Sustainable building sector development

The growing interest in eco-sustainable buildings and circular economies is encouraging the smart recycling of Construction and Demolition Waste (CDW), one of the heaviest and most voluminous waste streams generated in the EU. This type of recycling contributes to waste valorization and environmental impact reduction by avoiding waste landfill and preserving natural raw materials.

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The pathway towards recycling has been paved by the Waste Framework Directive (2008/98/EC) stipulating that „Member States shall take the necessary measures designed to achieve that by 2020 a minimum of 70% (by weight) of non-hazardous construction and demolition waste [...] shall be prepared for re-use, recycled or undergo other material recovery (including backfilling operations using waste to substitute other materials)". However, to date only a few countries have been able to meet such an ambitious objective (e.g. Germany, the Netherlands, Belgium...) and hence there is still a lot to do.

Within this framework, the VEEP project (acronym for "Cost-effective recycling of CDW in high added-value, energy-efficient prefabricated concrete components for the massive retrofitting of our built environment" – www.veep-project.eu) was conceived and is now on-going under the European funding research and innovation programme HORIZON 2020.

VEEP aims at developing competing upcycling technologies for waste treatment to recover recycled aggregates and ultrafine cementitious materials at a high rate and acceptable costs, as well as new processes for the production of new materials, such as low-cost, closed-loop aerogel, by using silica containing CDW fractions and precast concrete elements with a high percentage of CDW content (>75% by weight).

VEEP builds upon previous research projects funded by the European Commission focused on the recycling of CDW that demonstrated the economic and environ-

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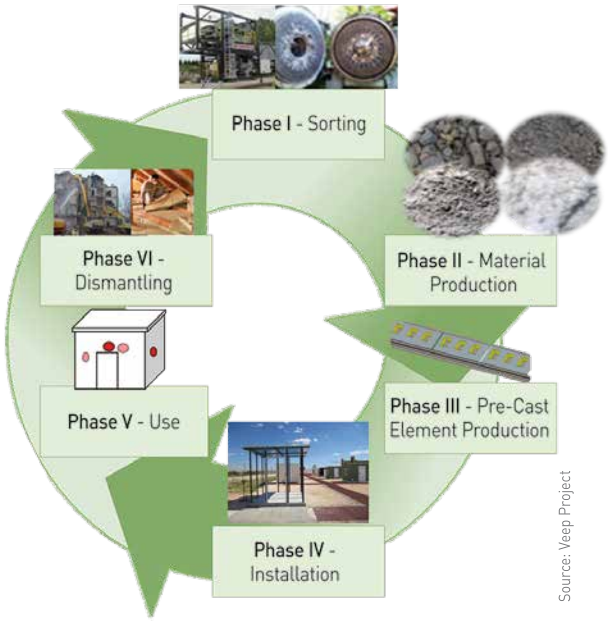
mental feasibility of the use of secondary raw materials from the building sector such as IRCOW, C2CA and HISER. The IRCOW project (no. 265212, http://www.ircow.eu/), completed in 2014, introduced an innovative insulating concrete from recycled cellular concrete that, when compared to aerated concrete with similar properties, performed better in all environmental impact categories, reducing costs as well. The C2CA project (no. 265189, http://www.c2ca.eu/), completed in 2014, developed a semi-mobile advance dry recovery (ADR) set that converts waste concrete on demolition sites to coarse aggregates. Finally, the HISER project (no. 642085, http://www.hiserproject.eu/), to be completed in 2018, goes a step beyond to include the recovery of concrete aggregates from complex CDW, exploring even more cost-effective solutions for the 0-4 mm fraction of the waste concrete.

In the framework of the VEEP project, the whole circular value chain (herein depicted) – from the recovery and sorting of CDW up to the production of innovative precast panels, their installation, use and deconstruction – will be demonstrated in Spain and the Netherlands, representing varying European climate conditions. The first phase (Phase I) of the process is the sorting of the CDW, thanks to the development of innovative technologies for the highly efficient, cost-effective recovery of mineral resources. The sorting process foresees the combination of different technologies, namely: a new generation of Advanced Drying Recovery (ADR) and an innovative Heating-Air classification System (HAS) adapted for processing and recycling low-weight and normal-weight End-of-Life (EoL) concretes. The innovative, movable technologies make it possible to obtain primary-grade recycled concrete aggregates and sands as well as cementitious recycled ultrafine particles to be used as secondary aggregates and cement in new "green" concretes. To process building insulating mineral and glass wool wastes, which are commonly landfilled, an ultra-fine wet grinding and refining technology, which is currently under development, will also produce recycled mineral microfibres and cementitious ultrafine particles for use as secondary raw materials.

The five phases of the circular economy

Each phase of the process is considered in the project.



The secondary raw materials sorted in Phase I are embedded in the production of innovative materials within Phase II. In particular, Low Weight and Normal Weight concretes will be developed, demonstrating the feasibility of partially replacing coarse and fine aggregates (i.e. sand) in the concrete. Moreover, a cost-effective, sustainable, closed-loop aerogel composite ($\lambda \leq 0.015$ W/mK) that uses at least 80% (of the total silica content by weight) highly silica-rich CDW recycled materials will be developed by means of a new disruptive process, in-line integrating hydrothermal and low-temperature supercritical drying technology developed by Keey Aerogel and Tecnalia.

These new materials will be used to produce Precast Concrete Elements (Phase III). These Precast Elements will be designed for re-cladding and over-cladding applications and have insulation properties in terms of their overall heat transfer coefficient with a significantly reduced thermal bridge. Demonstration of the energy efficiency and cost-effectiveness (Phase V) and the potential disassembly of the new precast concrete elements (Phase VI) are performed in two diverse European climatic scenarios (Madrid, Spain and Hoorn, the Netherlands), through the design and execution of real-scaled building mock-ups.

Within VEEP, the environmental and economic performances of the innovative circular value chain will be assessed via a step-by-step approach – developed at the beginning of the VEEP project. The approach allows the use of integrated Life Cycle Assessment and Life Cycle Costing (LCA-LCC) to guide the VEEP technological development and estimate the potential overall impact of VEEP innovation for the two case study countries. By performing an LCC in parallel, this allows us to understand how different business operating conditions affect the environmental impact and therefore identify the optimum conditions for a win-win situation. The approach will be performed according to recognised standards (ISO 14040, ISO 14044 and ISO 21930).

The first step consists of the integrated screening LCA and LCC study of each phase individually with ad-hoc analysis by considering the perspective of the individual stakeholder. This approach will identify the main impacting flows (energy, material) for each technology and inform technology developers as to where improvements to reduce the environmental impact are most needed. The screening LCA-LCC enables technology improvement prior to the demonstration case studies.

The second step in the integrated LCA-LCC applies to the demonstration case studies. Here, the LCA-LCC assesses the overall impact of the new circular value chain, based on real data. The results will be compared with current practices, taking into account a dual-function perspective, i.e. a waste management perspective as well as building element production and utilisation perspectives. The impacts of VEEP will be compared with those associated with Business-As-Usual practices.