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ADVANCE

ACCOMPANYING MEASURE FOR DISSEMINATION, VALORISATION
AND COLLABORATIVE EXPLOITATION OF CIRCULARITY
OF CONSTRUCTIONAL STEEL PRODUCTS



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Accompanying Measure for Dissemination, Valorisation and Collaborative Exploitation
of Circularity of Constructional Steel Products
(ADVANCE)

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Abstract

The concept of reusing building components has roots in the past when availability of building materials was relatively poor and their production was slow, tedious and expensive. The practice gradually became difficult or even impossible along with the mass production of building products and with the demands for high levels of structural safety, quality of the materials and health & safety requirements of demolition/deconstruction. Fulfilling these current standards and enabling the most environmentally efficient material circulation at the same time is a challenge recognized by the research community in the recent years. The need for innovations in building materials recovery is becoming more important also for the contractors in building industry who will have to change their operations from the traditional demolition process to more difficult deconstruction in order to retain the value of the building elements. Therefore, the reuse of building components is one of the international strategic spearheads in developing the circular economy in the construction sector.

Large quantities of waste are generated during the production of building components, during construction and demolition. According to Eurostat, construction and demolition activities in Europe are responsible for 35% of solid waste production. The construction sector also consumes about half of all the natural resources extracted in Europe every year, with very high energy demands on their transformation into building products. It is estimated that 40 - 50% of all extracted raw materials are transformed into building products. The vast amount of energy is used in the first three stages of the production process: resource generation, resource extraction and intermediate product manufacture. However, steel construction, as part of the construction sector, has a very good potential to contribute to resource efficiency because steel is particularly suited for reuse (in addition to recycling).

ADVANCE project addressed these challenges in both deconstruction and reuse of existing steel buildings, and in the design of new buildings, their construction and documentation to facilitate future reuse. Reliable performance data and guidance is provided to engineers, investors, contractors and other decision makers by disseminating the information about the products, systems, methods and protocols that facilitate reuse of various components of constructional steelwork using the tools and methodologies developed within activities of the consortium partners. The outcomes of the project include recommendations to enable reuse of building components and support better design for future reuse, mobile and web-based LCA app and various dissemination materials introduced in this report.

Project overview

Table 1 Project overview

Project overview	
Sector	Steel
Technical Group	TGA4
Grant Agreement no.	101112269 (RFCS-02-2022-AM)
Title	ADVANCE
Acronym	Accompanying measure for Dissemination, Valorisation and Collaborative Exploitation of circularity of constructional steel products
Beneficiaries	VTT Technical Research Centre of Finland (VTT) Universitatea Politehnica Timișoara, Romania (UPT) European Convention for Constructional Steelwork (ECCS) University of Coimbra, Portugal (UC) RWTH Aachen University, Germany (RWTH) Finnish Constructional Steelwork Association (TRY) Czech Technical University in Prague, Czech Republic (CTU) Industrial Technical Centre of Metal Construction, France (CTICM) Purkupiha Group, Finland (PUR)
Associated partners	The British Constructional Steelwork Association, UK (BCSA) Bauforumstahl, Germany (BFS) ArcelorMittal Belval & Differdange (AMBD)
Project duration	24 months (1 September 2023 – 31 August 2025)
Work undertaken	Refer to Sections 1 to 5 of this report
Main results	Refer to Sections 1 to 5 of this report
On schedule	The project followed the original schedule
Main problems encountered	World Steel Association released alternative methodology for LCA assessment in 2024.
Correction actions	The World Steel Association's LCA methodology was implemented in ADVANCE outputs.
Reports and other deliverables	Refer to Sections 1 to 5 of this report and [1] to [22]
Dissemination and communication activities	Refer to Sections 4 of this report

Table 2 Budget information per beneficiary

Beneficiary	Budget costs
VTT Technical Research Centre of Finland (VTT)	120 952.40 €
Universitatea Politehnica Timișoara, Romania (UPT)	91 422.00 €
European Convention for Constructional Steelwork (ECCS)	173 283.65 €
University of Coimbra, Portugal (UC)	106 700.00 €
RWTH Aachen University, Germany (RWTH)	70 554.35 €
Finnish Constructional Steelwork Association (TRY)	47 348.00 €
Czech Technical University in Prague, Czech Republic (CTU)	36 649.00 €
Industrial Technical Centre of Metal Construction, France (CTICM)	77 297.35 €
Purkupiha Group, Finland (PUR)	69 810.00 €

Project scope

ADVANCE project contributes to greenhouse gas reduction and circular economy goals by addressing these challenges in both deconstruction and reuse of existing steel buildings, and in the design of new buildings, their construction and documentation to facilitate future reuse. Its scope includes reuse of constituent products, fabricated components, and reuse of component assemblies. The reused material may originate from primary structures, secondary structures and envelopes.

The reduction of greenhouse gas emissions of steel industry became essential in the recent years with the major focus on the construction sector, the single largest source of its environmental footprint. The construction sector comprises the opportunity to establish steel-based technologies in a leading position for the decarbonisation of other relevant industries dependent on steel solutions. The activities supporting this goal can be divided into two categories (a) efficient and clean energy utilization in steelmaking and (b) taking advantage of excellent durability of steel products that enable their re-manufacturing and reuse without the need of energy intensive recycling. ADVANCE project focused on the latter category and utilized and further developed the outcomes of several successful background projects such as PROGRESS, SB STEEL and LVS3.

Although some of the background projects had more general or more limited scope than ADVANCE project, it was possible to generalize or select the topics suitable for the proposed ambition. For instance, PROGRESS project focused primarily on the single-storey, steel framed buildings, but its outcomes are generally not limited to those structural typologies. Many of the project results can be directly applied to all constructional steelwork and, with some modifications, to the timber and prefabricated concrete elements as well. Single-storey buildings were typically used in the project as demonstration cases because of their simplicity, demountability and relatively large number of successful reuse cases over the last decades.

It is expected that existing steel buildings can be reused in-situ, relocated or deconstructed into elements such as cold-formed or hot-rolled sections, sheets, panels, frames or truss girders. These components have very high reuse potential, but require verification of the material quality, dimensions and tolerances in order to be included in new building projects. The future reuse of modern buildings, however, may be different, because those structures are increasingly designed as systems and their design information can be easily maintained for instance as a building information model (BIM). Therefore, the ADVANCE project addressed both topics and its results cover both, existing and future buildings.

The ambition to provide pathway to achieve impact beyond the scope of existing projects can be described in three levels: (1) to address all constructional steelwork with the support of partners and background from PROGRESS, SB STEEL and LVS3 projects, (2) to extend it to other construction products and materials in the generalized recommendations for reuse and (3) to select suitable outcomes (such as LCA methodology and reusability assessment methodology) supporting recovery and reuse of any other fabricated building products (see Figure 2).

Project objectives

The primary objective was to increase the recovery and reuse of constructional steelwork by providing engineers, investors, contractors and other decision makers with reliable performance data and guidance. This was achieved by disseminating the information about the products, systems, methods and protocols that facilitate reuse of various components of constructional steelwork using the tools and methodologies developed within activities of the consortium partners.

The outcomes of the project include recommendations to enable reuse of building components in-situ or in different location(s), and in the original layout or in a different design with the necessary modifications/adaptations to resist the new external loads (due to the relocation) or internal loads (due to the modification of the structural layout). Our goal is to address the wider scientific, business and engineering community in the Member States with the localized Recommendations for Reuse, information brochure, mobile app and presentation materials.

In particular, the objectives were to:

- Provide necessary guidance for the successful reuse of existing components or structures and design of new ones with improved reusability, introduce recommendations for product/waste status and material testing protocol for re-certification of steel products in the updated Recommendations for Reuse (European Recommendations for Reuse of Steel Products in Single-Storey Buildings) from PROGRESS project (measured by KPI3 from Table 4);
- Support systematic and transparent declaration of the environmental benefits of steel reuse with the methodology to declare LCA beyond the system boundary implemented in the mobile LCA app and web tool (measured by KPI2 from Table 4);
- Increase awareness about the alternative end-of-life options for constructional steel and steel-based products by sharing information about successful reuse cases and circular business models in 7 workshops (measured by KPI1, KPI4-6 from Table 4);
- Identify the possibilities and roadmaps for scaling up the outcomes of the core background projects beyond their original focus area to reach two milestones (a) universal framework for the constructional steelwork and (b) universal framework for any reusable building components and works connected by steel connectors (finalizing Deliverable D2.1).

Contribution to the objectives of the RFCS programme

Within the scope of the Council Decision 2008/376/EC, ADVANCE project addresses the products of the processing of steel that can enhance the competitive position of the iron and steel products. In particular, as stated in Article 10 / Conservation of resources and improvement of working conditions: *“In both steel production and steel utilisation, the conservation of resources, the preservation of the ecosystem and safety issues shall form an integral part of the RTD work”*. ADVANCE was focused on:

- Clause (a): “techniques for recycling obsolete steel from various sources and classification of steel scrap”; Such recovery techniques are in the scope of the ADVANCE project;

- Clause (b): “steel grades and design of assembled structures to facilitate the easy recovery of steel scrap and its reversion into usable steels”; The design for deconstruction and reuse was covered by the PROGRESS project and will be disseminated.

Added value of the project

The dissemination activities in the linked research projects (PROGRESS, SB-STEEL, LVS3, ...) focused mostly on presenting the work in progress and collecting feedback from the stakeholders. The workshops and webinars were carried out in English and the dissemination materials were limited to technical presentations, reports and flyers. The added value of the ADVANCE proposal is therefore development of professionally formatted dissemination materials (such as ECCS Recommendations for Reuse, brochure, factsheets and visual presentations) in several languages. The workshops were also organized by local partners in their countries to address a wider audience and discuss the issues related to steel reuse in a local context. The ADVANCE project addressed circular economy of constructional steelwork in general, and the combined outcomes of its background projects will be disseminated together. For instance, the digital tools are on the work under LVS3 and SB-STEEL and modified with the methodology from PROGRESS project. The European standards and regulations related to constructional steel reuse only started to be developed in recent years, and therefore the outcomes of the background projects were based on the existing knowledge and national standards such as SIA 269:2011. The added value of the ADVANCE project is that it is harmonized with the revised Construction Products Regulation, new standards and technical specifications under CEN/TC135, CEN/TC250, CEN/TC350, and the 2nd generation of the Eurocodes.

Project outputs

Project outputs were communicated to the European Commission through the Deliverables (see Table 3). Public deliverables are published on the project webpage <https://www.steelconstruct.com/eu-projects/advance/project-outputs/>.

Table 3 List of deliverables

Deliverable	Reference	Type
D1.1 Comprehensive overview of the project	[1]	Sensitive report
D1.2 Final report	this document	Public report
D2.1 Report on the Circular Economy of steel-based components	[2]	Public report
D3.1 EN Recommendations for Reuse	[3] and [4]	Book (2 volumes)
D3.2 RO Recommendations for Reuse	[5] and [6]	Book (2 volumes)
D3.3 PT Recommendations for Reuse	[7] and [8]	Book (2 volumes)
D3.4 DE Recommendations for Reuse	[9] and [10]	Book (2 volumes)
D3.5 FI Recommendations for Reuse	[11] and [12]	Book (2 volumes)
D3.6 CZ Recommendations for Reuse	[13] and [14]	Book (2 volumes)
D3.7 FR Recommendations for Reuse	[15] and [16]	Book (2 volumes)
D4.1 Methodology report	[17]	Public report
D4.2 LCA mobile app	[18]	Software tool
D4.3 LCA web tool	[19]	Software tool
D5.1 Brochure (incl. translations)	[20]	Online materials
D5.2 Presentations (incl. translations)	[21]	Online materials
D6.1 Dissemination plan	[22]	Sensitive report

Project consortium

The project consortium consists of four industrial associations (ECCS, TRY, BFS and BCSA), steel manufacturer (AMBD), demolition contractor (PUR), two technical research institutes (VTT and CTICM) and four universities (UPT in Timisoara, UC in Coimbra, RWTH in Aachen and CTU in Prague). The consortium is geographically widespread over the Europe including partners from 3 widening countries (Romania, Czech Republic and Portugal).



VTT Technical Research Centre of Finland Ltd

VTT (www.vttresearch.com) is a state owned and controlled non-profit limited liability company established by law and operating under the ownership steering of the Finnish Ministry of Employment and the Economy. VTT is an RTO whose activities are focused on three areas: Knowledge intensive products and services, Smart industry and energy systems, and Solutions for natural resources and environment. All three areas will contribute to the implementation of ADVANCE project. VTT is impact-driven and takes advantage from its wide multi-technological knowledge base to strengthen Finnish and European industrial competitiveness. VTT can combine different technologies, produce information, upgrade technology knowledge, and create business intelligence and value added for its stakeholders. VTT has a staff of 2083, net turnover in 2019 was 147,2M€ and other operational incomes were 97,7M€. Over the years, VTT has gained vast experience from participation and coordination of numerous European projects including R&D Framework Programme projects and other thematic frameworks and programmes. VTT is ranked among the leading European RTOs. In December 2017, VTT has been recognised with the “*HR Excellence in Research*” award by the European Commission and the work on PROGRESS project was awarded with the prize for “*The most innovative project or service*” at Construmat building fair in Barcelona in 2019.



Universitatea
Politehnica
Timișoara

Universitatea Politehnica Timișoara, Romania

UPT (www.upt.ro) participates into the project through the Department of Steel Structures and Structural Mechanics (CMMC), with the Research Center of Mechanics of Materials and Structural Reliability (CEMSIG, www.ct.upt.ro/centre/cemsig) chaired by Prof. D. Dubina, former president of ECCS, member EB and TMB, and in TC7, TC8, TC10, TC13. The CEMSIG research team has achieved significant reputation through participating in important EU projects, such as: FP4 Copernicus RECOS, FP6 PROHITECH, FP 7 SERIES: "DUAREM"; RFCS projects i.e. PROGRESS, STEELRETRO, SB STEEL and LVS3, DIFISEK and HSS-SERF (CO), EQUALJOINTS and STEELEARTH projects; ERA-NET INSPIRE. The Research Institute of Renewable Energies (ICER, www.icer.ro), of UPT, chaired by Prof. V. Ungureanu, member of CMMC/CEMSIG and member of TC 7 and TC 14 of ECCS, will be also involved in the project for specific tasks asking competences in sustainable development.



European Convention for Constructional Steelwork

ECCS (www.steelconstruct.com) is a federation of national associations representing the steel fabrication industry in their respective countries. The aim of ECCS is to promote the use of steelwork in the construction sector by the development of standards and promotional information. It also helps to influence decision makers through the management of working committees, publications, conferences, and by active representation on European and International Committees dealing with standardization, research,

development and education. The ECCS brings together the steel producers, the fabricators and contractors organizations, and the academic world through an international network of construction representatives, steel producers, and technical centres. ECCS also includes non-European associations as International Members, professional European organizations as associate members, and representatives of upstream or downstream products or activities as Supporting Members. Its General Secretariat is located in Brussels.



University of Coimbra, Portugal

UC is a Portuguese public and autonomous higher education institution created in 1290, which promotes an active Agenda towards a carbon neutral institution. Internationalization has been one of the University of Coimbra's main concerns with special emphasis on Education and Training. UC has a dedicated unit, UC BUSINESS, responsible for Transfer of Knowledge, managing Innovation and Entrepreneurship. The work to be carried out in this project will be developed by the university's Institute for Sustainability and Innovation in Structural Engineering, ISISE (<https://www.isise.net/site/>) that involves about 240 researchers (80 PhD members and 160 PhD students). It possesses full expertise to address the seven basic requirements needed to bring building products to the market (Mechanical resistance and stability; Safety in the case of fire; Hygiene, health and the environment; Safety in use; Protection against noise; Energy economy and heat retention; Sustainability). It is well known that assessment of the environmental performance of building products can only be provided considering the building concept and use. ISISE can contribute to this vision by high-level research and development, which fosters innovation, in aspects such as the planning and design of the built environment, the structural and technical concept, and the quality achieved with the construction works.



RWTH Aachen University, Germany

RWTH, the Institute of Steel Construction (RWTH-STB) comprises a staff of about 70. The Institute covers a wide range of topics including structural aspects, energy saving, comfort conditions etc. both theoretically and experimentally and has at present 6 active working groups for structures, materials, dynamics, wind engineering, building physics and life cycle engineering. A very important research item of RWTH-STB in recent years is the investigation of the building physics performance of steel constructions and buildings with numerical and experimental methods, where RWTH-STB as leading institute in Germany in this field is involved as co-ordinator or partner in several national and European research and dissemination projects. Therefore, testing facilities e.g. a hotbox-climate-chamber, IR-camera, an airtightness test rig and the modular research building in steel equipped to test mechanical and physical properties of new lightweight steel components will be used. In addition, various equipment for in-situ measurements of physical building properties are available. Furthermore, RWTH-STB with its expert team on sustainable construction is a founding member of the German Green Building Council (DGNB) and Member of the Round Table Sustainable Building of the German Government (Federal Ministry for Transport, Building and Urban Development, BMVBS).



Teräsrakenneyhdistys
Finnish Constructional Steelwork Association

Finnish Constructional Steelwork Association

TRY (www.terasrakenneyhdistys.fi) aims to promote and develop the use of steel and other metals in construction. These targets are implemented through information distribution services and activities, by organizing training courses, seminars and events, publishing the Steel Construction journal and textbooks, providing technical advice, as well as participation in research projects and the development of regulations and standards in the field, both in Finland and within the European Union. The members of the Finnish Constructional Steelwork Association represent a wide range of the metal construction industry. In addition to companies, the Association also collaborates closely with universities and other educational institutions in Finland. Several expert groups discussing different technical aspects of steel construction are regularly brought together. In the annual main event, the Steel Construction Day, the association grants an award 'Steel Structure of the Year' to an architecturally high-quality construction project utilizing steel and other metals in an innovative manner. The office of the Finnish Constructional Steelwork Association is located in Helsinki.



Czech Technical University in Prague, Czech Republic

CTU (www.cvut.cz) has over 20000 students, with 6000 in the Faculty of Civil Engineering. The Department of Steel and Timber Structures covers buildings, industry and transport, as well as road and railway bridges. Research currently focuses on steel, timber and steel- concrete composite structures, fire design, thin-walled structures and structural connections. The Department has 14 staff and 47 PhD students. The research in sustainability focusses to reuse, new bridges, HSS and CO₂ reduction. Prof František Wald, the Head of Department, has published about 62 papers on connections, fire, aluminium structures and scaffolding, he is member of ECCS TC-10 Connections. He is involved in working group for EN1993-1-8:2020, takes care of Erasmus Mundus Master Programme Sustainable constructions under natural hazards and catastrophic events, and chaired COST action TU0904 Integrated Fire Engineering and Response. He is involved in research projects on connections and fire design, and coordinates nine European and twenty-seven national projects.



Industrial Technical Centre of Metal Construction CTICM, France

CTICM (www.cticm.com) is a research institute for constructional steelwork industry in France, with about 60 employees, the vast majority of whom are engineers and doctors. Established in 1962, these main activities combine study services and extensive and applied research and deal with structural aspects and corrosion, fire safety, thermal behaviour and sustainability. It is also the founder of the Carnot MECD Institute which aims to develop innovative construction processes based on hybrid components and mix of materials. With several engineers who are members of ECCS technical committees (TC9, TC13, TC14) and European standardization committees and working groups, the CTICM research teams have taken part in many European research and development projects, including Inprest, Prossus, Tabasco, Robust, Equaljoints +, LVS3 and provides long life learning and technical publications. For ten years CTICM has been developing a strong competence in the field of the life cycle of products and buildings and is involved in several national projects on circular economy, as well as definition of the next French environmental

regulation. CTICM's role in the project is to share information and adapt processes from project PROGRESS and contribute to the dissemination of the results to the French speaking professionals, in order to promote the reuse of metal components in construction.



Purkupiha Group Oy, Finland

PUR is a leading Finnish demolition company for buildings and industry. Demolition of entire buildings and industrial plants is only part of the company's actions. Purkupiha is also a pioneering company in dismantling and reuse of used construction parts, especially steel structures. Purkupiha has proven record of several deconstruction cases and the company has developed reuse working methods to remove suitable products from the structure in high quality, has knowledge on evaluation and traceability of building parts and documentation. Company has created a public digital sales platform to support visibility and discoverability of reusable construction parts and to support reuse in construction sites www.purkutori.fi. In several different dismantling sites, the validity of the reusable steel products and solutions is demonstrated in practice and the company has gained expertise in reuse of construction parts. In 2022, Purkupiha was awarded with the prestigious "Demolition of the year" prize for the innovative approach to decommissioning and reuse of steel hall.

The company has three business units 1/ heavy demolition 2/ hazardous substances removal and 3/ recycling. It has four recycling sites and performs also renovation demolition and asbestos removal and other demolitions carried out by means of deconstruction with expertise. Measured by turnover from demolitions, Purkupiha is one of the largest demolition companies in Finland. Purkupiha's is certified with the ISO 9001:2015 quality certificate, the ISO 14001:2015 environmental certificate and the ISO 45001:2018 occupational health and safety certificate. Certified operations apply to both heavy demolition, hazardous materials removal and recycling units. Company has its own production, quality control and sale of Demorock® crushed concrete at demolition sites and recycling plants. The Construction Quality Association has granted Purkupiha RALA qualification, which includes demanding demolitions, ordinary demolitions and demolitions involving hazardous materials. We are also a member of the Reliable Partner register approved and supervised by Suomen Tilaajavastuu Oy.



