices also across different sectors". [interviewee]*

Research stakeholders

> "*Since the built environment is related to people's everyday life, everything that needs to change should be supported by strong communication campaigns*" [Interviewee].

Debate involving people is crucial also to highlight barriers and ways to overcome them together.

A motivation for involvement in participatory processes is the possibility to interact and reflect with other people, the need to create connections (also with stakeholders in different positions along the value chain) and share good practices. Similar co-creation actions are provided by ICESP (Italian Circular Economy Stakeholder Platform) and the Green Building Council.

> *"Artificial Intelligence should also be introduced in co-creation processes in order to support dialogue between different stakeholders with completely different backgrounds" [Interviewee].*

Finally, a large part of the interviewed experts shown interest in receiving the final report of the interviews made by SocKETs, to know the information and perspectives collected from other types of stakeholders.

7. Conclusions

In this report the possible role of KETs-based innovation in supporting the building and construction transition towards a circular economy is analysed. The study has been conducted both through desk research and experts' interviews and will be useful to the SocKETs project to build a case study to experiment co-creation to drive the development of technologies or innovation strategies in the sector.

The most relevant Key Enabling Technologies for the sector emerged from literature and interviews are: -Advanced manufacturing processes, IoT and AI, Advanced materials (also including solutions based on recycled materials and natural materials).

Few examples of co-creation, open innovation or Corporate Social Responsibility actions have been highlighted, probably due to a still limited diffusion of these practices in the sector. However, connections between the innovations having the potential to support a transition towards a circular model and a variety of societal and ethical aspects have been underlined. Most of them will need further assessment and discussion during the co-creation activities connected to this case study.

A crucial societal aspect emerging from the interviews is that the best possible innovations are not the most performing ones in absolute terms, but the ones ensuring the broadest application throughout both the value chain and the built environment. This will ensure to maximise the social, environmental and economic benefits but will also need strong participatory processes to enhance inclusiveness, cooperation between stakeholders and interaction with citizens.

However, different barriers to the diffusion of KETs-based innovation in the sector to support circular economy are envisaged, such as regulatory unpreparedness, business culture and fragmentation in the sector, lack of formation, scarce integration between stakeholders, scepticism with respect to innovation.

All the stakeholders agree on the fact that innovation will push for deep changes both in the value chains and in the way people are used to consider and live their homes and the whole built environment.

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9. Annex

9.1. List of participants

- Legambiente Onlus, Edoardo Zanchini, Vice President
- STRESS, Marco Iuorio, General Manager
- CETMA, Luigi Barone, General Manager
- ENEA, Laura Cutaia, Manager of laboratory for resources valorization in territorial and production systems
- DuePunti Architetti, Matteo Romanelli, Executive Manager
- CasaClima, Mariadonata Bancher, R&I Manager
- Politecnico di Milano, Monica Lavagna, Professor of the Department of architecture, construction engineering and built environment
- WoodBeton, Giovanni Spatti, CEO
- Idea-re, Alberto Garinei, Scientific Manager
- ANCE Lombardia, Sara Grassi, Senior Manager Sustainable development, territory and environment

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