The British Constructional Steelwork Association Ltd, United Kingdom

BCSA is the UK national organisation for the steel construction industry: its member companies undertake the design, fabrication and erection of steelwork for all forms of construction in building and civil engineering. Industry members are those principal companies involved in the direct supply to all or some members of components, materials or products. Corporate members are clients, main contractors, professional offices, educational establishments etc., which support the development of national specifications, quality, fabrication and erection techniques, overall industry efficiency and good practice. Through this network of members, the BCSA has close links with all parts of steelwork design, supply chain, and fabrication. The personnel involved will include Dr. Michael Sansom, Sustainability Manager, and Dr. Ana M. Girão Coelho, Director of Engineering, who have experience in steel reuse.



Bauforumstahl e.V., Germany

BFS is the leading association for building with steel in Germany. Together with the German Steel Construction Association DSTV, it represents the concerns of its members in politics, the professional world, the media and the public, offers knowledge transfer and is involved in research and standardization. The overarching goal is to promote steel construction, taking into account holistic aspects such as economy, safety, flexibility and sustainability. The approximately 350 members include all well-known German steel construction companies, upstream suppliers and subsequent trades, architectural and engineering offices as well as colleges and universities. Core services are specialist advice on application issues in steel construction, support and influence on standardization and technical rules as well as application research and development for steel construction, promotion of young talent through knowledge transfer at universities, information on current market developments and a wide range of specialist event.



ArcelorMittal

ArcelorMittal Belval & Differdange S.A. (AMBD) is part of the ArcelorMittal Group, the world's largest steel producer. It is represented by the Research and Development Centre for Long Products located in Esch/Alzette, Luxembourg. ArcelorMittal is the main hot-rolled profile producer for the European construction market. The company actively supports sustainable developments, decarbonization activities through low-carbon production, steel reuse and recycling. The R&D centre in Esch supports the plants producing hot-rolled long products of Belval and Differdange in Luxembourg, Bergara, Olaberria in Spain, Dabrowa in Poland, etc. It has been working for decades with universities, research centres, steel producers, and customers all over Europe, and is strongly represented in the F6 committee "Steel Structures" of ECSC, highly involved in the TGS8 committee of RFCS, and active in standardization activities in CEN/TC250, CEN/TC350, CEN/TC135, and other technical committees of ECCS such as TC9, TC11, and TC14. It is primarily engaged in: a) developing new applications, products, and technical solutions to enhance the use of steel in construction; b) creating user-friendly software for pre-design tailored to engineering offices and architects; c) modifying international codes to facilitate the use of steel; and d) disseminating knowledge through real-building applications in collaboration with engineering offices and architects. AMBD has been involved in projects SB STEEL, LVS3, ESE, along with other RFCS projects such as SECHALO, FS+, COSIMB, ADBLAST, ROBUSTIMPACT, DISCCO, SMARTCOCO, EUROBUILD+, PRECO+, PrECo-Beam, LWO+, INPREST, FICEB, ROBUSTFIRE, LOCAFI+, SECHALO, ROBUSTNESS, TRAFIR, SLIMAPP, DREAMERS, FAILNOMORE, etc.

Final summary

The main goal of ADVANCE project, funded by the European Commission's Research Fund for Coal and Steel (RFCS) programme was to enhance the circular economy of constructional steel products by promoting their reuse and reducing greenhouse gas emissions. The project aimed to increase the awareness about recovery and reuse of constructional steelwork, which was achieved by providing engineers, investors, contractors, and other decision-makers with reliable performance data, tools and guidance. The project focused on both existing and future buildings, addressing the reuse of constituent products, fabricated components, and component assemblies.

Key activities in the ADVANCE project included update of existing methodologies, protocols, and tools to facilitate the reuse of steel components and their harmonization with the new standards and European legislation. The project built upon the outcomes of previous projects such as PROGRESS, SB STEEL, LVS3 and REDUCE and extended their scope to cover a wider range of constructional steel products. The project also updated recommendations for the reuse of steel products and software tools. The ADVANCE project outcomes were translated into several languages to ensure wide dissemination. Dissemination and communication activities were a significant part of the project, with workshops, presentations, and publications aimed at raising awareness about the benefits of steel reuse.

The ADVANCE project successfully demonstrated the potential for steel reuse to contribute to a circular economy, reduce environmental impacts, and create economic opportunities. The project's outcomes provide a solid foundation for future research and development in the field of constructional steel reuse.

1. Circular economy of steel and steel-based components

1.1 State-of-the art of steel component reuse

Circular economy is a rapidly developing area with the ambition to mitigate negative impacts of climate change and scarcity of natural resources. Construction sector plays an essential role in the implementation of circular economy principle because it is responsible for a large share of carbon emissions and waste. Although reuse of constructional steel components seems to be a very small part of the circular construction, its importance reaches far beyond the direct environmental impact of the currently reused elements because of the following reasons:

- Constructional steel is becoming the first building material with the fully developed set of European technical standards supporting its deconstruction and reuse. Reuse concept will be implemented in the execution standards and the Eurocodes, and the Product Category Rules (PCR) for the steel components are under development. The whole process is then supported by many industry guides and national standards, especially in material qualification and environmental assessment; many of those existing documents being already implemented by the industries.
- Deconstruction and reuse of construction products from other materials largely depends on steel-based solutions. Bolted and clamped connections made of steel are used to join prefabricated concrete and timber elements to enable easy and efficient separation at the building's end-of-life.
- According to the numerous case studies and interviews conducted in the previous projects, it is obvious that reuse of constructional steel elements can be profitable and desirable solution in a wide range of situations. We have carefully mapped and categorized successful case studies and highlighted the main reasons, benefits and bottlenecks during their execution.
- Structural steel has highly developed and efficient distribution and collection chain across the Europe. Almost 100% of the end-of-life steel scrap is recovered and recycled, and therefore the adaptation to cover collection and re-distribution of reusable building elements will be easier than in the case of other materials without similar infrastructure.
- Reused constructional steel components can serve well in the changing environment during the following decades and centuries. They are suitable for the modern construction and inspection techniques and the reused material itself does not need any alterations or modifications to reach the demanding sustainability targets.

1.1.1 Reuse of existing steel

Pre-deconstruction audits

Pre-deconstruction audits are structured assessments conducted before demolition or renovation to identify materials, including hazardous substances, and to optimize reuse and recycling in construction projects. These audits aim to enhance material recovery while ensuring safety and compliance with regulations. They are initiated by building owners to document materials and provide recommendations for demolition or renovation and generally performed by qualified experts and

include hazardous waste identification. Related to the constructional steel reuse, we would like to highlight the following examples:

- **European guidelines** [1]: Guidelines provide best practices for waste stream assessment to maximize material recovery and reuse without compromising safety.
- **Guidelines in EU Member States** [24]: Voluntary or compulsory rules for pre-demolition audits that support the national waste management plans and EU's target of 70% material utilization by mapping materials and hazardous substances.
- **Material or product specific instructions** [25]: PROGRESS project developed a specific audit protocol for single-storey steel buildings, emphasizing waste prevention and reuse per EU directives.

Deconstruction

The new EU Construction & Demolition Waste Management Protocol [26] focuses on improving waste separation and recycling quality, while the PROGRESS Deconstruction Protocol [25] provides specific guidance to ensure safe reclamation and reuse of structural steel elements by treating deconstruction as a careful reversal of erection with added precautions.

Selection, acceptance criteria and design considerations

The effective reuse of steel structural elements involves selecting, assessing, and designing to ensure safety and performance. Various standards and guidelines analysed in Deliverable D2.1 [2] provide frameworks for this process, for instance:

- **European standards and specifications** like CEN/TS 17440 [27] establish bases for assessment and retrofitting together with the initiative of CEN/250 SC3 to develop Eurocode 3 design rules for reused steel components.
- **National standards and specifications** such as the Swiss Code SIA 269/3 [28] focus on extending the service life of constructional steel, applicable to heritage structures and reclaimed components.
- **Guides and industry protocols** (e.g. CTICM guide [29]) offer detailed methodologies for auditing, assessing, testing, and requalifying steel elements.

Qualification of reclaimed steel and testing

Standards and protocols for testing and qualifying reclaimed structural steel are essential for ensuring its safe reuse in construction. Various national and international guidelines provide detailed methodologies for inspection, material testing, certification, and re-certification of reclaimed steel, focusing on maintaining material integrity and compliance with regulatory requirements. For example:

- **European standards and specifications** are being developed or were recently published such as CEN/TS 1090-201[30] that supplements EN 1090-2 [31] by providing specific guidance on material testing for constituent products, consistent with PROGRESS methodology [32].
- **European recommendations** for single-storey buildings [33] cover steel products made after 1970 excluding damaged or complex members, aligning testing procedures with SCI

P427 [34] and PROGRESS protocols [32], and supports CE marking under EN 1090-2 [31] for re-certified steelwork.

- **National guidelines and specifications** such as Norwegian Steel Association testing procedures [35], UK Steel Construction Institute protocol [34] and supplement [36], Swedish MVR guidance [37], Finnish FCSA guide [38] and Dutch NTA 8713 specification [39] provide more specific rules and recommendations for the qualification of reclaimed steel.

Labelling and certification of reusable constructional steel

The standards and regulations for assessing, marking, and certification of constructional steel to ensure safety, quality, and traceability are important part of the circular economy spanning from the historical practices in post-war Germany, where steel from demolished buildings was classified and labelled for reuse until the modern harmonized European standard (such as EN 1090-2 [31]) to outline technical requirements for reused steel and to comply with the European Construction Products Regulation [40].

1.1.2 Design for future reuse

While reusing of existing steel components is already becoming firmly embedded in the standards and regulations, a systemic approach to design for future reuse is still mainly a domain of research activities [41]. It is, however, essential to enhance sustainability in construction as it involves creating buildings that are easy to dismantle with modular, clearly separable components and using durable, recyclable materials to extend service life and adaptability. Several recommendations specifically targeting constructional steel reuse were published recently [33][42].

1.1.3 Sustainability assessment

Life Cycle Assessment (LCA)

ADVANCE project provides an overview of methodologies used to assess the environmental impacts and benefits of reusing steel components in construction, highlighting the complexities and standards involved in lifecycle assessments.

- **International (ISO) standards and specifications:** LCA following ISO 14044 [43] is the common method to assess these impacts at product or end-of-life stages. It does not specifically address reusing steel components or structures but provides a basis for the development of more detailed specifications.
- **European standards and specifications:** EN 15804+A2 [44] introduces Module D for calculating loads and benefits of the product system beyond its system boundaries for multiple reuse and recycling operations. This calculation is then further specified according to complementary Product Category Rules for steel in EN 17662 [45] and projected to the building-level assessment according to EN 15897 [46].
- **Other methodologies:** Several assessment methods based on the LCA principles were developed in parallel to the European standards. The Product Environmental Footprint (PEF) methodology [47] accounts for multiple recycling options and benefits of steel reuse but aggregates future reuse benefits with current lifecycle impacts, making distinctions difficult. The World Steel Association's methodology [48] uses a complex system with closed-loop

allocation for recycled steel benefits and open-loop reuse. PROGRESS project methodology [49] provided connection between EN 15804 [44] and PEF [47] and ADVANCE methodology [17] expanded this connection to the World Steel Association methodology [48].

Circularity assessment

Various frameworks and methodologies have been developed to assess and enhance circularity in construction, enabling reuse, repair, and recycling of materials to minimize environmental impact and resource consumption.

- **European Level(s) framework** [50] provides core sustainability and circularity indicators including allocation of lifespans to building elements, waste management plans, design for adaptability, and design for deconstruction to support reuse and recycling in steel constructions.
- **BRE design for deconstruction methodology** [51] assesses deconstruction potential of residential and similar buildings via criteria including reuse potential, connections, accessibility, and process, weighted by embodied CO₂ or component mass for steel structures.
- **PROGRESS reusability index** [52] offers a technical and economic scoring system for assessing constructional steel reusability, adaptable by mass and expert evaluation, with potential extension to multi-material components using environmental criteria.
- **Material Circularity Indicator (MCI)** [53] measures product circularity on a scale from 0 (linear) to 1 (fully circular), focusing on material circulation without assessing material type or other impacts, and supports design decisions to improve circularity.
- **Buildings As Material Banks (BAMB)** [54] promote maximizing residual value in buildings by designing for disassembly and reuse, supported by material passports detailing product features and reuse potential to underpin whole-building circularity.

Sustainability certification schemes

Sustainability certification schemes play a crucial role in promoting environmentally responsible construction practices worldwide. These schemes assess and rate buildings based on various sustainability criteria, encouraging reuse, recycling, and resource efficiency to minimize environmental impact. They are developed nationally, but several are used worldwide.

- **BREEAM** [51] promotes reuse and resource efficiency and incentivizes the reuse of building components by minimizing waste and reducing impacts from new material production, while providing guidance on sustainable refurbishment.
- **LEED** [55] encourages material reuse and innovation and rewards projects that reuse materials, preserve existing structures, and use recycled content, also recognizing innovative sustainability strategies beyond standard credits.
- **DGNB** [56] has several criteria catalogues for assessing the sustainability of buildings. The DGNB Criteria for New Buildings and the DGNB Criteria for Deconstruction are of interest for deconstruction.
- **Green Star and CASBEE** [57][58] also support sustainable materials. Green Star prioritizes reuse over recycling and awards points for certified sustainable products, while CASBEE

inherently values reducing life-cycle resource use, including component reuse, though it may vary by implementation.

- **Other regional schemes** also emphasize life cycle and quality. For example, Nordic Swan Ecolabel [59] applies strict life-cycle criteria for construction products and recently updated repair and renovation standards and SBToolCZ [60] offers national framework for sustainable building assessment and certification, aiming for widespread adoption and quality improvement.

1.1.4 Case studies

Over 45 case studies with constructional steel reuse were collected from the previous projects, experiences and networks of the partners and analysed in ADVANCE project [2]. Several of them were reported in more detail as factsheets [61]. The case studies were categorised as

- **Relocation of industrial halls and warehouses** is the most common way to utilize the durability of the structural steel in the relatively short-lived buildings. The structural systems span from dismantlable temporary structures to traditional industrial halls and warehouses. We focused on the cases that were not initially intended to be disassembled and reused.
- **Relocation and conversion of old hangars** is similar to relocation of industrial halls and warehouses but may require small modifications of these post-war structures.
- **Reuse of other buildings and engineering structures** covers market halls, tribunes and other structures relatively easy to dismantle.
- **Partial reuse of the primary structure** focuses on recovering only the primary structure or its part.
- **Reuse of cladding and secondary structure** is sometimes performed separately while the primary structure stays or is demolished and recycled.
- **Reuse of constituent products in multistorey buildings** is a common practice in countries (such as UK) where the welded structural systems are limiting structural steel reuse to cutting and reclaiming individual sections.
- **Reuse of constituent products in other projects** covers sports facilities, transportation and other buildings.
- **Conversion of primary structure into a multistorey building** is a typical in-situ reuse and reutilization of old industrial building complexes.
- **Changing the general purpose of the building** keeps most of the structural components reused in place but may require adjustments and strengthening due to different loads.
- **Major refurbishments are another in-situ reuse category** when the structure retains its original purpose.
- **Buildings designed for reuse** are typically new projects with the specific design requirements to be deconstructed and reassembled in the future.
- **Unsuccessful reuse cases** cover projects that were not finalized due to the technical or economic difficulties. They provide a source of invaluable information for the future development of targeted recommendations and technical guidance.

1.2 Business models

This section provides an overview of European initiatives and business models promoting circular economy principles in the construction and housing sectors. It highlights challenges, innovations, and economic impacts associated with transitioning from linear to circular building practices.

1.2.1 Buildings as material banks (BAMB)

BAMB represents an EU research initiative comprising 15 partners from seven European countries. Their collective goal is to catalyse a transformative shift in the building sector by championing circular solutions. The dynamics of value creation and distribution within society are evolving, diverging from conventional linear value chain frameworks. Unlike traditional models, which rely on cost-plus value calculations, emerging ecosystem-based models prioritize the 'willingness' to pay for participation in the value network.

Contrary to the rigidity of traditional value chains, circular ecosystems demonstrate heightened flexibility among individual players and the group. The flows within these ecosystems are multidirectional across various dimensions, fostering intensified collaboration and information sharing. Moreover, the complexity of value creation in these ecosystems is more group-oriented, allowing for a more proportional allocation of value to all participants. This shift is attributed to increased data availability and transparency within the system. A major obstacle to the introduction of circular economy practices in the construction industry is the lack of high-quality shared information. Professionals, including designers, builders, and recyclers, often face limited access to crucial product specifications, conditions, and availability information. This information gap substantially restricts the potential for reuse at different levels. The evolving landscape necessitates new methods of collaboration and data sharing among stakeholders. While existing approaches and technologies focus on integrating building models through data, such as Building Information Modelling/Management (BIM), they do not adequately address the information gap concerning the current building stock. BIM systems, while powerful, remain complex and are primarily accessed by experts for data management and extraction. Many roles in the construction industry still lack specialized knowledge in utilizing these intricate information systems. Despite this, the application of BIM in new builds, extensive renovation projects, and facility management is on the rise.

Existing methodologies and technologies primarily concentrate on incorporating building models stored in data, such as Building Information Modelling/Management (BIM), to establish foundational information. However, they have yet to effectively address the information gap associated with the current building stock. Additionally, BIM systems, known for their complexity, are predominantly utilized by experts for data management, reworking, and extraction, leaving many professionals in the construction industry without specialized knowledge of these intricate systems. Nevertheless, the utilization of BIM is on the rise in new construction and extensive renovation projects, extending to applications in facility management and maintenance.

Several key drivers are poised to foster the adoption of circular building practices within the European Union, including:

- Urbanization
- Legislative measures
- Resource scarcity
- Land constraints
- Transition to modular construction
- Challenges in a tightly margined industry
- Emphasis on Corporate Social Responsibility
- Advancements in Recycling Technology
- Optimization of construction processes (utilizing technologies like BIM)
- Enhanced Asset Lifecycle Management.

These factors collectively contribute to the momentum of circular building practices, reflecting a broader shift toward sustainable and efficient construction processes in the European context.

1.2.2 ReLondon (Former: The London Waste and Recycling Board (LWARB))

ReLondon emerged as the rebranded identity of The London Waste and Recycling Board (LWARB), reflecting a strategic move to underscore their dedication to fostering a sustainable and resource-efficient urban environment. This transformation aimed to signal a broader commitment to shaping London into a city that prioritizes environmental responsibility. In essence, ReLondon seamlessly carried forward the ongoing initiatives spearheaded by LWARB, placing heightened emphasis on comprehensive waste reduction strategies, advancing recycling efforts, and championing the principles of a circular economy within the metropolitan landscape. Through this evolution, ReLondon continued to serve as a pivotal force in driving positive environmental change and promoting sustainable practices across London's waste management and recycling sectors.

The built environment, given its expansive scope and scale, presents an ideal platform for the integration of circular economy practices, enabling the sector to spearhead transformative shifts in construction methods and building utilization not only in London but also throughout the UK and globally. London's dynamic pace of change provides a unique opportunity to embrace circular economy principles early on, reaping benefits swiftly. Current projections estimate that circular economy initiatives within the built environment could contribute an annual boost of £3 – 5 billion to GDP by 2036, encompassing advantages realized locally in London and those associated with activities originating in the city.

Key areas of impact include:

- **Innovation in Modular Construction:** Implementation of modular construction techniques and forward-thinking approaches like widespread adoption of 3D printing and additive manufacturing can significantly reduce structural waste and construction time, resulting in an annual benefit exceeding £800 million.
- **Optimized Building Utilization:** Practices such as peer-to-peer renting, enhanced urban planning, office sharing, and repurposing buildings contribute to increased value for new

constructions in London. Doubling the utilization of 20% of buildings by 2036 could lead to annual savings surpassing £600 million.

- **Effective Building Disassembly and Material Management:** Designing buildings for efficient disassembly, coupled with strategic material management through high-value closed loops, material passports, innovative business models, and reverse logistics ecosystems, has the potential to save over £200 million.

The adoption of circular economy principles in London's built environment not only results in direct cost savings but also opens up new opportunities across interconnected facets. These opportunities span areas such as land restoration programs, adherence to design principles (e.g., energy-neutral buildings), exploration of new materials, collaborative equipment and parking space sharing, and integration of information and communication technologies. In essence, the circular economy not only benefits from but also actively contributes to reshaping the overall economy.

1.2.3 EU circular economy in construction research

Cinderella - New Circular Economy Business Model for More Sustainable Urban Construction

The EU-28 total waste generation in 2014 was 2598M tones, the highest since 2004, 33.5% of which was from the construction sector, being also one of the larger consumers of inorganic raw materials. Construction activities are mainly localized in urban areas where by 2050 about 86% of the developed world is expected to live. CINDERELLA project aims to develop a new Circular Economy Business Model (CEBM) for use of secondary raw materials (SRM) in urban areas, connecting different industries, the construction sector and municipal services, decision makers and the general public with the support of CinderOSS, a “One-Stop-Shop” service, articulated in (i) an on-line ICT platform for tracking and modelling the urban waste-to-product flows, on-line marketing and sharing knowledge and information along the value chain (ii) production and marketing of (SRM) based construction products and (iii) building with SRM based construction products supported by building information modelling (BIM). Different streams of waste will be exploited in the project, i.e. construction and demolition waste, industrial wastes, heavy fraction from municipal solid waste and sewage sludge, mostly of them currently landfilled and/or incinerated. Their suitability for use for building materials will be demonstrated through large scale demonstration activities in Slovenia, Croatia and Spain while the ICT platform will be demonstrated in Slovenia, Croatia, Spain, Poland, Italy and The Netherlands. The project will contribute to 20% reduction of environmental impacts along the value and supply chain, reducing virgin material exploitation and converting wastes to products. Sustainability of CEBM will be proven with the environmental, economic and social assessment through whole life (LCA, LCC and S-LCA). The pre-feasibility analysis of the proposed CEBM indicates an increase of recycling by 30% of CDW, 13% of industrial waste, 100% of heavy fraction and 25% of sewage sludge with a net profit of 18%.

The Project provides deliverables as a result of the project regarding the following topics:

- **Policy Recommendations:** This deliverable is connected with Task 8.2 Exploitation of project results Based on implemented pilot demonstrations stakeholders interaction and other activities project consortium will give several propositions of policy legislation and administrative development on local regional national and EU levels which will be communicated with policy and decision-making stakeholders This will includes proposal for

new GPP procurements guidelines explanatory documents on construction products legislation and End-of-Waste protocols use of SRM-based products in other fields e.g. agriculture and others. All recommendations and results on communication with relevant stakeholders' ministries regional and local governments will be recorded in report.

- **End of waste criteria protocol for recycled waste used as aggregates:** This deliverable is connected with Task 5.2 (Preparing End-of-Waste criteria based on the intended use of recycled waste). It will define a proposal of harmonized approach for End-of-Waste protocol (including lab and field tests, parameters to be assessed, limit values, etc.), which will be based on already existing normative/regulation, the involved stakeholders' requirements, and main outputs from the different related tasks of the project.
- **Final Report including "Sustainability Footprint Declarations" and Policy Recommendations Paper:** This deliverable is connected with Task 7.4 Development of decision making criteria and positioning of the CinderCEBM according to the SDGs. It will include Catalogue of Sustainability Footprints of the new materials together with a list of sustainability criteria that should be considered in procurement public and private of SRM based constructions and guidance on how to use them.
- **Protocols for the implementation of encouraging practices:** Based on evaluated and demonstrated pilots in different environments technical as well as economical this document will gather protocols how to transfer optimized CinderCEBM in different environments in Europe.
- **Environmental LCA assessment report for each pilot demonstration:** This deliverable is connected with Task 7.1 Environmental assessment and LCA during all phases of the project from materials to demonstrations value chains. It will be in the form of a report for the LCA studies applied to each pilot case performed in WP6.
- **LCA, LCC and S-LCA methodology report:** This deliverable relates to Task 7.2 (Socio-economic assessment, including LCC and S-LCA) but will follow up the framework set in Task 7.1 (Environmental assessment and LCA during all phases of the project (from materials to demonstrations, value chains)). The report will describe the methodology that will be applied to assess all the aspects of sustainability in the project: environmental (by means of LCA techniques), economic (by means of LCC techniques) and social (by means of a S-LCA approach).
- **Blueprint for a resource-efficient secondary raw material based urban and peri-urban construction sector:** This deliverable is connected with Task 3.4 (Setting up a new framework for SRM based urban and peri-urban construction). The blueprint will include the study of needs, conditions, potentials, and obstacles (technological, legislative, administrative, socio-economic, and environmental) across Europe for implementation of SRM in urban construction sector. Report will be prepared based on literature survey and stakeholders' interactions, including initial conference / workshop carried out in WP8.
- **Report on the valorisation of existing end-of-life scenarios and alternative value chain:** This deliverable is linked with Task 3.3 (Value chain assessment and assessment of actors along the value and supply chains). Report will be prepared on evaluation of the potential new value chains as well as existing (waste to landfill/incineration) that connect multiple sectors within urban and peri-urban areas. This deliverable is important for follow up activities in Task 3.4 and beyond.

- **Flow maps and data based for selected urban areas:** This deliverable is connected with Task 3.1 (Flow map of urban and peri-urban areas). It will provide the urban metabolism analyses of the studied regions, i.e. Maribor region (Slovenia), selected county in Croatia, Madrid (Spain), Trento (Italy), Amsterdam (The Netherlands) and Silesia region (Poland).
- **Report on impact of disruptive construction technologies on CinderCEBM:** This deliverable relates to Task 4.3 CinderCEBM optimisation more specifically subtask 4.3.2. It will include benchmark study on beyond state of art innovativeness of waste to resource solutions as well as further development of circular business ecosystem thinking methodology and innovative circular business ecosystem in connection with new emerging technologies in construction sectors such as additive manufacturing 3D printing advanced robotics and peopleless construction prefabrication and modular construction and others.

HOUSEFUL Innovation circular solutions and services for new business opportunities in the EU housing sector

The housing sector is a major contributor to current global problems of resource depletion and climate change, representing one of the most important consuming sectors at EU level: 50% of all extracted materials, 40% of final energy consumption, 33% of water consumption and 33% of all produced waste. The lock-in to the linear business models of today is causing many environmental problems and is one of the major barriers in transition towards a circular economy. HOUSEFUL project proposes an innovative paradigm shift towards a circular economy for the housing sector by demonstrating the feasibility of an integrated systemic service composed of 11 circular solutions. HOUSEFUL will introduce solutions to become more resource efficient throughout the lifecycle of a building, taking into account an integrated circular approach where energy, materials, waste and water aspects are considered. This approach fosters new forms of co-creation, increasing the collaboration among stakeholders of the housing value chain to develop new circular solutions and services. HOUSEFUL concept will be large scale demonstrated at 4 demo-sites in Austria and Spain, adapting the concept to different scenarios, including in social housing buildings. HOUSEFUL solutions will be evaluated from an environmental (Life Cycle Assessment), economic (Life Cycle Cost) and social (Social Assessment) point of view. The results obtained will be used to define an integrated HOUSEFUL service which will be driven and promoted through a SaaS (Software as a Service). The SaaS will integrate a Circularity Tool to quantify the circularity level of buildings and will include different circular solutions to be offered as services, encouraging the housing value chain to redesign traditional business models towards circular ones. 10 EU Follower buildings will be engaged with the support of a Collaborative Community of Housing Experts to replicate HOUSEFUL results and maximise the impact of the project. The results are documented in 20 deliverables regarding among others the following topics:

- Social conditions for the co-creation of all HOUSEFUL services and co-created materials
- Social perceptions and beliefs in circular economy at building scale (version I)
- Report on end-users' requirements and CEBO on residential buildings
- Social assessment
- Existing market circularity solutions and product

1.2.4 Hire or leasing of Products

In this business model, the products, which can be buildings or construction components, are leased rather than sold. Leasing of buildings is common practice throughout the property sector. Generally, rented buildings are permanent structures however, there are many examples of companies that lease temporary, relocatable buildings. These include temporary events structures and seating, temporary office, education, industrial and medical buildings, etc. Most of these buildings are of a modular form and the structural steel used is most often cold-rolled, hot-dipped galvanised coil sections. Benefits of temporary, relocatable buildings include:

- No capital outlay
- Generally, no maintenance costs
- Flexible terms i.e. can be hired over different timeframes according to the users' requirements.

At the product level, there are many existing examples of temporary works, steel products that are commonly hired. These include:

- Piles, particularly sheet piles
- Road plates
- Scaffolding
- Props and formwork.

Steel props vary from large, generally tubular sections used in large construction projects to more domestic scale props.

When constructing cofferdams, shoring, support structures and large infrastructure projects like railroads, road construction, and excavations, many alternate construction methods exist to retain soil or water, whether temporary or permanent. Steel sheet piles are particularly well-suited because they are relatively light and easy to handle, can be supplied in long lengths, can be extended or cut, easy to retrieve after use, and can be reused several times.

ArcelorMittal has implemented a rental and buy-back business model; new and used steel products such as steel sheet piles, tubes, etc. can be rented or purchased with a buy-back contract. Steel sheet piles can be used up to 10 times with proper handling and repair. With a buy-back option for purchase, after the execution of a project (temporary applications), customers can either choose to keep the sheet piles for reuse in other projects or sell them as second-hand or return them to ArcelorMittal at a price negotiated before the sale, provided the piles are in good shape. Upon return of the buy-back, the sheet piles are either sold as second-hand for reuse or added to the stocks for rental. Reused sheet piles are inspected, jet-washed, and trimmed and can be re-used several times in temporary applications or applied in permanent applications. At the end of life, sheet piles are recycled for new products.

ArcelorMittal has been continuously improving the steel sheet pile range by more sophisticated steel grades and optimizing the shape's geometry, which enable lighter, wider, more resistant steel sheet pile solutions. ArcelorMittal's stock and service facilities in France, Germany, and the UK stock a wide range and large quantity of sheet piles for fast supply for both sales and rental, and offer services such as interlock sealant application, drilling, cutting, welding, pairing, etc. Additionally,

upon the return of rental or buy-back, the service centre also takes care of cleaning, reconditioning, grinding if necessary, and repair welding. ArcelorMittal begun transitioning its sheet pile rental stocks to the EcoSheetPile™ Plus range, produced in Luxembourg from ca. 100% scrap through the electric arc furnace route with a guaranteed 100% renewable electricity supply, which further reduces the environmental impact.

The added value of reusing steel sheet piles is that:

- The buy-back & rental business model contributes to a circular economy: higher up in the waste hierarchy, it switches volumes from new production or from recycling into reuse; thus, reduces the environmental impact.
- The physical inventories at construction companies are reduced – these are now held by the rental business rather than the construction companies and can be put to much more intensive use. Storage on the project site is also minimized.
- Better soil and land quality – as steel sheet piles are completely removed from the ground when they are no longer needed.
- Logistics: ensuring a fast response & delivery to the construction site.

The main challenges regarding the rental business are related to:

- Financial: working capital required for ensuring that a large variety of sections is readily available from stock to satisfy customer demand.
- Technical: when piles are returned damaged, they must be repaired or sent for premature recycling. Traceability, sorting, cleaning, and ensuring that the material is fit-for-purpose requires a team of professionals.
- Regulatory: lacking incentives to support the rental business model by recognition of environmental performance, e.g., in Green Public Procurement.

1.2.5 Product as a service or servitisation

Servitisation is the innovation of an organisation's capabilities and processes in order to create value by shifting from selling products to selling product-service systems. A product-service system is an integrated product and service offering that provides added value when used. It should be noted that most servitisation has been developed primarily in the manufacturing industry.

The idea of the "service economy", developed by Walter Stahel in the 1970s, focuses on the importance of selling services rather than products. This method allows manufacturers to retain greater control over the products they produce and the energy and materials they contain, enabling better maintenance, recycling and recovery. Customers also benefit, as they only pay for the service they need and use, and often receive a better service as the manufacturer has a greater interest in delivering a long-lasting product.

Product-as-a-Service (PaaS) is a business model that allows customers to purchase a desired outcome rather than the equipment that delivers that outcome. In the context of construction, where the end-product is a physical building that must safely withstand forces, provide a comfortable and safe indoor environment, etc., it is not immediately obvious how these functions could be servitised. In contrast, building management is a good example of servitisation that is relevant to the property sector and has been around for a long time.

The product as a service is comparable to a rental or leasing model but is based on a service rather than a product. For example, the structural support for a building over a period of time or the provision of a safe, watertight and thermally efficient envelope for a building over a period of time.

The challenges associated with servitisation business models include

- Understanding what value means for customers and consumers (not producers and suppliers)
- Developing the ability to design and deliver services rather than products
- Developing a service culture
- Embedding all these aspects into a service organisation.

1.2.6 Take back/buy-back model

A take-back scheme is an initiative, usually set up by a manufacturer or industry, to collect used products or materials from consumers (usually at the end of a product's life) and return them to the original processing and manufacturing cycle. A buy-back scheme is the same as a take-back scheme, except that the manufacturer pays the consumer to return the product.

Take-back schemes are increasingly being introduced in many sectors to improve waste management and resource efficiency. This is most prevalent in the retail sector and for electrical and electronic equipment (and batteries) under the WEEE Directive. More recently, take-back schemes for plastic waste have been introduced in response to the increasing problems associated with discarded plastic waste. Companies appear to be increasingly recognising the public relations benefits of take-back and buy-back schemes. Examples of take-back schemes in the construction industry are less common, but there are some examples in the UK and Europe, including:

- Steel sheet piles
- Rockwool offer a recycling scheme where they accept uncontaminated, packaged Rockwool stone wool insulation for recycling at their manufacturing facility.
- Plasterboard manufacturers offer recycling programmes, but these are limited to new build waste and offcuts from new products, i.e. they do not include demolition waste.
- Insus: buy back system for polyurethane core material for sandwich panels

It should be noted that the few construction-specific schemes that have been identified relate only to construction and not demolition waste. One exception is the Europe-wide PVC recycling initiative Reconvinyl, which covers both construction and demolition waste streams. Another example from the UK is Armstrong Ceiling Tiles, which takes back (for recycling) mineral fibre, glass wool and rock wool ceiling tiles manufactured after the year 2000. Steel products have the advantage over many competing non-metallic building products in that their scrap value has always been high enough to ensure that steel is recovered from construction and demolition waste streams for recycling. This has meant that steel manufacturers have not been obliged (or have chosen voluntarily) to introduce take-back schemes to improve recovery and recycling rates. One exception is the deposit systems for drinks packaging, which include steel cans. Some manufacturers of construction products have introduced take-back schemes, but these are currently limited to buying back waste generated during the construction phase and not demolition waste at the end of its life. Again, it is the longevity of construction products that limits the feasibility of take-back/buy-back programmes to construction

rather than demolition waste streams. Extended Producer Responsibility (EPR) is a policy concept whereby producers are made significantly responsible - financially and/or physically - for the treatment or disposal of post-consumer products. Assigning such responsibility can, in principle, incentivise the prevention of waste at source, promote environmentally sound product design and support the achievement of public objectives in the areas of recycling and materials management. In the European Union, extended producer responsibility is mandatory under the WEEE, Batteries and ELV Directives, which make producers responsible for financing the collection, recycling and responsible disposal of waste electrical and electronic equipment, batteries, accumulators and vehicles. The Packaging Directive also indirectly refers to the EPR principle by requiring Member States (MS) to take the necessary measures to ensure that systems are set up for the collection and recycling of packaging waste. Other waste streams for which producer responsibility organisations have been identified most frequently in the European Union include tyres, waste oil, paper and cardboard, and construction and demolition waste. Despite being the largest waste stream in the EU, an end-of-life directive has never been developed for both construction and demolition waste.

1.3 Policies

The main instruments available to promote re-use at the EU level are:

- The revised Construction Products Regulation (CPR)
- The European Taxonomy
- The Waste Framework Directive (WFD)

While initial versions of the abovementioned policies were intended to promote re-use of construction production, setting minimum requirements for re-use in the case of the Taxonomy or the revision of the Waste Framework Directive and framework facilitating the CE marking of re-used products in the case of the revised CPR, final versions of the mentioned regulations assumed more conservative positions or like in the case of the Waste Framework Directive, there has not been a revision of the criteria applied to construction products.

1.3.1 The revised CPR

On April 2024 Regulation (EU) No 305/2011 of the European Parliament and of the Council was adopted in the context of the internal market, to harmonise conditions for the marketing of construction products and to remove obstacles to trade in construction products between Member States. The CPR was published in the EU Official Journal in December 2024 and entered into force on January 7, 2025. The CPR applies to construction products including used products as stated in its article 2 "Scope" and defines in its "article 3" "used product" as a product that is not waste or has ceased to be waste in accordance with Directive 2008/98/EC" while setting the difference with remanufactured products as remanufactured products have been subjected to transformative process.

The new CPR adopted text considers the re-use of construction products as part of the shift to a circular economy and the reduction of environmental and carbon footprint. The text recognizes that the second-hand materials market is not developed and as demonstrated in section above, there are a wide variety of requirements being implemented amongst member states. Therefore, the new text recommends proceeding with a long-term harmonization process under the CPR in which the

Harmonized Technical Specifications must explicitly include whether re-used products are covered or excluded from the scope although it will always be possible for economic operators to apply the standards on re-used products. Standards applying to re-used products will also apply to those re-used products that have undergone a non-essential transformative process.

No burdens before the last de-installation will affect re-use products, thus the CPR creates a framework for re-used components as the shortest path to carbon neutrality, as long as the “safety first” principle is not committed.

The new CPR text includes not only re-use states that product requirements must align with the CEAP listing reuse and the associated necessary preparation for re-use requirements, for example, facilitating deinstallation, separation of products as well as information for safe use of components. This information must be accessible in passports and websites.

Instructions for use and safety information are necessary to make decisions to promote re-use and recycling including installation use, maintenance and dismantling for reuse and recycling. Elements to be covered by use and safety information will be specified in the CPR and relevant information integrated in the harmonized standards. The information will not only fall under the responsibility of manufacturers, and the Commission will implement the obligation to provide instructions for use and safety.

The will to introduce re-used products in new construction is reflected in CPR:

- **Annex I**, “Basic requirements for Construction Works” set in section 8. “Sustainable use of natural resources of construction works” point (f) “the maximization of the reuse and or recyclability of the construction works, in part or in whole, and of their material after deconstruction and demolition and in point (g) ease of deconstruction. The fulfilment of such is considered to be referred to “voluntary harmonized standards”
- **Annex III** “Product Requirements” includes the harmonized standard specifications to be established by delegated acts that will specify how products are to be designed, produced, maintained and packaged to maximized environmental and circularity requirements including re-used content, durability, upgradability and repairability.
- **Annex IV** includes the recommendations for a product re-installation and re-use in section 2.7

The development of the “voluntary harmonized standards” is being implemented at CEN Committees where the CEN/TC 350/SC 1/WG 6 Committee is working on a horizontal standard which first draft was subjected to internal consultation by the end of the ADVANCE project. CEN TC 350/SC 1/WG 7 is in parallel in circular design aspects. The ADVANCE Consortium members are being active in both processes, providing inputs and recommendations. The ADVANCE project partners have also actively contributed to the CEN/TS 1090-201:2024.

1.3.2 The Taxonomy

The Taxonomy sets as part of both “Construction of New Buildings” and “Renovation of Existing Buildings” substantial contribution to “Transition to a Circular Economy” environmental objective, maximum primary materials requirements based on thresholds for each different waste fractions and considers re-used materials as 100% secondary materials. However defined thresholds in the final

published version does not include a specific requirement for re-used components as it was the case of the first drafts; (*Minimum 15% comes from re-used components*)

1.3.3 European Waste Framework Directive

The directive sets the by 2020, the preparing for re-use, recycling and other material recovery, including backfilling operations using waste to substitute other materials, of non-hazardous construction and demolition waste excluding naturally occurring material defined in category 17 05 04 in the list of waste shall be increased to a minimum of 70 % by weight. The inclusion on backfilling as E.o.L option and the different level of achievement in the different member states have generated hesitates on the Waste FrameWork Directive implementation. Latest amendments are limited to the textiles and food waste and despite it was expected that a new revision with ambitious high-quality recycling and re-use target should entry into force in a short term, this revision is not in place.

1.4 Roadmap for the future development

The part of ADVANCE project dedicated to identification of possibilities to promote wider uptake and implementation of constructional steel reuse, is published within the report called Circular Economy of Steel-Based Building Components [2]. It is divided into two parts: (1) analysis of the possibility to upscale the outcomes of the previous projects and apply them outside of the original scope of those projects and (2) analysis of the most important future technological and other trends affecting the reuse of constructional steelwork.

- **Upscaling recent research outputs:** Several projects including PROGRESS, SB STEEL, LVS3, and REDUCE were evaluated for their outcomes related to steel reuse and sustainability in construction. Outcomes were assessed based on their applicability to constructional steel, other materials, and the extent of modifications needed for broader use. More details are provided in Section “Exploitation of research results” of this report.
- **Addressing future trends:** Future trends affecting steel reuse include digitalization, decarbonization, industrial IoT, smart circular buildings, and external factors like extreme weather and demographic changes. Their possible implications on structural steel reuse are discussed in the report [2].

2. Recommendations for reuse

The aim of WP3 was to provide updated guidance for reuse of existing components or structures and design of new ones with improved reusability and to introduce recommendations for product/waste status and material testing protocol for recertification of steel products in the updated *Recommendations for Reuse of Reclaimed Steel Products*, based on the *European Recommendations for Reuse of Steel Products in Single-Storey Buildings* developed in the frame of RFCS PROGRESS project. The final draft of the 2nd edition of the *Recommendations for Reuse of Reclaimed Steel Products* was produced in Task 3.1.

The 1st edition of the Recommendations for Reuse (European Recommendations for Reuse of Steel Products in Single-Storey Buildings) [33] was produced during 2017-2019 in the format used in the ECCS Design Manual series and launched in spring 2020. However, it was not published in the ECCS series mainly due to the development and publication schedule of the new Eurocodes. The objective of this WP was to bring the publication closer to this goal, to provide a detailed review of the Technical Committees TC14 “Sustainability and Eco-efficiency of Steel Structures” and TC9 “Manufacturing and Erection Standards” of ECCS (European Convention for Constructional Steelwork), and additional partners involved in the ADVANCE project.

The scope of the work was to extend from single- to multi-storey buildings within the research project ADVANCE (Accompanying measure for dissemination, valorisation and collaborative exploitation of circularity of constructional steel products) and the additional content was included in this second edition of the Recommendations for Reuse of Reclaimed Steel Products.

These recommendations address the key aspects that designers should consider to facilitate greater reuse of steel structures and present examples of successful structural reuse. The recommendations outline the requirements for functional reusability, but do not cover in full detail the economic feasibility or environmental benefits of reuse.

The scope of reuse of structural steel is limited here to:

- Members to be reused should not be subjected to damages, inclusive plastic deformations, and reduced cross sections (e.g., through holes, openings, cracks or excessive corrosion),
- All members to be reused should come from a building structure built with elements produced in or after 1970, which is about the time when the Limit State design became common practice,
- All salvaged primary members are rolled steel sections. Welded and built-up members are not included in the scope of this document,
- For the members to be reused, they must be recovered in as much of their original shape as possible, although some additional fabrication and preparation work may be required.

Part I and Part II of the original recommendations were published separately as two volumes:

Volume 1: Reusing existing steel products and buildings,

Volume 2: Building design recommendations to facilitate future deconstruction and reuse,

Additionally, Technical Committee TC14 of ECCS agreed to produce one more volume covering non-design aspects to complement two volumes produced in ADVANCE project:

Volume 3: Environmental aspects and practical implementation.

- **Volume 1** [3] discusses general technical issues related to the structural use of reclaimed steel from existing steel and composite steel-based structures. It presents a brief description of the anatomy of single- and multi-storey buildings, classification of different reuse scenarios, an historical review of European codes of practice and product standards, selection and acceptance of materials, and their classification for “new” designs in accordance with the Eurocodes. It also discusses structural design aspects in terms of Limit States principles. The protocol for condition assessment, sampling and testing of reclaimed steel is given in Appendix A. The derivation of the modified partial factor for the buckling resistance of the reused steel members is presented in Appendix B.
- **Volume 2** [4] covers the design of new buildings with the goals of functionality, ease of fabrication, demountability and future reuse, together with aesthetics. The general principles for the design for disassembly and reuse of steelwork. It defines the loads and combination of actions to be used in design calculations and proposes general improvements in construction details that facilitate future reuse.
- **Volume 3** is a follow-up activity planned for autumn 2025 – spring 2026. It will present the assessment of the environmental benefits of reusing reclaimed steel members and offers information on practical aspects of the fabrication and erecting of structures from reclaimed steel. Several case studies are presented in the last section of this volume, which illustrate the use of reclaimed steel structures in various EU countries and some of the technical issues that were overcome.

This publication is intended for architects, structural engineers, designers, and construction professionals involved in the design, fabrication and erection of steel buildings. It is particularly relevant for those who want to incorporate circular economy principles into their projects, ensuring that steel structures are designed with future deconstruction and reuse in mind.

2.1 Volume 1: Reusing existing steel products and buildings

The publication is divided into the following sections:

- **Chapter 1** highlights how the 9R circularity strategies - Refuse, Rethink, Reduce, Reuse, Repair, Refurbish, Remanufacture, Repurpose, Recycle, and Recover - can be applied to steel structures to minimise environmental impact and support the circular economy. The guide emphasises the importance of designing buildings for adaptability and ease of disassembly to facilitate the reuse of steel components. It explores technical challenges such as verifying the performance of reclaimed steel, assessing its compliance with Eurocode standards, and overcoming barriers related to sourcing, cost, and certification. It focusses on single-storey steel buildings and also addresses the complexities of reclaiming steel from multi-storey composite structures.
- **Chapter 2** provides an in-depth technical overview of the structural components and systems used in single-storey and multi-storey steel buildings. It details the design principles, framing options, bracing systems, secondary steelwork, roof and cladding systems specific to single-storey buildings, emphasising their efficiency, adaptability, and construction speed. For multi-storey steel buildings, it discusses various structural systems such as moment-resisting frames, braced frames, and shear wall systems, along with considerations for floor structures, cladding types, and load-bearing requirements. The document also references a wide range

of design guides and standards relevant to the structural design and construction of steel buildings, offering practical information for engineers, architects, and construction professionals.

- **Chapter 3** outlines the classification and scenarios of steel reuse within the life-cycle of constructional steel components, based on the CEN/TC 350 standards for life-cycle assessment and costing. It describes each stage from raw material supply to use and eventual end-of-life or reuse, emphasising different types and configurations of reuse such as in-situ, on-site in altered form, and relocated reuse. Reuse is categorised on the basis of the degree of disassembly, from entire structures to individual components, and explores logistical and technical implications such as transport needs and component integrity. Special considerations are given to cladding elements such as sandwich panels, which pose unique challenges due to weathering and design variability.
- **Chapter 4** provides a historical review of structural steel design codes and product standards relevant to the reuse of steel components. It outlines the evolution of European and national standards from the 1970s to the present, highlighting the importance of consistent material properties in steel grades such as S235, S275, and S355. The document explains how steel quality has been controlled through chemical and mechanical testing, and discusses the shift from national standards to unified European standards under the Eurocodes. It also covers the development of design practices for both hot-rolled and cold-formed structural steels, including the use of limit state design and the role of testing in verifying performance, especially for complex cold-formed components.
- **Chapter 5** outlines the processes and standards involved in the reuse of structural steel, focussing on testing, traceability, and compliance with material specifications. It emphasises the need to verify mechanical and chemical properties through standardised testing methods, including tensile, impact, and hardness tests, particularly when original certification is not available. The document explains how reused steel components must be assessed for conformity to current product standards and discusses procedures for visual inspection, sampling, and marking. It also highlights the importance of maintaining traceability throughout the reuse process to ensure safety, reliability, and compliance with modern construction codes. It presents procedures for the verification of the structural reusability of steel members as constituent products, structural components or entire primary structure.
- **Chapter 6** provides comprehensive guidance on the structural analysis and design of buildings using reclaimed steel members, in accordance with Eurocode standards. It covers essential aspects such as the ultimate and serviceability limit states, structural reliability, partial safety factors, and member stability. It discusses how reclaimed steel can meet modern design requirements by applying standard resistance checks, accounting for imperfections, and potentially adjusting design life or safety factors based on project-specific conditions. The document also addresses seismic design considerations, connection detailing, bracing systems, and serviceability criteria such as deflections and cladding performance. It emphasises that with proper inspection, quality control, and thoughtful design adjustments, reclaimed steel can be safely and effectively integrated into new or retrofitted structures.
- **Annexes A and B** serve as a technical appendix that details the assessment, testing, and verification protocols for reclaimed structural steel. It outlines procedures for evaluating

material properties, including both non-destructive and destructive testing methods such as hardness tests, tensile strength tests, chemical composition analysis, and impact toughness assessment. It emphasises the importance of defining test groups based on source, size, and structural role to ensure traceability and consistency. The document also covers inspection techniques for welds, geometric tolerances, and specific guidelines for cold-formed steel. In addition, it introduces testing protocols A to D, adapted to different levels of known provenance, and provides statistical approaches to determine the characteristic material values. A final section proposes a modified material partial safety factor for structural design using reclaimed steel, ensuring compliance with the safety and reliability principles of Eurocode.



Figure 1. Cover page of the 2nd edition of Recommendations for Reuse of Constructional Steel Products. Volume 1

2.2 Volume 2: Building design recommendations to facilitate future deconstruction and reuse

This second volume of the *Recommendations for Reuse of Reclaimed Steel Products* provides targeted design guidance aimed at facilitating future deconstruction and reuse of steel elements in building construction. In line with the circular economy principles and sustainability goals, the guide addresses the design of new buildings, including single-storey industrial facilities and multi-storey residential or office buildings, with a focus on modularity, demountability, and material longevity.

It presents practical strategies for designing structures that maximise the reuse potential of steel members by promoting standardisation, efficient construction detailing, and the use of accessible mechanical connections over permanent welding.

The growing need to mitigate environmental impacts from the construction sector has led to significant interest in the reuse of building materials, particularly structural steel. This publication addresses this need by focussing on design strategies that facilitate the future disassembly and reuse of steel elements. A key point discussed is the importance of integrating design for disassembly (DfD) principles early in the design process, ensuring that structures are not only functional and durable but also adaptable to future needs. The emphasis is placed on modular design, standardised components, and accessible mechanical connections, which collectively enhance the ease of deconstruction and extend the life cycle of materials.

Furthermore, the document underlines the need for traceability and comprehensive documentation throughout the life of a building. Implementing Building Information Modelling (BIM) and maintaining detailed building memos ensure that critical information, such as material properties, design specifications, and fabrication details, is preserved, greatly facilitating future reuse efforts. The guide also carefully considers the loading and structural analysis requirements to ensure that buildings designed for deconstruction maintain high performance standards during their initial and subsequent service lives. By coupling technical rigour with practical strategies, the guide presents a holistic approach to sustainable construction practices.

Additionally, it provides technical recommendations on load combinations, structural analysis, and detailing best practices that enhance the structural integrity and reusability of building components.

By addressing these aspects, the publication aims to minimise environmental impacts, reduce waste, lower embodied carbon, promote the circular use of construction materials and foster a more sustainable and resource-efficiency construction industry.

The following key conclusions can be drawn from this volume:

- **Design for Reuse:** Integrating design for disassembly (DfD) principles early in the design process enables the future reuse of structural steel elements, supporting a circular economy in construction.
- **Modularity and Standardisation:** Modular building designs and standardised steel components enhance the ease of deconstruction and increase the potential for material recovery and reuse.
- **Reversible Connections:** Using bolted and mechanical connections, rather than permanent welded joints, facilitates the dismantling and repurposing of structural elements.
- **Traceability and Documentation:** Detailed record keeping, including Building Information Modelling (BIM) and building memos, ensures that essential material and fabrication data are preserved for future reuse.

- **Structural Performance:** Designs must balance the need for reusability with rigorous performance standards, ensuring durability, safety, and adaptability over multiple life cycles.
- **Environmental Impact Reduction:** By facilitating the reuse of reclaimed steel products, the recommendations contribute to significant reductions in construction waste and embodied carbon emissions.
- **Industry Advancement:** The guidelines promote a shift in the construction industry towards sustainable practices without compromising functionality, economic feasibility, or safety.
- **Policy and Practice Alignment:** The publication supports the development of industry standards and regulations that can drive broader adoption of reuse-oriented design strategies.



Figure 2. Cover page of the 2nd edition of Recommendations for Reuse of Constructional Steel Products. Volume 2

2.3 Translations and final publication

The Recommendations for Reuse (Volumes 1 & 2) were translated into six additional languages (Romanian by UPT [5][6], Portuguese by UC [7][8], German by RWTH [9][10], Finnish by TRY [11][12], Czech by CTU [13][14] and French by CTICM [15][16]) and received ECCS code and ISBN (see Figure 3 and Table 4). They are published by ECCS as publications No.146 and 147. Volume 3 will contain the English version only, being not part of the outcomes of the ADVANCE project.



Figure 3. Cover pages of the translated Recommendations for Reuse Volume 1

Table 4 Codes and ISBNs of the translated Recommendations for Reuse

Language	Vol.1 Code	Vol.1 ISBN	Vol.2 Code	Vol.2 ISBN
English	ADV1-EN	978-92-9147-202-4	ADV2-EN	978-92-9147-203-1
Romanian	ADV1-RO	978-92-9147-214-7	ADV2-RO	978-92-9147-215-4
Portugues	ADV1-PT	978-92-9147-212-3	ADV2-PT	978-92-9147-213-0
German	ADV1-DE	978-92-9147-205-5	ADV2-DE	978-92-9147-205-5
Finnish	ADV1-FI	978-92-9147-208-6	ADV2-FI	978-92-9147-209-3
Czech	ADV1-CZ	978-92-9147-210-9	ADV2-CZ	978-92-9147-211-6
French	ADV1-FR	978-92-9147-206-2	ADV2-FR	978-92-9147-207-9

3. ICT tools and methodologies

3.1 LCA methodology

The LCA methodology from PROGRESS project [49] was updated in ADVANCE project [17] and harmonized with the newest World Steel Association's modelling guide [48]. It was validated on several case studies reported in Deliverable D4.1 [17] and finally used as a basis for the update of mobile LCA application and web tool delivered in ADVANCE project. Environmental impacts of reuse shall be expressed in Modules A, C and D of LCA, but the methodological challenge addressed in ADVANCE project was specifically focused on the robust and transparent calculation rules for the Module D.

3.1.1 Impacts of today reuse

Product Category Rules (PCR) for construction products, EN 15804 [44], do not provide specific rules how to allocate LCA impacts of reuse of construction products in Modules A1 to A3. However, new Construction Products Regulation (CPR) [40] is taking a position that should be used, when and how LCA impacts of reused products are allocated to Module A3. The CPR text is aligned with the principles and definitions of EU Waste Framework Directive [62] as well as with the principle included also in EN 15804 [44] and EN 15978 [46]. This means that the life cycle in which a product has been manufactured will end at the point when the product has been dismantled from the construction works and it is reused directly (Module C2) or has undergone processes for preparation for reuse and by which it ceases to be waste. These processes include checking, cleaning, and repairing, by which products or components of products are prepared so that they can be reused in general for construction purposes without any other pre-processing (Module C3). This is the case e.g., when an audit before deconstruction is done.

If a product that intends to be reused in the next life cycle is not valid for reuse in the specific intended use without further processing, the impacts of these processes shall be addressed to Module A3. The new CPR [40] recognises two different cases when the product needs to be transformed in a way that it fulfils the requirements of the relevant harmonised product standard:

- intended use requires transformation to modify product's non-essential characteristics (e.g., cutting to the new size, decorative repainting) or,
- intended use requires remanufacturing to ensure or modify product's essential characteristics for structural use ensuring functional and technical performance of a product (e.g., by including relevant testing of technical characteristics, galvanisation and repainting for proper surface treatments)."

3.1.2 Loads and benefits of future reuse

The loads and benefits of future reuse are part of mandatory module D of LCA calculation. Their calculation shall follow the allocation procedure of reuse, recycling, and recovery of materials in Section 6.4.3.3 of EN 15804 [44]. Formula D.6 (Eq. (1)) "*specific loads and benefits per unit of analysis for module D related to the export of secondary materials*" in the informative Annex D of the standard describes the practical application of this procedure.

$$e_{moduleD1} = \sum_i (M_{out,i} - M_{in,i}) \cdot \left(E_{MR,i} - E_{VM,i} \frac{Q_{R,i}}{Q_{Sub,i}} \right) \quad (1)$$

Closed-loop model

Closed-loop product system or open-loop product system without inherent material changes can avoid allocation of secondary material over several lifecycles by assuming that the secondary material substitutes virgin (primary) material in the product until the point of their functional equivalence. In this procedure, reported in detail in the PROGRESS guide [49], the material amounts M_{in} , and M_{out} are the amounts of secondary materials entering and exiting the lifecycle of the particular product under assessment (see Figure 4). Therefore, total amount of input material and output material cannot be higher than the amount of the material contained in the product. Reuse and recycling flows can be fully separated and the value of E_{VM} for recycling and for reuse refers to virgin (primary) material.

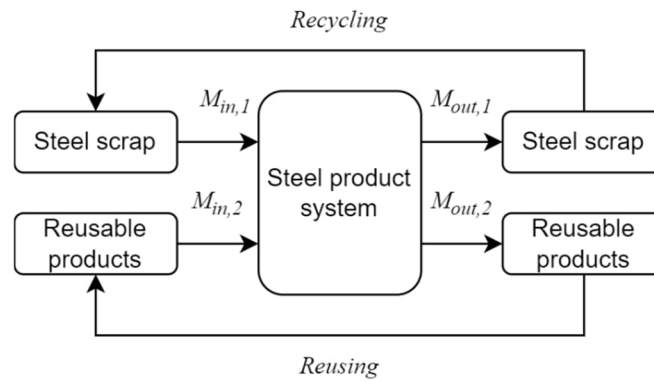


Figure 4 Closed-loop allocation of material flows

Constructional steelwork commonly involved reuse and recycling in the same product system, and therefore Eq. (1) can be written as sum of impacts related to recycling (Eq. (2)) and those related to reuse (Eq. (3)) with indexes 1 and 2 corresponding to recycling and reuse respectively. Material quality loss is typically neglected (quality factors $Q_{R,i}$ and $Q_{Sub,i}$ for the constructional steel are considered to be 1.0), but the loss of material in the recycling process has to be acknowledged, and therefore the complementary PCR for steel, EN 17662 [45], uses yield factors Y based on World Steel LCI methodology [63].

$$e_{moduleD1.1} = (M_{out,1} - M_{in,1}) \cdot (E_{MR,1} - E_{VM,1}) Y_1 \quad (2)$$

$$e_{moduleD1.2} = (M_{out,2} - M_{in,2}) \cdot (E_{MR,2} - E_{VM,2}) Y_2 \quad (3)$$

Open-loop model

Open-loop allocation procedure for reused steel is used in the current steel Environmental Product Declarations (EPDs) [64] and is recommended by World Steel Association [48]. It assumes open-loop system with limited number reuse cycles embedded in the closed-loop recycling system (see Figure 5).

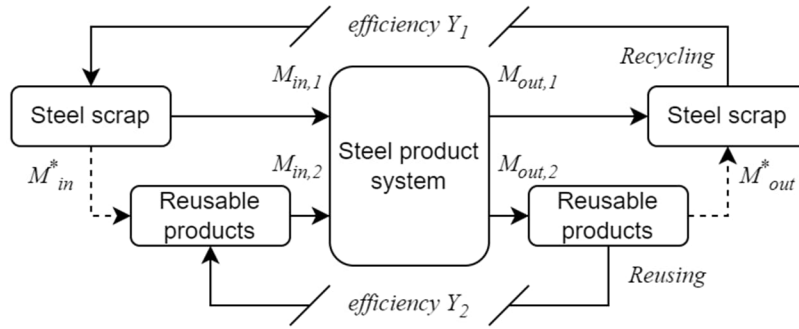


Figure 5 Open-loop allocation of material flows

The reusable product carries load of the scrap used in its original production and benefit of the scrap generated after its decommissioning (see Eq. (4)). On the other hand, the substituted impacts $E_{VMSub,out}$ cannot be related to virgin (primary) production and shall be determined from the avoided product's production substituted in the following lifecycle (see Eq. (5)).

$$e_{moduleD1.1} = (M_{out,1} - M_{in,1} + (M_{out,2} - M_{in,2}) \frac{M_{out}^* - M_{in}^*}{M}) \cdot (E_{MR,1} - E_{VM,1}) Y_1 \quad (4)$$

$$e_{moduleD1.2} = (M_{out,2} - M_{in,2}) \cdot (E_{MR,2} - E_{VM,2} - \frac{M_{out}^* - M_{in}^*}{M} (E_{VM,1} - E_{MR,1}) \frac{Y_1}{Y_2}) Y_2 \quad (5)$$

Both adjustments of Eqs. (1-2) are based on the World Steel Association methodology [48], where the negative values of $e_{moduleD1.1}$ and $e_{moduleD1.2}$ are called *net benefit of recycling* and *net benefit of reuse* respectively and can be calculated by Eqs. (6-8). It should be noted that material flows R in the World Steel Methodology [48] are fractions of the total mass, and therefore the difference $R_2^* - R_1^*$ has to be expressed as $(M_{out}^* - M_{in}^*)/M$ in the equivalent formula (Eq. (5)) to be compatible with EN 15804 [44].

$$net\ benefit\ of\ recycling = (R_2 - R_1 + (R_{u2} - R_{u1})(R_2^* - R_1^*)) X_{sc} \quad (6)$$

$$net\ benefit\ of\ reuse = (R_{u2} - R_{u1})(X_m - X_{refurb} - (R_2^* - R_1^*) X_{sc}) Z \quad (7)$$

where

$$X_{sc} = (X_{pr} - X_{re}) Y \quad (8)$$

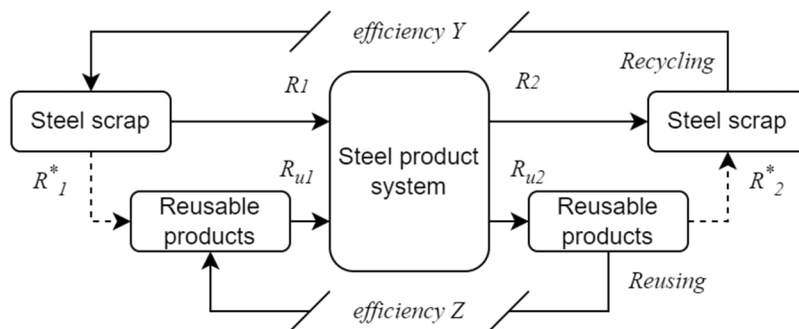


Figure 6 Open-loop allocation of material flows according to the World Steel Association

Table 5 shows corresponding parameters of World Steel Association's methodology and modified EN 15804. It can be demonstrated that when Eq. (5) uses Y_1/Y_2 ratio instead of Y from Eqs. (7-8),

the additional benefits of recycling in Eq. (4) are exactly equal to the decreased substituted emissions in Eq. (5). Therefore, the total Module D1 ($e_{moduleD1.1} + e_{moduleD1.2}$) is the same for both, closed-loop (Eqs. (2-3)) and open-loop (Eqs. (4-5)) models.

Table 5 Corresponding parameters of CEN and World Steel Association's methodology

	EN 15804 EN 17662	World Steel Association
amounts of input and output recycled material to the product system	$M_{MR,in,1}$ $M_{MR,out,1}$	R_1 R_2
amounts of input and output reused material to the product system	$M_{MR,in,2}$ $M_{MR,out,2}$	R_{u1} R_{u2}
specific emissions from recycling of the current system and specific emissions of the primary material	$E_{MRafterEoW,out,1}$ $E_{VMSub,out,1}$	X_{re} X_{pr}
specific emissions from reuse of the current system and of the manufactured product	$E_{MRafterEoW,out,2}$ $E_{VMSub,out,2}$	X_{refurb} X_m
yield (efficiency) of the recycling and reuse process	Y_1, Y_2	Y, Z

Comparison of both models

The comparison between the models was performed on five scenarios proposed by the World Steel Association [48], where the external flows of 1 tonne of steel product are $M_{in}^* = 0.07 t$ and $M_{out}^* = 0.95 t$ (R_1^* and R_2^* in [48]). The yield factors are $Y_1 = 0.92$ [63] and $Y_2 = 1$ (Y and Z in [48]). The LCI of steel scrap $(E_{MRafterEoW,out,1} - E_{VMSub,out,1})Y_1 = 1.62 tCO_2e/t$ (X_{sc} in [48]). GWP of manufacturing of the new product and the refurbishment of the reused one are then $E_{VMSub,out,2} = 2.7 tCO_2e/t$ and $E_{MRafterEoW,out,2} = 0.1 tCO_2e/t$ (X_m and X_{refurb} in [48]). The net material loads of the calculated scenarios are presented in Table 2. It should be noted that the net loads in Table 6 are negative values of net benefits (see Eq. (3) and Eq. (6)) and their sum corresponds to the negative value of World Steel Association's end-of-life method without the manufacturing part.

Table 6 Net impacts based on the scenarios from the World Steel Association guidance [48]

Material flows [t]	(A) No reuse, 95% end of life recycling	(B) 100% reused input	(C) 100% reused output	(D) 100% reused input and output	(E) 50% reused output
$M_{MR,in,1}$ (R_1)	0.07	0	0.07	0	0.07
$M_{MR,out,1}$ (R_2)	0.95	0.95	0	0	0.5
$M_{MR,in,2}$ (R_{u1})	0	1	0	1	0
$M_{MR,out,2}$ (R_{u2})	0	0	1	1	0.5
Open-loop net loads [tCO ₂ e/t] acc. to Eqs. (4-5) and World Steel Association [48] (Eqs. (6-8)).					
recycling	-1.43	-0.11	-1.31	0.00	-1.41
reuse	0.00	1.17	-1.17	0.00	-0.59
total ($e_{moduleD1}$)	-1.43	1.06	-2.49	0.00	-2.00
Closed-loop net loads [tCO ₂ e/t] according to CEN methodology (Eqs. (2-3))					
recycling	-1.43	-1.54	0.11	0.00	-0.70
reuse	0.00	2.60	-2.60	0.00	-1.30
total ($e_{moduleD1}$)	-1.43	1.06	-2.49	0.00	-2.00

As can be seen from Table 6, both models produce the same total net loads of reuse and recycling across all scenarios. When dealing with recycling only (scenario A), both models are identical. However, with the addition of reuse, the closed-loop model shows larger difference between recycling and reuse components of the model (scenarios B, C and E). The reason is that the open-loop model considers part of the impacts of the reused material to be attributed to recycling because of the original material production and the final scrap recycling after the last reuse cycle. The recycling flows are increased (see Eq. (4)) and the emissions substituted by reuse are proportionally decreased (see Eq. (5)).

Summary and conclusions

We successfully demonstrated that it is possible to align the World Steel Association’s methodology [48] with EN 15804 [44], which is commonly used for the development of Environmental Product Declarations (EPDs) in the EU. Both methodologies produce equivalent results in terms of the total impact of recycling and reuse. However, their components related to recycling and reuse are different with the open-loop (Figure 5) and closed-loop (Figure 4) model. Both methods can be used to determine the total impact of combined recycling and reuse (e.g. Module D1 in EPDs), and the World Steel Association method can be further simplified without the need of external flows R_1^* and R_2^* (M_{in}^* and M_{out}^*). This is particularly important for businesses dealing with reused material, where the original amount of scrap R_1^* is not always known [65]. On the other hand, it is not recommended to report contribution of recycling and reuse separately with closed-loop model without these additional parameters.

The models described in this report are generally not restricted to constructional steel. They can be applied also to materials suitable for closed-loop recycling, such as plastics or glass, where reuse is feasible. However, further methodology development is required for materials unsuitable for closed-loop recycling. Examples of different materials are given in the ADVANCE report [17].

3.2 Mobile app

3.2.1 Introduction

In the project ADVANCE, the ‘Buildings LCA’ tool developed in the scope of the RFCS project SB STEEL was upgraded [18]. The updated dashboard of the tool is illustrated in Figure 7. The original tool was developed to provide a simplified and quick evaluation of the sustainability of steel-framed buildings in the early stages of design, considering the life cycle environmental performance of the building. The adopted approach was based on a macro-component approach to cope with the lack of data in the early stages of building design [66].



Figure 7. Main dashboard of the updated tool.

The original tool was freely available for smartphones and tablets and could be downloaded from the App Store or the Google Store. The updated version is also freely available for smartphones and tablets, and a new version is also available online.

The main upgrades of the current tool are:

- Implementation of the LCA approach for the reuse of steel products (as described in sub-section 3.1)
- Additional macro-components for industrial buildings
- Development of the online tool, which additionally allows for the creation of BIM objects of the macro-components, including the environmental LCA data

3.2.2 Use of the tool

The tool is user-friendly and the LCA calculation is made according to the flowchart represented in Figure 8.

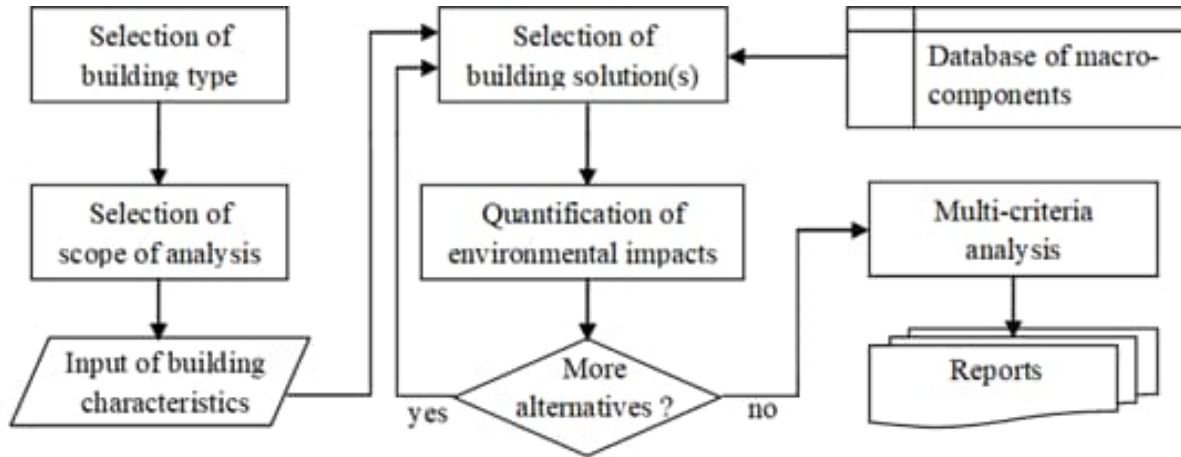


Figure 8. Flowchart of the LCA calculation.

The details of the LCA calculation are given in the following paragraphs.

Goal and scope of the LCA

The goal of the tool is to quantify the environmental impacts of buildings or building components (in m²), using predefined macro-components. Moreover, the approach enables the assessment to be made at three different levels: (i) the material level (e.g.: a steel beam with 10 m); (ii) the component level (single macro-components); and (iii) the building level.

PRODUCT LEVEL

Home • Catalog • Product level



Figure 9. Product level (i) elements, and (ii) macro-components.

Functional unit

At the building level, the functional unit is a building with a defined typology (e.g. residential, office, etc) designed for a predefined period of life (e.g. 50 years) fulfilling all the standard requirements.

At the level of a building component, the functional unit (m²) is a building component with a defined typology (e.g. external wall, internal slab, etc) used for a period of life (e.g. 50 years). In this case, the function of the building component may be included or not (in case of comparative assertions, then the function of the building component should be included).

System boundaries

The life cycle environmental analysis comprehends three main calculations: (i) a cradle-to-gate analysis (Modules A1-A3); (ii) a cradle-to-date analysis plus end-of-life stages (Modules A1-A3, plus C1-C4 and D); and (iii) a cradle-to-grave analysis, including all modules.

Life Cycle Inventory

In the updated version, environmental datasets are provided from the database of the software 'LCA for Experts' [67].

Life Cycle Impact Assessment

The environmental categories selected to describe the environmental impacts of the building are indicated in Table 1.3 and correspond to the environmental categories recommended in the European standards for the assessment of environmental performance of buildings (EN 15804 [44] and EN 15978 [46]). As already mentioned, the modular concept of the standards was adopted in the approach. Therefore, the output of the life cycle environmental analysis of the building is provided per module. In the current version of the tool, the life cycle environmental analysis of each macro-component was performed by 'LCA for experts' software [67].

3.2.3 Macro-components approach

Macro-components were defined for different building components according to the UniFormat classification scheme [68]. The following categories are considered: (A) Substructure, (B) Shell and (C) Interiors. Each main category is further sub-divided. The detailed classification scheme is represented in Table 7 Building component classification scheme .

Table 7 Building component classification scheme [68]

(A) Substructure	(A40) Slabs-on-grade	(A4010) Standard slabs-on-grade	
(B) Superstructure	(B10) Superstructure	(B1010) Floor construction	(B1010.10) Floor structural frame (B1010.20) Floor decks, slabs and toppings
		(B1020) Roof construction	(B1020.10) Roof structural frame (B1020.20) Roof decks, slabs and sheathing
(B) Shell	(B20) Exterior vertical enclosures	(B2010) Exterior walls	(B2010.10) Ext. wall veneer (B2010.20) Ext. wall construction
		(B2020) Exterior windows	
		(B2050) Exterior doors	
	(B30) Exterior horizontal enclosures	(B3010) Roofing	
		(B3060) Horizontal openings	
(C) Interiors	(C10) Interior construction	(C1010) Interior partitions	
	(C20) Interior finishes	(C2010) Wall finishes	
		(C2030) Flooring	
		(C2050) Ceiling finishes	

Within each building component (see Table 7) the corresponding macro-components have the same function and have similar properties. The functional unit of each macro-component is 1 m² of a building component with similar characteristics, to fulfil a service life of 50 years.

3.2.4 Illustrative example of the LCA of a macro-component

In the following, an illustrative example of a macro-component LCA calculation is provided. It is noted that, in some cases, to fulfil the function of a building component, different macro-components have to be considered simultaneously. The following example refers to the interior slab of a residential building, as illustrated in Figure 10.

The interior slab indicated in Figure 10 is composed of the following elements:


- a OSB plate with 18 mm;
- a layer of wood fibre insulation with 40 mm;
- a gypsum board with 15 mm;
- a density of cold-formed steel of 14 kg/m².

It is noted that the quantities of each macro-component are fixed, except the thickness of the insulation layer, which may be specified by the user.



(B1010.10.1) LIGHT-WEIGHT STEEL SLABS

- B1010.10.1a ▶
- B1010.10.1b ▶
- B1010.10.1c ▶
- B1010.10.1d ▶
- B1010.10.1e ▶
- B1010.10.1f ▶
- B1010.10.1g**
- B1010.10.1h ▶
- B1010.10.1i ▶



Inputs Parameters

Wood fibers [mm]

Lifespan [Years]

Scope of Analysis

Cradle-to-gate + End-of-life (C1-C4 & D) ▾

OSB

Thickness	18 mm
Weight	12.55 kg/m ²
End-of-life	Incineration
RR	80

Wood fibers

Thickness	40 mm
-----------	-------

Calculate

Figure 10. Main dashboard of the tool

The functional unit of the building component is an interior slab (per m²) of a residential building, with a required service life of 50 years. The selected macro-component(s) must fulfil the same functional unit of the building component. Therefore, the estimated service life of the different materials must be considered.

Furthermore, to fulfil the environmental information in all modules, scenarios and assumptions are needed. All the scenarios are set in accordance with the rules provided in EN 15804 and EN 15978.

(i) Scenarios for the transportation of materials (Modules A4 and C2)

When a cradle-to-grave analysis is selected, the transportation distances between the production plants to the construction site (module A4) and the distances between the demolition site and the respective recycling/disposal places (module C2) are assumed, by default, to be 20 km and the transportation is made by truck with a payload of 22 tonnes. However, the designer is able to specify other distances, enabling sensitivity analysis to be made in relation to the transportation of different materials.

(ii) Scenarios for the end-of-life stage (Modules C1:C4) and recycling (Module D)

Different end-of-life scenarios are specified for the materials according to their inherent characteristics, as indicated in Table 8. Thus, OSB is considered to be incinerated (80%) in a biomass power plant, and credits are given to energy recovery. Steel is recycled, assuming a recycling rate of 90%, and credits are obtained due to the net scrap at the end of the life-cycle

process. Likewise, wood fibres are considered to be recycled (80%). However, due to the lack of data of the recycling process, no credits are obtained apart from the reduction of waste sent to landfill.

Table 8 EOL options for materials

Material	Disposal/Recycling scenario	Credits
Gypsum plasterboard	Landfill (100%)	-
Wood fibers	Recycling (80%) + Landfill (20%)	-
OSB	Incineration (80%) + Landfill (20%)	Credit due to energy recovery
Light-weight steel	Recycling (90%) + Landfill (10%)	Credit due to net scrap

3.2.4.1 Environmental analysis

The LCA results of the macro-component are provided in PDF format (see Figure 11).

LCA of 1m² of a weight steel slabs macro-component

Indicators describing environmental impacts

Indicator	Unit	A1-A3	A4	A5	C1	C2	C3	C4	D1.1	D1.2	D1	TOTAL
GWP-total	[kg CO2 eq.]	3.34e+1	0.00e+0	0.00e+0	0.00e+0	0.00e+0	0.00e+0	0.00e+0	-1.38e+1	0.00e+0	-1.38e+1	1.96e+1
GWP-fossil	[kg CO2 eq.]	3.34e+1	0.00e+0	0.00e+0	0.00e+0	0.00e+0	0.00e+0	0.00e+0	-1.38e+1	0.00e+0	-1.38e+1	1.96e+1
GWP-biogenic	[kg CO2 eq.]	-6.14e-2	0.00e+0	0.00e+0	0.00e+0	0.00e+0	0.00e+0	0.00e+0	8.20e-2	0.00e+0	8.20e-2	2.06e-2
GWP-luluc	[kg CO2 eq.]	5.27e-3	0.00e+0	0.00e+0	0.00e+0	0.00e+0	0.00e+0	0.00e+0	-1.84e-3	0.00e+0	-1.84e-3	3.42e-3
ODP	[kg CFC-11 eq.]	-6.21e-13	0.00e+0	0.00e+0	0.00e+0	0.00e+0	0.00e+0	0.00e+0	1.87e-11	0.00e+0	1.87e-11	1.81e-11
AP	[Mole of H+ eq.]	7.89e-2	0.00e+0	0.00e+0	0.00e+0	0.00e+0	0.00e+0	0.00e+0	-3.40e-2	0.00e+0	-3.40e-2	4.49e-2
EP-freshwater	[kg P eq.]	1.35e-5	0.00e+0	0.00e+0	0.00e+0	0.00e+0	0.00e+0	0.00e+0	-3.23e-6	0.00e+0	-3.23e-6	1.03e-5
EP-marine	[kg N eq.]	1.69e-2	0.00e+0	0.00e+0	0.00e+0	0.00e+0	0.00e+0	0.00e+0	-5.45e-3	0.00e+0	-5.45e-3	1.14e-2
EP-terrestrial	[Mole of N eq.]	1.82e-1	0.00e+0	0.00e+0	0.00e+0	0.00e+0	0.00e+0	0.00e+0	-4.88e-2	0.00e+0	-4.88e-2	1.33e-1
POCP	[kg NMVOC eq.]	6.64e-2	0.00e+0	0.00e+0	0.00e+0	0.00e+0	0.00e+0	0.00e+0	-2.22e-2	0.00e+0	-2.22e-2	4.43e-2
ADP-minerals&metals	[kg Sb eq.]	8.48e-6	0.00e+0	0.00e+0	0.00e+0	0.00e+0	0.00e+0	0.00e+0	-7.88e-5	0.00e+0	-7.88e-5	-7.03e-5
ADP-fossil	[MJ]	3.82e+2	0.00e+0	0.00e+0	0.00e+0	0.00e+0	0.00e+0	0.00e+0	-1.38e+2	0.00e+0	-1.38e+2	2.43e+2
WDP	[m ² world equiv.]	-1.01e+0	0.00e+0	0.00e+0	0.00e+0	0.00e+0	0.00e+0	0.00e+0	-9.29e-1	0.00e+0	-9.29e-1	-1.94e+0

Figure 11. Example output: Life cycle environmental analysis of macro-components (per m²).

All macro-components are computed in a similar way, and the LCA of the building is assembled based on the different macro-components selected for each building component.

3.3 Web tool

The web tool [19] may be freely accessed through the link: <https://buildingslca.onesource.pt>.

This tool allows follows the same procedure for the LCA as the mobile app introduced in the previous section but offers additional functionality. The additional update was the development of parametric BIM objects of each macro-component that include all life cycle environmental indicators, as illustrated in Figure 12.

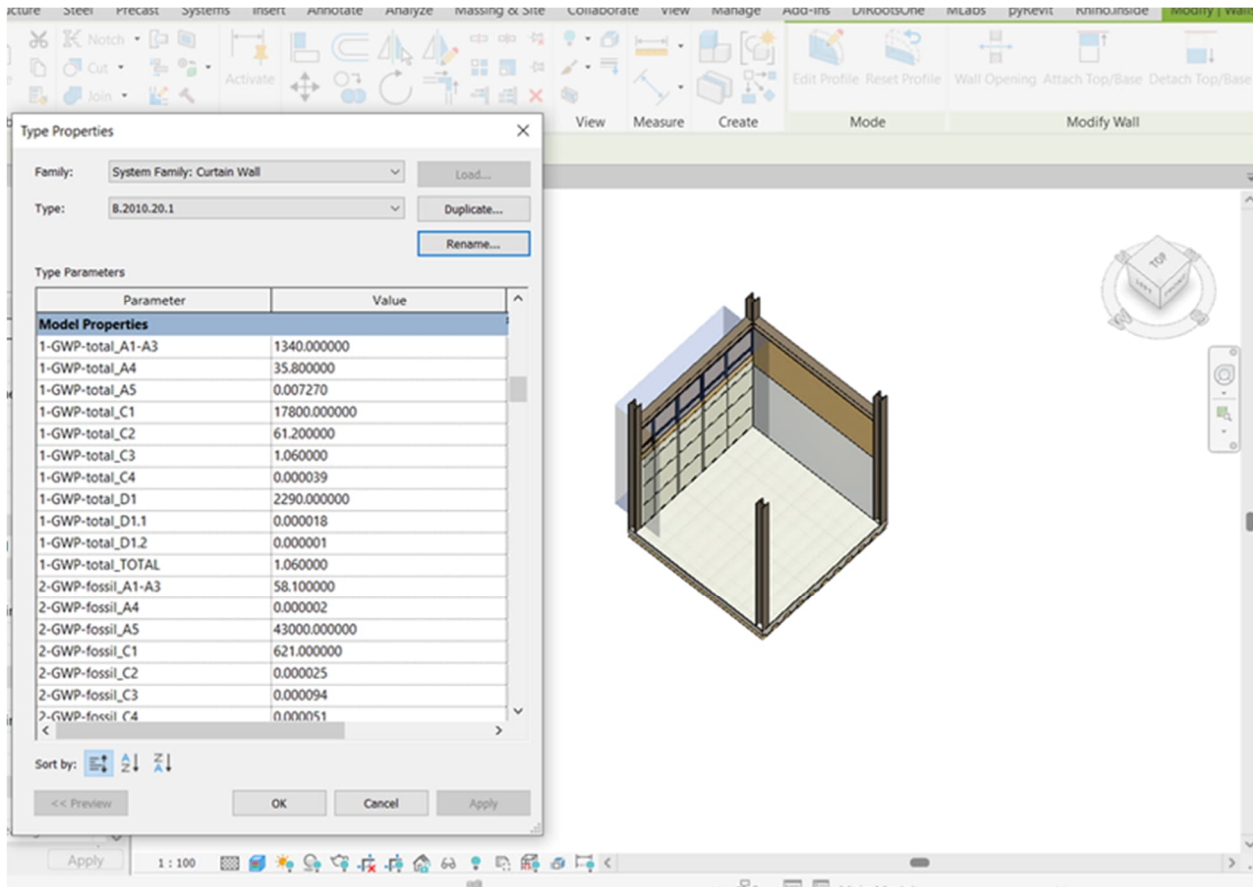


Figure 12. BIM model with objects containing LCA data.

This enables building designers not only to optimize a building's LCA using the tool, but also to construct the BIM model with the exported BIM objects, ensuring that the model's LCA is directly integrated into the BIM environment.

3.4 Steel Reuse on Scratch minigame

To demonstrate ease of use of the ADVANCE LCA methodology and to address the youngest audience, VTT prepared a minigame in a free, visual, block-based programming language, Scratch [69], developed at MIT for creating interactive stories, games, and animations, designed for ages 8 to 16. The game can be accessed via the link:

<https://scratch.mit.edu/projects/1161220510/>

This minigame guides the player through the environmental choices he may face when designing a steel structure. The main character, Scratchy, estimates the carbon intensity of the player's idea and possible saving in the future according to the ADVANCE LCA methodology with the following pre-defined scenarios using virgin material, recycled steel or reused steel as input and reuse, recycling or disposal as end-of-life scenario. The ratio of recycling and reuse on input and output can be also defined by the player. The goal is to achieve the highest CO₂ saving and learn how different choices affect the sustainability of constructional steel.



Figure 13. Steel Reuse on Scratch minigame

4. Dissemination and communication

The European Convention for Constructional Steelwork was responsible for WP5 Dissemination Material and WP6 Dissemination activities for the whole duration of the project according to the project dissemination and communication plan [22]. Besides main events, small meetings and visits have been held and are listed in the Dissemination list at the end of Chapter 4.

4.1 General dissemination & communication materials and tools

Webpage

A dedicated webpage of the project is hosted by ECCS website on www.steelconstruct.com under EU Projects (see Figure 14). The webpage was regularly updated with the newest information about the project and materials (reports, presentations, factsheets, brochures, etc.).

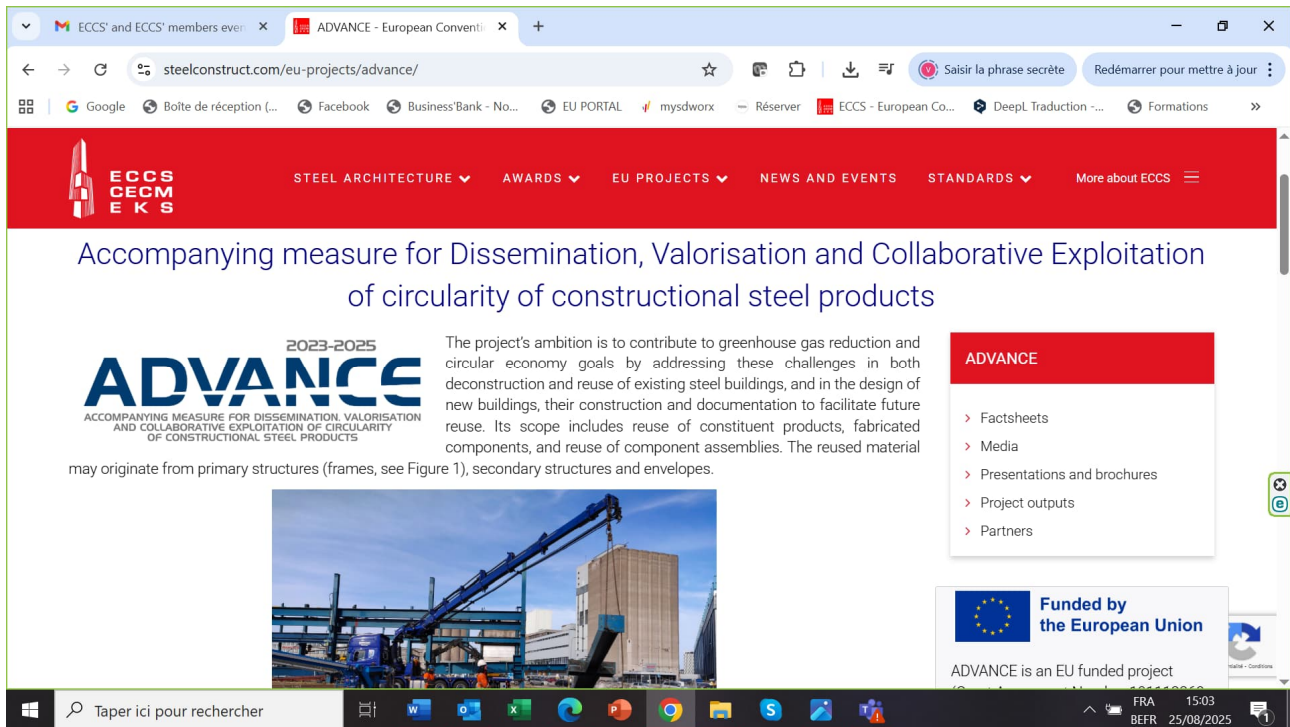


Figure 14. ADVANCE webpage

It gives an overview of the project and is divided into topics such as:

- **Factsheets:** 15 fact sheets demonstrating success stories about reuse of steel structures. Examples covering North and South of Europe. These fact sheets were also presented in an attractive way via LinkedIn and have collected good return messages and likes.
- **Media:** there are listed and visible via a link, a) the different flyers which exist about the Advance project and Reuse, b) some useful links such as YouTube videos showing deconstruction solutions, and c) the presentations which have been presented on the occasion of the Final Workshop in Brussels, d) and last but not least, the list of public dissemination activities of the project.

- **Presentations and brochures:** There are available the power point presentations [21] which have been disclosed during the respective local workshops of the partners, i.e Czech Republic, Germany, Finland, France, Portugal, Romania and an English version for Europe. In addition to that, the accompanying brochures [20] translated into the different local languages. The brochures, which were due to be translated into the 7 languages of the Consortium partners, have been translated into some additional 12 languages by European experts active within ECCS Technical Committees and some partners' network. In total, we are gathering 20 languages, English included.
- **Project outputs:** The project outputs such as described here above are repeated under this button, together with some reports such as methodology report and a report on circular economy of steel-based components.
- **Partners:** links to all the partners of the Consortium.

Analysis of the views and total users by Google Analytics for the period covering September 2023 to August 2025, i.e. the whole duration of the project is in Figure 15.

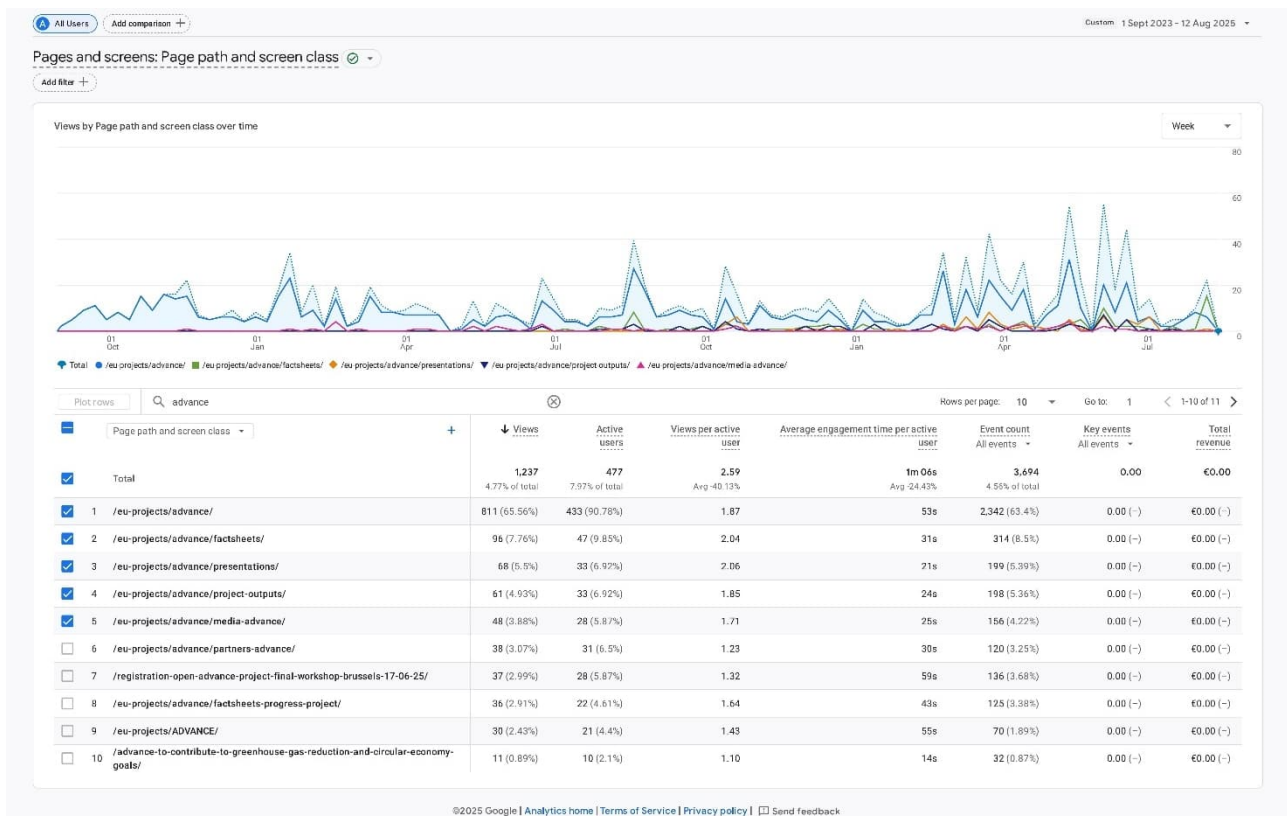


Figure 15. Google analysis of ADVANCE webpage, September 2023 – August 2025

Flyer

ECCS created one A4 page summarizing all the information linked to the project and the webpage where it can be found has been prepared and printed in 500 copies by ECCS for distribution at the following main events:

- **EUROSTEEL 2023** from 12 to 14 September 2023, Amsterdam,
- **International Symposium on Steel Bridges** from 11 to 13 September 2024, Prague
- **Advance Final Workshop** on 17 June 2025, Brussels.

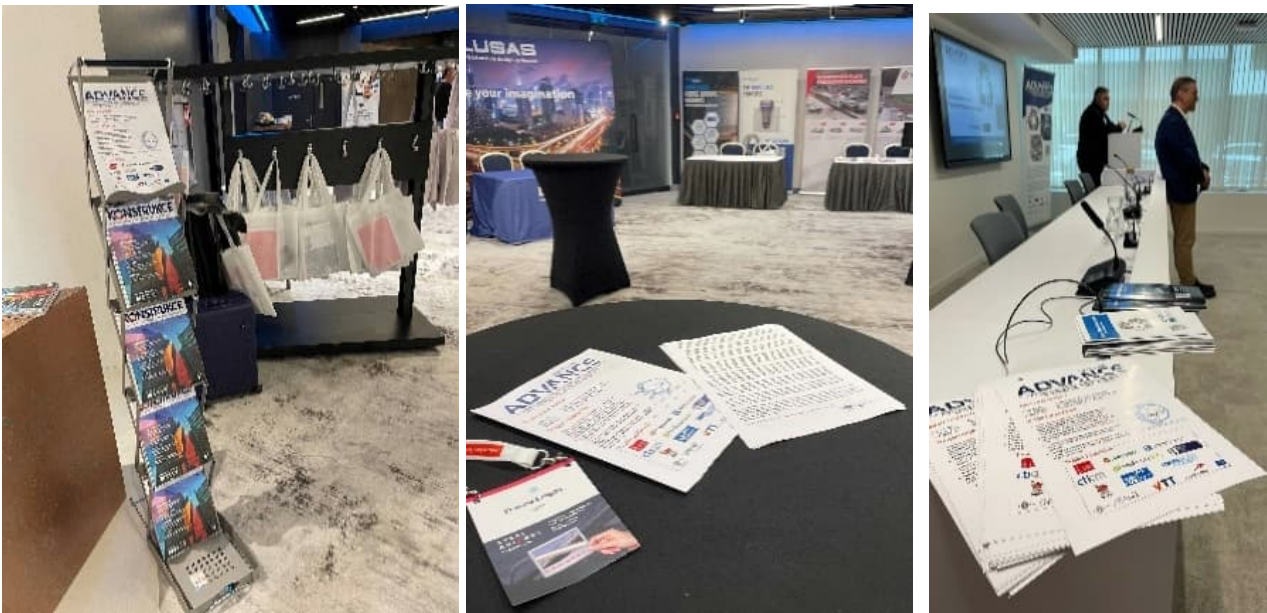


Figure 16. ADVANCE project flyers present in international events

Banner

a dedicated banner has been designed by ECCS and the file has been distributed to the partners as a tool for dissemination in their local workshops, and in their national languages.

The banner has been displayed on several occasions by ECCS on events, meetings, and visits at the Office where the banner or rollup is permanently visible from the main office entrance, together with the promotional flyers easily accessible for the visitors.



Figure 17. Mr Marek Janda, Czech Constructional Steelwork Association at the International Steel Bridges Symposium in Prague, 11 September 2024 (left) and Advance Final Workshop in Brussels, 17 June 2025 (right).

QR code

ECCS generated QR code for the easy access to the ADVANCE project online resources published on their website. The code has been extensively used in the project presentations (it was embedded in the PowerPoint template) and other occasions.



LinkedIn

ECCS and other partners have regularly published and shared communication about Advance Project on their own LinkedIn page or on the ADVANCE dedicated page, for instance see Figure 18.

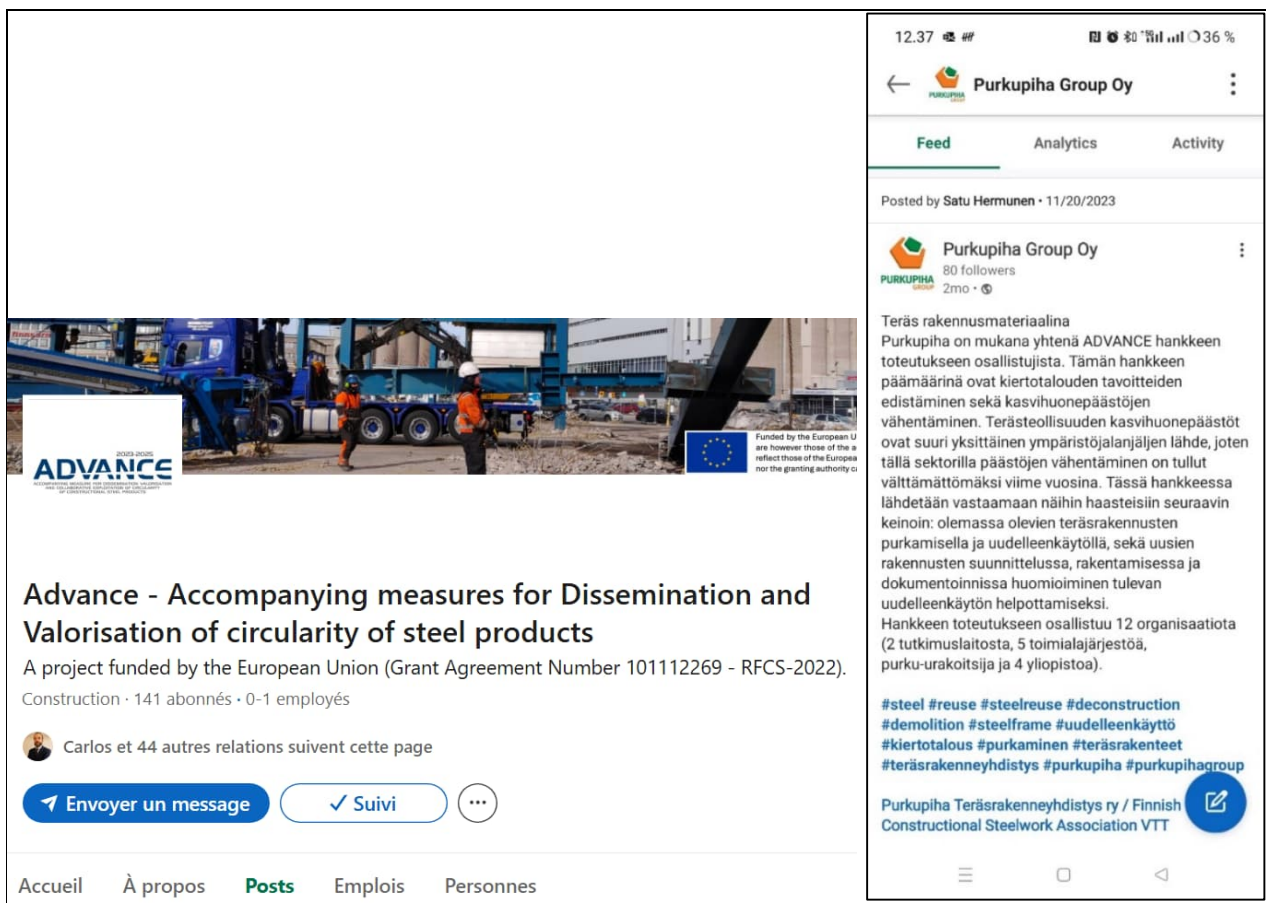


Figure 18. ADVANCE dedicated page on LinkedIn (left) and Example of communication on ADVANCE by Purkupiha (right)

4.2 Brochure

A short document (8 pages) to promote the reuse of steel structures, in short, has been produced for use in the local and final workshops [20]. The brochure is two folds:

- **White side** about Reuse of steel structures. This one deals with existing buildings and contains four pages detailing briefly the benefits of reuse, several facts and figures, and information about the quality assessment of steel products.
- **Black side**, Design for Reuse of steel structures, related with future buildings, contains four pages tackling design considerations, environmental assessment and good practices.

This is an appealing short document, summarizing in a few arguments the advantages of reuse of steel structures, translated into 20 languages: Bulgarian, Croatian, Czech, Dutch, English, German, Finnish, French, Hungarian, Italian, Macedonian, Norwegian, Polish, Portuguese, Romanian, Slovak, Serbian, Spanish, Ukrainian. For instance, the English version has been printed by ECCS and distributed in the final workshop in Brussels on 17 June 2025. The translated brochures were distributed in the respective ADVANCE workshops (e.g. the French version has been distributed on the 2025 Congress of the French Association member of ECCS which was taking place in Strasbourg on 20 June 2025, the Czech version was distributed on 26 March 2025, during the Czech workshop in Prague).



Figure 19. ADVANCE brochure (English version) front and back

The translated brochures can be accessed from the ADVANCE project webpage:
<https://www.steelconstruct.com/eu-projects/advance/presentations/>

Hergebruik van staalconstructies | Повторно използване на стоманени конструкции | Ponovna uporaba čeličnih konstrukcija | Opětovné použití ocelových konstrukcí | Wiederverwendung von Stahlkonstruktionen | Teräsrakenteiden uudelleenkäyttö | Réemploi de structures en acier | Acélszerkezetek újrahasználat | Riuso dei componenti metallici | Повторна употреба на челични конструкции | Ombruk av Stålkonstruksjoner | Ponownie wykorzystanie konstrukcji stalowych | Reutilização de estruturas metálicas | Reutilizarea structurilor metalice | Ponovna upotreba čeličnih konstrukcija | Reutilización de estructuras metálicas | Повторне використання сталевих конструкцій | Opätovné použitie ocelových konštrukcií



Figure 20. Examples of ADVANCE brochure translations, front page



Figure 21. Examples of ADVANCE brochure translations, front page

4.3 Presentations

A template of power point presentation to introduce the project and its results to the audience has been prepared and translated into 6 languages [21], corresponding to the languages of the local workshops or national events.

<https://www.steelconstruct.com/wp-content/uploads/ADVANCE-Presentation-EN.pdf>

- Czech: [ADVANCE-Presentation-CZ.pdf](#)
- German: [ADVANCE-Presentation-DE.pdf](#)
- Finnish: [ADVANCE-Presentation-FI.pdf](#)
- French: [ADVANCE-Presentation-FR.pdf](#)
- Portuguese: [ADVANCE-Presentation-PT.pdf](#)
- Romanian: [ADVANCE-Presentation-RO.pdf](#)

The presentation materials were used in many other occasions as well (see Table 9) organized or attended by the ADVANCE project partners. For instance, in addition to these workshops, ArcelorMittal made a presentation of the ADVANCE project and the reuse case study “Petite Maison” at the SP2024 - Sustainable Places (SP) conference in September 2024 in Luxembourg. The presentation was fit for the theme “Decarbonization & Circularity”.

4.4 Publications

Several presentations of the project have been published in the ECCS quarterly journal, Steel Construction Design and Research, distributed to the profession and available via abonnement (see Figure 22 to Figure 24).



Figure 22. Steel Construction Journal, Design and Research 03/24

Steel Construction News

Events

Place and date	Event	Details
Webinar 2 June 2025	Circular construction through reuse of steel structures and components	((to be added during correction))
Brussels, Belgium 17 June 2025	Save the date: Advance final workshop	https://www.steelconstruct.com/wp-content/uploads/ADVANCE-Programme-Final-workshop.pdf

Figure 23. Steel Construction Journal, Design and Research 01/25

ECCS NEWS

ADVANCE

The project's ambition is to contribute to greenhouse gas reduction and circular economy goals by addressing these challenges in both deconstruction and reuse of existing steel buildings, and in the design of new buildings, their construction and documentation to facilitate future reuse. Its scope includes reuse of constituent products, fabricated components, and reuse of component assemblies. The reused material may originate from primary structures, secondary structures and envelopes.

The primary objective is to increase the recovery and reuse of constructional steelwork by providing engineers, investors, contractors and other decision makers with reliable performance data and guidance. This will be achieved by disseminating the information about the products, systems, methods and protocols that facilitate reuse of various components of constructional steelwork using the tools and methodologies developed within activities of the consortium partners.

The outcomes of the project will include recommendations to enable reuse of building components in-situ or in different location(s), and in the original layout or in a different design with the necessary modifications/adaptations to resist the new external loads (due to the relocation) or internal loads (due to the modification of the structural layout). Our goal is to address the wider scientific, business and engineering



community in the Member States with the localized Recommendations for Reuse, information brochure, mobile app and presentation materials.

- In particular, the objectives are to:
1. Provide guidance for reuse of existing components or structures and design of new ones, introduce recommendations for product/waste status and material testing protocol for recertification of steel products in the updated Recommendations for Reuse
 2. Support declaration of the environmental benefits of steel reuse implemented in the mobile LCA app and web tool

3. Increase awareness about the alternative end-of-life options for constructional steel and steel-based products
 4. Identify the possibilities and roadmaps for scaling up the outcomes of the background projects beyond their original focus area
- 12 organisations will be participating in the project implementation (2 research institutes, 5 industrial associations, demolition contractor and 4 universities).

Steel LCA calculator

Easy-to-use LCA calculation tool for early assessment of the impact of constructional steelwork including recycling and reuse benefits according to the new EN 15004, EN 15079 and ISO 14544.

- based on BUILDINGS LCA mobile app <https://apps.apple.com/sk/app/buildings-lca/id15302291>
- extended to cover reuse of components and include BIM inputs
- ported to web server (to be accessed from the browser), possible API access
- updated to reflect new methodologies



Figure 24. Steel Construction Journal, Design and Research 02/25

As well as in Partner's local Journals, for instance in Czech Republic [70][71].

4.5 Workshops

The outcomes of the project were disseminated in 7 workshops (6 local and 1 central workshop in Brussels).

Local workshops

In the workshops the partners had the possibility to present in the local language and invite speakers and experts on the local building, deconstruction and sustainability issues and to adjust the programme of the workshops to address the particular barriers and opportunities of steel reuse in each country. The printed and translated brochures were distributed in the workshops.



CZECH REPUBLIC

26.3.2025 in Prague, Czech Republic

In the framework of the Week of Steel, Timber and Glass 2025.



FRANCE

27.3.2025 in Paris, France

In the framework of CTICM and APK Scientific and Technical Days



FINLAND

28.8.2024 in Helsinki, Finland

Dedicated ADVANCE workshop for TRY members

24.9.2024 in Helsinki, Finland

Dedicated ADVANCE workshop for Finnish building authorities



GERMANY

12.6.2025 in Krefeld, Germany

In the framework of PPA Sustainability Working Group day



PORTUGAL

4.6.2025 in Porto, Portugal

In the framework of Portugal Steel seminar



ROMANIA

21.5.2025 in Cluj Napoca, Romania

In the framework of AICPS33 "The Future of Structural Design: Romanian and European Standards and Innovation"

2.7.2025 in Timisoara, Romania

Dedicated ADVANCE workshop organized by UPT

Final workshop



BELGIUM

The Final Workshop took place in Brussels on 17 June 2025, under the umbrella of ECCREDI, the European Council for Construction Research, Development and Innovation. The presence of the ECCREDI President, Mr Ralph Pasker, and of the European Construction Technology Platform (ECTP), Mrs Cornelia Partsch and of the Architects of Europe (ACE) in the person of Mrs Larissa de Rosso, has given additional value to the event.

It was also the occasion to invite other projects dealing with circularity of steel in order to reinforce the interest and the visibility of our project. The first one was GREENVESTS, presented by Dr.-Ing. Rafaela Don from RWTH Aachen, dealing with green/vegetal facades in steel and the second project was REBRIDGE, Presented by Dr.-Ing. Sara Uszball from the University of Stuttgart. REBRIDGE stands for “Reliability of Reused Bridge Structures and the Impact on the Design for a Green and Circular Eternity”.

The workshop was successfully concluded by a panel of discussion where different actors of the metallic sector could express themselves and confront their arguments to the audience. The debate was very rich in ideas and resulted in very interesting questions such as the position of the client, the need for harmonization of the regulations all over Europe, and the need to further enlarge the circle for discussion to policy makers, economists, and real estate representatives. The conclusion was that Reuse is an opportunity for the sector more than a challenge and the importance of collaborating between the different sectors is essential. Architects and constructional industry should work hand in hand and make sure they are tackling and framing all the obstacles so that our generation does not create problems for our children. The workshop was moderated by Dr Bernhard Hauke, former ECCS Promotional Management Board chairman.



Figure 25. Mr Ralf Pasker, President of ECCREDI



Figure 26. Mrs Cornelia Partsch, European Construction Technology Platform



Figure 27. From left to right, Dr Bernhard Hauke, Dr.-Ing. Rafaela Don



Figure 28. Dr.-Ing. Sara Uszball University Stuttgart



Figure 29. ADVANCE Final Workshop Brussels, Petr Hradil presenting



Figure 30. ADVANCE Final Workshop Panel of Discussion. From left to right: Larissa de Rosso (ACE), André Beyer (CTICM), Petr Hradil (VTT), Bernhard Hauke (Ernst&Sohn)

Final Webinar

In order to further increase the audience and the visibility of the results of the project, the Consortium have decided to offer the public a last opportunity to listen to the very last results and offered a free webinar on 27 August 2025. Some 32 participants joined the webinar and asked particularly relevant questions about Module D and the situation of EN 17662.

Figure 31. ADVANCE final webinar programme (left) and interface (right)

4.6 Communication activities

ADVANCE project partners engaged in many communication activities (see Table 10). These included liaison with experts and expert groups (for instance organized under ECCS Technical Committees TC14 and TC9), giving interviews, promoting the ADVANCE project activities in panel discussions and so on.

Just after the final workshop in Brussels, ECCS attended the French Syndicat de la Construction Métallique de France’s annual Congress and accompanied the President of the French association to the European Parliament in Strasbourg (see Figure 32). The objective was to meet with Mrs Marie Pierre Vedrenne, French Eurodeputy and pass a few messages regarding the role of steel construction in the Green Deal. The message given to the Commission regarding reuse was clear: steel construction is the unique sector able to generalise the reuse of structural materials. To our knowledge, no European Platform for Reuse of constructional materials exist at European level. Though structural steel reuse allows CO₂ emissions reductions during the life cycle and allows the creation of a regulated secondary market. ECCS and SCMF proposed the Commission to support the creation of a pilot European Platform for constructional materials reuse in steel.



Figure 32. from left to right: Hervé Gastaud (SCMF), Emmanuel de Laage (SCMF President), Marie Pierre Vedrenne (EU), Georg Matzner (ECCS President), Véronique Dehan (ECCS)

4.7 Overview of dissemination and communication activities

Table 9 Overview of ADVANCE dissemination activities

Conference/seminar/workshop [presented by]	Link	Date	Place	Online resources [Other materials]	Audience [Number of participants]
Eurosteel 2023 [ECCS]	https://www.eurosteel2023.org/	12-14.9.2023	Amsterdam, the Netherlands	[flyer]	International academics and practitioners related to the use of steel and composite structures in structural applications [600 participants]
Statika a Technologie 2023 [CTU]	https://www.statika-technologie.cz/	26-27.9.2023	Brno, Czech Republic	[presentation]	Czech structural engineers and building technology experts [97 participants]
ESTEP 2023 Annual Event [REA]	https://www.estep.eu/events/2023-estep-annual-event	3-5.10.2023	Barcelona, Spain	[presentation]	International experts on steel construction
Keynote lecture at Trimble, Finland	n/a	24.10.2024	Espoo, Finland	[presentation]	Trimble employees [120 participants]
Green Building Blocks for Built Environment [VTT]	https://www.hamk.fi/tapahtuma/green-building-blocks-for-built-environment/	7-8.2.2024	Hämeenlinna, Finland	[presentation]	Finnish experts on construction and infrastructure [56 participants]
Digital-4-Environment ESTEP workshop [REA]	https://www.stiima.cnr.it/2023/10/30/digital-4-environment-workshop/?lang=en	20-21.2.2024	Bardolino, Italy	[presentation]	International experts on the digitalisation in built environment
CESARE'24 [UPT]	https://www.ct.upt.ro/cesare24/	29-31.5.2024	Timișoara, Romania	[banner]	International experts on structural sustainability and resilience [97 participants]
ICSAS 2024 [UC]	http://www.labciv.eng.uerj.br/icsas2024/	5-7.6.2024	Rio de Janeiro, Brazil	[presentation]	International experts on steel and aluminium structures
CEN TC135 Workshop on Reuse		21.6.2024		Presentation	Presentation of outcomes
FI workshop 1/2 ADVANCE workshop for TRY members [TRY]	https://www.terasrakennehdistys.fi/fin/teras/co2-ja-kiertotalous/advance-teraksen-uudelleen kaytto-projekti/	28.8.2024	Helsinki, Finland	https://www.youtube.com/watch?v=q2zT65qJOPY	Finnish experts on constructional steel [31 participants]
Steel Bridges 2024 [ECCS]	https://steelbridges2024.com/	11-13.9.2024	Prague, Czech Republic	[banner]	International experts on steel and composite bridges [153 participants]
Sustainable Places 2024 [AMBD]	https://www.sustainableplaces.eu/	23-25.9.2024	Luxembourg	[presentation]	International experts on the built environment [600 participants]
FI workshop 2/2 ADVANCE workshop for Finnish Building Control authorities [TRY]	https://www.terasrakennehdistys.fi/fin/teras/co2-ja-kiertotalous/advance-teraksen-uudelleen kaytto-projekti/	24.9.2024	Helsinki, Finland	https://www.youtube.com/watch?v=i31VnJXBbig	Finnish building control
Workshop On Reuse of Offshore Assets for Construction and Infrastructure Industries [VTT]	https://stavangerregion.no/events/workshop-reuse-repurpose-of-offshore-decommissioned-steel-platforms-for-construction-and-infrastructure-industries/	7.10.2024	Stavanger, Norway	[presentation]	Norwegian constructional steel community [43 participants]
Advancement for Metal Buildings [UPT]	https://ifbs.eu/wp-content/uploads/2024/07/2024_Congress_new2.pdf	10-11.10.2024	Isatnbul, Türkiye	[presentation]	International experts on sustainable use of metal products and envelopes
ISO TC167 Committee meeting	n/a	14.10.2025		Presentation	Dissemination work and practices observed in Europe. Prepare standardization work at ISO level
Workshop on the development of national LCA database in Uruguay [VTT]	n/a	1.11.2024	Montevideo, Uruguay	[presentation]	Uruguayan representatives of public authorities and construction industry [16 participants]
FCSA Steel Construction Day [TRY, VTT]	https://www.terasrakennehdistys.fi/document/1/1383/590b19a/terasrakennepaiva_2024_ohjelm_a.pdf	19.11.2024	Helsinki, Finland	[presentation]	Finnish experts on constructional steel [140 participants]
ECCREDI Council meeting	n/a	4.12.2024	Limelette, Belgium	[presentation]	ECCREDI members (10 persons)
Factsheets presentation on LinkedIn [ECCS]	https://www.linkedin.com/company/www.steelconstruct.com/	9.1.2025 16.1.2025 23.1.2025 30.1.2025 6.2.2025 13.2.2025 20.2.2025	online	[video]	[>1500 total views]

		27.2.2025 6.3.2025 13.3.2025 20.3.2025 27.3.2025 3.4.2025			
Steel Structures Review webinar [TRY]	n/a	28.2.2025		[presentation]	[29 participants]
CZ workshop In the framework of the Week of Steel, Timber and Glass 2025	https://ocel-drevo.fsv.cvut.cz/cz/?p=6097	26.3.2025	Prague, Czech Republic	[workshop]	60 participants
FR workshop CTICM and APK Scientific and Technical Days [CTICM]	https://asso-apk.org/page/index.php?page=973&id_ressources=9610	27.3.2025	France	[workshop]	107 participants
RO workshop 1/2 AICPS33 "The Future of Structural Design: Romanian and European Standards and Innovation" [UPT]	https://33.aicps.ro/en/national-conference/	21.5.2025	Cluj Napoca, Romania	[presentation]	AICPS - Romanian Association of Structural Design Engineers [300-400 participants]
Circular construction through reuse of steel structures and components at EU Green Week [ECCS]	https://green-week.event.europa.eu/partner-events/circular-construction-through-reuse-steel-structures-and-components-2025-06-02_en	2.6.2025	online	[workshop]	[160 registered, 116 present]
PT workshop Portugal Steel Seminar[UPC]	https://portugalsteel.com/en/show/233	4.6.2025	Porto, Portugal	[workshop]	[80 registered, 44 present]
DE workshop with PPA Sustainability WG [RWTH/BFS]	n/a	12.6.2025	Krefeld, Germany	[workshop]	20 participants
Final workshop [ECCS]	https://www.steelconstruct.com/wp-content/uploads/ADVANCE-Final-workshop-Programme-With-names-V2.pdf	17.6.2025	Brussels, Belgium	[workshop, panel discussion]	[27 registered]
SCMF Annual Congress within the SCMF annual congress [SCMF]	https://www.linkedin.com/company/scmf/posts?lipi=urn%3Ali%3Apage%3Ad_flagship3_compan_y_posts%3BYiOHU92mTY%2BJLltBJAfHzA%3D%3D	20..6.2025	Strasbourg	Annual Congress of the French ECCS member	110 persons
RO workshop 2/2 [UPT]	n/a	2-3.7.2025	Timisoara, Romania	[workshop]	28 participants

Table 10 Overview of ADVANCE communication activities

Communication activity [attended by]	Date(s)	Place(s)	Audience [Number of participants]	Feedback	Conclusions
Attending meeting of ECCS Technical Committee TC14 (Sustainability and Eco-efficiency of steel structures) [UPT, all partners]	1.9.2023 8.3.2024 11.9.2024 13.3.2025 28.8.2025 [on-going activity]	Espoo, FI Coimbra, PT Prague, CZ Esch, LU Espoo, FI	[25 members]	Comments and suggestions for the development of LCA methodology in WP4 and the communication towards different CEN Technical Committees	The methodology was finalized in D4.1 and one short report was prepared specifically for CEN/TC350/WG3.
Attending meeting of ECCS Technical Committee TC9 (Manufacturing standards) [BFS, all partners]	11.5.2023 1.9.2023 [on-going activity]	online Espoo, FI	[25 members]	Comments and suggestions for the development of new Recommendations for Reuse and its alignment to the new TS 1090-201	Outline of the new Recommendations was distributed for comments
Organizing ADVANCE External Advisory board meetings [VTT]	12.2.2024 6.6.2024 [on-going activity]	online online	[8 members]	Comments and suggestions for the overall project implementation.	The members of the board are regularly updated with the project outcomes and helping with the dissemination using their own channels.

Attending meeting of ECCS Sustainability WG [VTT]	13.4.2023 14.9.2023 24.10.2023 14.12.2023	online	[10 members]	Comments and suggestions	Setting in place a strategy for the communication on sustainability of steel structures
Meeting with experts from the World Steel Association [BCSA, VTT]		online	[3 experts]		
Attending meeting of FCSA TC on Structural Steelwork [TRY]		online	[30 members]		
Giving interview to Zero Waste Scotland [VTT]		online	[1 participant]		
Attending meeting of CEN/TC350/SC1/WG1 [ECCS, AMBD]	30.11.2023 4.12.2024 16.6.2025		[WG members]		
Attending meeting of CEN/TC350/SC1/WG6 [ECCS, AMBD]	05.03.2025 (Drafting Group meeting) 16.06.2025 (WG 6 meeting) [on-going activity]	online	[around 10 experts in Drafting Group]	Two factsheets were briefly presented during the Drafting Group meeting on 5 th March 2025. The presented case studies were useful for understanding and later defining different reuse scenarios of constructional steel products. All ADVANCE factsheets (weblink) have been uploaded to CEN portal (SC1/WG6) as references for the Drafting Group of WG6.	
Attending ECCREDI Council Meeting [ECCS]	4.12.2024	BuildWise offices, Belgium	[7 ECCREDI members: ACE, EDA, FIEC, etc]	Presentation and discussion about Advance and the reuse concept	Raising the knowledge and attention to the deconstruction solutions and methodologies available.
Attending Annual congress of the French Association of steelwork contractors SCMF [ECCS]	19&20.6.2025	European Parliament Strasbourg	110 members	With SCMF President and ECCS President, ECCS participation to an interview with European Deputy Marie Pierre Vedrenne	This interview was the occasion raise the attention of the Commission to the reuse of steel structures and the need to support the development of a European platform for deconstruction and Reuse of steel structures
Giving interview to the Environmental Coalition on Standards (ECOS)	5.8.2025	Online	[3 participants]	Providing insight into the circular standardisation of constructional steel products and their relation to the new Construction Products Regulation	ECOS members gathered essential information about the state of the art in the area and are open for the continuous and deeper implementation of ADVANCE principles in their work.

To ensure the continuity of the project outcomes, the partners committed to several activities beyond the project implementation period (see Table 11).

Table 11 Overview of ADVANCE activities planned after the project ends

Activity [partner]	Link	Date	Place	Online resources [Other materials]
Continued maintenance of ADVANCE webpage [ECCS]	https://www.steelconstruct.com/eu-projects/advance/		online	[webpage and project outcomes]
CiBEn 2025 "2nd International Conference on Circularity in the Built Environment" [VTT]	https://events.tuni.fi/ciben2025/	16.9.2025	Tampere, Finland	[presentation]
CESB'25 "Central Europe towards Sustainable Building" [VTT and others]	https://cesb.cz/	16.9.2025	Prague, Czech Republic	[presentation]
SDSS 2025 International Colloquium on Stability and Ductility of Steel Structures [UC]	https://sdss2025.upc.edu/	8-10;9.2025	Barcelona, Spain	[presentation]
Stålbygg (steel construction) magazine, nr 3/2025 [VTT]	https://stalbygg.stalforbund.no/	October 2025	online and printed	[article]
NORSK STÅLDAG (Norwegian Steel Day) 2025 [VTT]	https://norskstaldag.no/	6.11.2025	Oslo, Norway	[presentation]
Eurosteel conference 2026 [UPT]	https://eurosteel2026.org/	16-18.9.2026	Krakow, Poland	[presentation]

5. Project management and coordination

This section presents the coordination activities on the project and Work Package level. The aim was to ensure effective project management by coordinating delivery of project results within planned budget and timescale, preparation of periodical reports and financial statements to the European Commission, promoting close interaction between partners and organising progress meetings with the whole consortium.

The delivery of the results was coordinated to follow the milestones and expected delivery dates indicated in the Grant Agreement of PROGRESS project. The deliverables submitted to the European Commission are listed in Table 3. Copies of all finished documents and drafts were stored in the shared workspace maintained by the project coordinator and the documents marked as public were published on the project webpage.

In addition to the deliverables, two periodic reports were submitted to the Commission covering periods from 1 September 2023 to 31 August 2024 [72] and from 1 September 2024 to 31 August 2025 [73].

The Consortium agreed to organize 5 face-to-face progress meetings during the project (every 6 months) and review meetings by teleconferences between them. One additional consortium meeting was organized together with the ADVANCE final workshop in Brussels. The overview of consortium meetings is in Table 12. Minutes and presentations from the meetings were stored in the shared workspace maintained by the coordinator. The work in the Work Packages and Tasks was discussed separately in teleconferences according to the needs of the Work Package leaders. Their plans were described in the minutes of consortium meetings.

General Assembly of the ADVANCE project was meeting after the consortium meetings and discussing issues related to the Consortium and Grant Agreements. The consortium vote was initiated in the first General Assembly meeting when the consortium unanimously agreed with the participation of one additional Associate Partner in the project, AMBD. The decision was communicated to the Project Officer and the Grant Agreement was amended accordingly.

Table 12 Overview of ADVANCE Consortium and General Assembly meetings

Meeting	Date and place
1 st Consortium and General Assembly meeting	30 August – 1 September 2023 Espoo, Finland
2 nd Consortium and General Assembly meeting	7-8 March 2024 Coimbra, Portugal
3 rd Consortium and General Assembly meeting	10-11 September 2024 Prague, Czech Republic
4 th Consortium and General Assembly meeting	11-13 March 2025 Luxembourg
5 th Consortium and General Assembly meeting	16 June 2025 Brussels, Belgium
6 th Consortium and General Assembly meeting	27-28 August 2025 Espoo, Finland

Exploitation and socio-economic impact of research results

Steel is the most circular construction material with a consolidated and profitable recovery and recycling industry because it does not lose properties through recycling. Steel is a near zero-waste material already today¹, but its recycling by re-melting requires high amounts of energy. Therefore, the next step in steel circular economy is the consolidation of reuse of steel components. Waste and carbon free economy is a key factor for the most urgent social need to mitigate the effects of climate change. Steel reuse will create a market of secondary steel products with near zero embodied emissions bringing also important cost benefits. It will form new industrial value chains including associated services that will generate economic activity and employment at both the local and regional levels. Moreover, building and infrastructure owners will benefit from the end-of-life value of steel components to be reused. Society still needs to recognize benefits of the buildings from reclaimed products, but such paradigm change is expected in the near future following the many successful examples from reusable consumer products.

Nowadays, steel is mainly collected from demolition sites and recycled in Electric Arc Furnaces (EAF). The use of renewable energy in EAF allows reducing steel carbon footprint by 85%. However, it is not certain whether decarbonized energy will be able to cover all future energy demand for steelmaking and the remaining carbon content cannot be easily reduced, because it is associated to steel transformation to products.

Despite recycling involves important economic and environmental benefits compared to primary steel production and it is the base of current steel circular economy and scrap represents 30% of the overall steel production, the shift to re-use of recovered material bring the following advantages summarized in the table below.

Table 13 Primary, recycled and re-used steel comparison.

	Primary	Recycled	Reused
GWP (kgCO _{2e} /t)	2600	500	46,3
Cost (€/tn)	380	380	380

Despite moderate cost reduction would even be feasible for reuse, a cost neutral scenario is considered. Compared to primary steel, recycling has a potential of over 80% GWP reduction and over 98% GWP reduction with reuse.

Steel forecasts consider that 50% of the steel being produced in 2050 will be produced from scrap². Steel consumption forecasts are 2.8 billion tonnes with 1.4 billion tonnes of steel coming from a secondary source.

The uptake of steel reuse as a common practice for the industry, shifting from current scenario in which most of the steel it is considered to be recycled at its end-of-life (but a residual fraction that it is reused), to a new scenario in which 40-60 % of constructional steel is reused, would represent that 20-30% of the overall constructional steel is obtained from reuse, a similar share from recycling

¹ World Steel Recycling in Figures 2016-2020, BIR Global Facts & Figures (www.bir.org/publications/facts-figures)

² Steel as Model for Sustainable Metal Industry in 2050 (www.bcg.com/publications/2015/metals-mining-sustainability-steel-as-a-model-for-a-sustainable-metal-industry-in-2050)

and the remaining 40-60% fraction obtained for carbon neutral steel processes (which are expected to involve cost increases over 70% compared to today's primary steel and EAF).

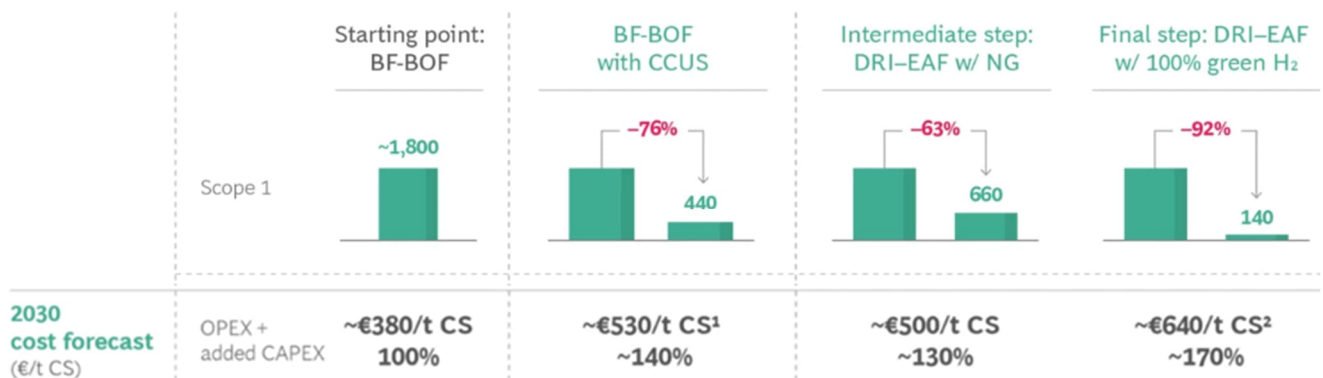


Figure 33 Green steel prices forecast 2020-2050²

Economic social and environmental impact are estimated based on the following assumptions:

- A non-linear growth on re-use rates is considered to progressively substitute a rate of recycling by reuse to a final similar re-use/recycling share by 2050.
- Reused steel is considered to be sold at the same prices that EAF and primary sourced materials.
- Prices are considered to increase according to the Figure 33 evolution and the GWP of primary and EAF steel are considered to be close to carbon neutrality (150 kgCO₂e/t) by 2050.
- Each 100 k€ results in a job creation.

According to study by SITRA, the expected direct savings from the steel component reuse are about 10 MtCO₂e and additional 20 - 40 MtCO₂e per year by materials efficiency, sharing (based on flexible modular design) and prolonged lifetime of steel products. The estimation based on the model by Boston Consulting Group³ and Eurofer statistics indicate that the constructional steel reuse potential in Europe could be even higher, growing from 13.6 MtCO₂e today to 72.8 MtCO₂e in 2050 (see Table 14).

Table 14 Summary of reuse steel impacts forecasts 2020-2050

	2020	2030	2040	2050
Steel (billion tons)	1.7	2.2	2.5	2.8
Scrap (billion tons)	0.6	0.9	1.1	1.4
Reuse (billion tons)	0.03	0.135	0.33	0.7
Recycle (billion tons)	0.57	0.765	0.77	0.7
Carbon savings (MtCO ₂ e/y)	13.62	47.79	67.32	72.8
Reuse revenues (M€)	12	75.6	171.6	618.8
Scrap revenues (M€)	142	229.5	246.4	245
Employment	120	756	1716	6188

³ Transforming the Steel Industry May Be the Ultimate Climate Challenge (www.bcg.com/publications/2022/steel-industry-carbon-emissions-challenge-solutions)

Exploitation of research results

ADVANCE project analysed the exploitation and upscaling potential of the results of background projects in [2]. The upscaling potential was divided into two main groups: (1) Reusable constructional steel (all products) and (2) extension to other materials and products. The outcomes of the assessment in the following tables are expressed as:

- Not applicable: The result is not required outside of its original scope, or it would need to be completely different.
- Applicable with major modifications: The result can serve as a basis for the development of the similar outcome in a different scope.
- Applicable with (unspecified) modifications: The result can be modified or extended to be applicable in a wider scope, but the extent of the modifications was not possible to determine.
- Applicable with minor modifications: The result can be updated to be applicable in a wider scope.
- Applicable: The result of the project was developed to be used in the given scope, or the change of the scope does not affect the applicability of the outcome.
- [XX] Applied: The result was exploited, updated and extended in ADVANCE project and documented in the referenced document(s).

PROGRESS

The PROGRESS project approached the most important aspect of the circular economy in steel construction, the reuse of components, across the whole lifecycle of the constructional steel products. Both, existing and future buildings were studied equally in the project to be able to provide continuity in the implementation of the sustainability goals. The methodologies, protocols and models were developed for the single-storey, steel framed buildings because of their relatively simple reusability, short service life and already emerging business models for their reuse or for the reuse of their components. The solutions for primary structure, secondary lightweight structure and envelope were developed in the project's Work Packages with the particular focus on their scalability and applicability beyond the single-storey steel buildings. It can be concluded that the project forms a solid framework for the future development of circular economy in steel construction.

Table 15. The most relevant results of PROGRESS project

Exploitable result	Reusable const. steel	Other materials or products
European Recommendations for reuse of steel products	[3] to [16]	●
Lifecycle assessment methodology	[17]	[17]
Reusability assessment methodology	●	●
Pre-deconstruction audit protocol	●	●
Deconstruction protocol	●	●
Material qualification protocol	●	●

SB STEEL

The main outcome of the SB Steel project was a pilot software for decision-making to support selection of steel-intensive solutions in the early phases of a building project that are known to be most crucial for the success of the construction work and for the performance and value of the completed building. The early design stages were defined as phases of conceptual design and pre-design that are characterized by a lack of precise data and drawings. The piloting web-based service was made available to various operators of the steel construction sector by the European Convention of Constructional Steelwork ECCS. The project produced two printed publications concerning design methods and processes of sustainable steel-framed and steel-intensive buildings. It organised four workshops in four European countries.

Table 16. The most relevant results of SB STEEL project

Exploitable result	Reusable const. steel	Other materials or products
Environmental Software Tool	●	●
Key indicators and macro-components for early stages of design	[18] and [19]	●
Databank of macro-components	[18] and [19]	●
Assessment methods focusing on deep structural renovations and functional upgrading	●	●
Background documents	●	●

LVS3

The main goal of LVS3 project was to disseminate the knowledge acquired in recent years about the environmental impact assessment of steel and composite buildings. During the previous decade, a lot of research projects have been funded to develop methodologies, systems and products aiming at improving the thermal efficiency as well as the global environmental footprint of steel buildings. The new standard EN 15804 intended for environmental calculation of buildings considered the fact that steel is a recyclable material (Module D). Therefore, the objective of this project was to summarise all this acquired knowledge into different documents (Background, Design guide, leaflet, User-friendly Software), to translate all these training and teaching support into the different European languages and finally to disseminate amongst Europe by the organisation of workshops.

Table 17. The most relevant results of LVS3 project

Exploitable result	Reusable const. steel	Other materials or products
Mobile LCA app	[18] and [19]	●
AMECO software	●	●
Presentation materials	[21]	●
Background document	●	●
Design guide	●	●

REDUCE

The overall objective of REDUCE was to provide practical tools and steel-based technologies to be able to design steel and composite structures for deconstruction and reuse. One objective was to develop and test demountable and reusable composite, steel-based flooring systems. This led to the use of demountable shear connector systems which were investigated in the project. The project investigated applications of the developed systems in commercial and residential buildings and explored options for greater standardisation. In the context of demountable composite construction systems, the shear connector systems with the greatest potential were tested and analysed using numerical modelling. The objective was to retain material efficiency through composite action while enabling future deconstruction and subsequent reuse.

Table 18. The most relevant results of REDUCE project

Exploitable result	Reusable const. steel	Other materials or products
Guidance on design for re-use	[3] to [16]	●
Technical solutions	●	●
LCA analyses considering reuse and application of BIM	[17]	●
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Annex A: Glossary of terms and definitions

This section presents hierarchical glossary of terms and definitions used in ADVANCE project. This glossary was used for the development of steel reuse ontology to be able to process information about circular steel use cases in machine-readable format.

Activity is action, process or operation performed on construction, product or waste during its life cycle.

Alteration is a transformative process of a product or component.

Minor alteration means transformation caused by checking, cleaning and repairing, which results in a product or component that retains most of its original material (by weight) and does not change its major dimensions by more than 10%.⁴

Major alteration is going beyond checking, cleaning or repairing recovery operations by which the product or components of products are prepared.⁵

Audit (or pre-development audit) is qualitative and quantitative assessment of materials and products prior to deconstruction, demolition or renovation of buildings and infrastructures. It includes demolition and refurbishment assessments of what can be reused from deconstruction and stripped out, respectively. It informs the potential to reuse products and materials in subsequent construction and/or fit out (of refurbishment)^{6 7}

Material audit (or resource audit) is the audit focusing on the materials, their characterisation, recycling and recovery. Such audit is typically performed before traditional demolition and can be also called **pre-demolition audit**.¹

Waste audit is the material audit focusing on different waste streams, their characterisation and management.³

Reclamation audit is the pre-development audit focusing specifically on building products before refurbishment or deconstruction, their characterisation and planning of their reuse. It results in the reclamation inventory.⁸

Pre-deconstruction audit is the reclamation audit before building deconstruction. Its main purpose is to prevent the reusable products becoming waste.¹

⁴ Based on PROGRESS project, Deliverable D9.1 Comprehensive Overview of the Project

⁵ Based on the adapted text of the new Construction Products Regulation (CPR)

⁶ Based on the European Commission's Waste Audit Guidelines

⁷ Based on BAMB project <https://www.bamb2020.eu/wp-content/uploads/2017/07/Reuse-of-building-products-and-materials-barriers-and-opportunities.pdf>

⁸ Based on FCRBE project https://opalis.eu/sites/default/files/2022-02/FCRBE-Reclamation_Audit-v12.pdf

Cascading is a repeated use of a resource usually starting at a level of high value with decreasing quantity and quality at each subsequent stage or cycle, depending on the processes used.⁹

Deconstruction (or disassembly) is the selective dismantlement of building components, specifically for reuse, repurposing, recycling, and waste management. It differs from demolition where a site is cleared of its building by the most expedient means.¹

Decontamination is reduction or removal of hazardous materials.¹

Deep renovation is a renovation, which focuses on essential building elements, and which transforms a building or building unit into a zero-emission building.¹⁰

Demolition is the tearing down of buildings and other structures typically resulting in their destruction. It contrasts with deconstruction, which involves taking a building apart while carefully preserving valuable components for reuse purposes.¹

Selective demolition is the demolition focused on specific waste materials that are treated separately from the mixed waste. It results in higher quality materials for recycling. It is often combined with deconstruction of selected reusable components.¹

Destruction is the intentional damaging or discarding of a product as waste with the exception of discarding for the only purpose of delivering a product for preparing for re-use or remanufacturing operations.¹¹

Distance selling is offer for sale, hire or hire purchase of products, online or through other means of distance sales, whereby the potential customer cannot physically access the product displayed.⁷

Execution means all activities carried out for the physical completion of the construction works including procurement, the inspection and documentation, such as work on site or fabrication of components off site and their subsequent erection on site.^{12 13}

Maintenance is an action (or series of actions) carried out during the working life of the structure or product to retain it in a condition where it can function as specified. It includes set of activities to enable it to fulfil the requirements for reliability.^{2 7 8}

Manufacturing is an activity required to produce and deliver the component, which may encompass fabrication, welding, mechanical fastenings, assembly, testing and documentation of the performance characteristics declared.^{9 14}

⁹ Based on ISO 59004

¹⁰ Based on the Energy Performance of Buildings Directive (EPBD)

¹¹ Based on the Ecodesign for Sustainable Products Regulation (ESPR)

¹² Based on EN 1990 (Eurocode 0)

¹³ Based on EN 1090-2

¹⁴ Based on EN 1090-1

Preparing for assembly is an activity performed on the constituent products to produce the parts ready for assembly and inclusion in components, such as identification, handling and storage, cutting, shaping and holing.⁹

Preparing for reuse means checking, cleaning or repairing recovery operations, by which products or components of products that have become waste are prepared so that they can be re-used without any other pre-processing.¹⁵

Recycling is a process where the waste materials are collected, broken down and processed to be converted into raw materials for new products. The process is typically energy intensive, requires a special facility and differs from reuse where the components do not enter the material stage.¹¹

Closed-loop recycling is a process in which materials are recovered to be continually used through unlimited use cycles without loss or degradation of their original properties. An example of closed-loop recycling is recycling steel into steel by re-melting.¹

Open loop recycling is a process in which materials are recovered to be used through limited use cycles because their original properties are lost or degraded so that further use is not possible.¹

Downcycling is a recycling process when the product created from recycled material is of lower commercial value, quality or functionality than the original product. One example is the crushing of concrete for use as road fill or aggregate.¹

Upcycling is a recycling process when resulting product or material is of a higher commercial value, quality or functionality than the original item.¹

Refurbishment (or reconditioning) means preparing or modifying an object that is waste or a product to restore its performance or functionality within the intended use, range of performance and maintenance originally conceived at the design stage, or to meet applicable technical standards or regulatory requirements, with the result of making a fully functional product.^{9 7}

Remanufacturing is an industrial process in which a product is produced from objects that are waste, products or components and in which at least one change is made to the product that affects the safety, performance, purpose or type of the product.⁷

Repair means returning a defective product or structure (fixing or replacing its defective components) to a condition where it fulfils its intended use. This activity falls outside the definition of maintenance.^{2 7 8}

Repurposing is any operation that changes the function or purpose of a component.¹

Reuse is any operation by which the building components are used again. They may be reused for the original function (a conventional reuse scenario), or repurposed, but the components will only have minor alterations, retaining a similar (or the same) form. The

¹⁵ Based on the Waste Framework Directive (WFD)

operation includes checking, cleaning or repairing, by which the components are prepared so they can be used without any other pre-processing. Components can be reused in closed-loop system without repurposing or open-loop system resulting in lower or higher value of the reused products.^{1 11}

Adaptive reuse (of buildings or building sites) is the process when the buildings or sites are repurposed for use other than the original design. Adaptive reuse is not the focus of the ADVANCE project.¹

In-situ reuse means that the component is reused locally in the same or neighbouring building site without the need to organize its transport.¹

Relocated reuse requires transport of the component over longer distances.¹

Upgrading means enhancing the functionality, performance, capacity or aesthetics of a product.⁷

Waste management is the collection, transport, recovery (including sorting), and disposal of waste, including the supervision of such operations and the aftercare of disposal sites, and including actions taken as a dealer or broker.¹¹

Waste prevention means measures taken before a substance, material or product has become waste, that reduce: (a) the quantity of waste, including through the re-use of products or the extension of the life span of products; (b) the adverse impacts of the generated waste on the environment and human health; or (c) the content of hazardous substances in materials and products.¹¹

Waste recovery is any operation the principal result of which is waste serving a useful purpose by replacing other materials which would otherwise have been used to fulfil a particular function, or waste being prepared to fulfil that function, in the plant or in the wider economy. Annex II sets out a non-exhaustive list of recovery operations.¹¹

Waste treatment means recovery or disposal operations, including preparation prior to recovery or disposal.¹¹

Actor is a natural or legal person/organisation responsible for carrying out any activity or in possession of the materials, products or components at any stage of the building's life cycle.

Constructor is any natural or legal person executing the construction works.⁹

Contractor is any natural or legal person acting on behalf of the owner of the construction, products, material or waste with the responsibilities specified in the contract.

Dealer is a retailer or any other natural or legal person who offers products for sale, hire or hire purchase, or displays products to customers in the course of a commercial activity, whether or not in return for payment.⁷

Distributor is any natural or legal person in the supply chain, other than the manufacturer or the importer, who makes a product available on the market, including by offering products for sale, hire or hire purchase, or displaying products to customers or installers during a

commercial activity, and including through distance selling, whether or not in return for payment.^{2 7}

Economic operator is the manufacturer, the authorised representative, the importer, the distributor, the fulfilment service provider or any other natural or legal person in relation to the manufacturing or remanufacturing of products, including reused products, or to making those products available on the market in accordance with CPR.^{2 7}

Holder is any natural or legal person that possesses, carries or legally owns the object of consideration.⁹

Waste holder means the waste producer or the natural or legal person who is in possession of the waste.¹¹

Manufacturer is any natural or legal person who manufactures a product or who has such a product designed or manufactured and markets that product under its name or trademark or, in the absence of such person or an importer, any natural or legal person who places on the market or puts into service a product.^{5 12}

Service provider is any natural or legal person providing a service to a manufacturer or to a supplier of a key part, provided that the service is relevant for the manufacturing of products, including to their design, or to their deinstallation in the case of reused products.²

Supplier is any natural or legal person providing raw materials, interim products, or used products to manufacturers or to other persons providing raw materials, interim products, or used products to manufacturers.²

User is any natural or legal person using a solution for commercial, private or public purposes.⁹

End user is any user, to whom a product has been made available either as a consumer outside of any trade, business, craft or profession or as a professional end user during its industrial or professional activities.¹⁶

Waste producer is anyone whose activities produce waste or anyone who carries out pre-processing, mixing or other operations resulting in a change in the nature or composition of this waste.¹¹

Building element is a technical building system or an element of the building envelope.⁶

Building envelope means the integrated elements of a building which separate its interior from the outdoor environment.⁶

CE marking is a marking by which the manufacturer indicates that the relevant product is in conformity with the applicable requirements set out in Union harmonisation legislation providing for its affixing.⁷

¹⁶ Based on the European Regulation (EU) 2019/1020.

Construction (or construction works) is everything that is constructed or results from construction operations whether over or in the ground or water. This term covers both building and civil engineering works comprising both structural and non-structural components.^{2 8 9 14}

Building is a roofed construction having walls, that provide shelter for its occupants or contents as one of its main purposes, usually partially or totally enclosed and designed to stay in one place permanently.^{6 17}

Civil engineering works means construction works including, but not limited to roads, bridges, tunnels, pylons and other facilities for transport of electricity, communication cables, pipelines, aqueducts, dams, airports, ports, waterways, and installations which is the bases for the rails of railways.

Structural steelwork means steel structures or manufactured steel components used in construction works.⁹

Degradation is loss of item performance due to changes in its material, geometry or connection to the system.

Design strategy is a set of rules and requirements for the design process to achieve optimal solution with respect to the specific set of goals.

Design for deconstruction (design for disassembly, DfD) is a design strategy considering how a building can be taken apart allowing for effective recovery of building materials and components.¹

Design for circularity (DfC) is a design strategy based on the circular economy principles.⁹

Design for end-of-life (DfEOL) is a design strategy considering one or more end-of-life scenarios including the communication of the relevant design information to the end-of-life industry.¹

Design for reuse is a specific DfEOL approach considering deconstruction and reuse of building components as one of the basic requirements. The design documentation should take into account also reuse process.¹

Design life (or design working life) is assumed period for which the component or structure is to be used for its intended purpose with anticipated maintenance but without major repair being necessary.¹⁰

Digital passport is a repository of machine-readable information about a physical entity or process in open data format according to the dedicated specification. The data may be open or with restricted access.

Building logbook (or Digital Building Logbook, DBL) is a common repository for all relevant building data, including data related to energy performance such as energy performance certificates, renovation passports and smart readiness indicators, as well as data related to the life cycle GWP, which facilitates informed decision making and information sharing within

¹⁷ Based on ISO 6707-1:2017

the construction sector, and among building owners and occupants, financial institutions and public bodies.⁶

Material passport (or Digital Material Passport, DMP)

Product passport (or Digital Product Passport, DPP) is a set of data specific to a product that includes the information specified in the applicable delegated act adopted pursuant to Article 4 of ESPR and that is accessible via electronic means through a data carrier in accordance with Chapter III of ESPR.⁷

Construction Product passport is the Digital Product Passport of construction products according to the new Construction Products Regulation.²

Renovation passport is a tailored roadmap for the deep renovation of a specific building in a maximum number of steps that will significantly improve its energy performance.⁶

Environment means surroundings in which an actor operates, including air, water, land, natural resources, flora, fauna, humans, and their interrelationships.⁹

Biosphere is part of the environmental system that is capable of supporting life.⁹

Technosphere is the realm of human technological activity which results in a technologically modified environment.⁹

Environmental impact means any change to the environment, whether adverse or beneficial, wholly or partially resulting from a product system during its life cycle or beyond the system boundary directly related to the product.⁷

Environmental footprint is a quantification of a product's environmental impacts, whether in relation to a single environmental impact category or an aggregated set of impact categories occurring in one or more life cycle stages.⁷

Carbon footprint is the sum of greenhouse gas emissions and their removals in a product system, expressed as CO₂ equivalents and based on a life cycle assessment using the single impact category of climate change.⁷

Whole-life-cycle greenhouse gas emissions are greenhouse gas emissions that occur over the whole life cycle of a building, including the production and transport of construction products, construction-site activities, the use of energy in the building and replacement of construction products, as well as demolition, transport and management of waste materials and their reuse, recycling and final disposal.⁶

Life-cycle global warming potential is an indicator which quantifies the global warming potential contributions of a building along its full life cycle.⁶

Essential characteristics are those characteristics of the product which relate to the basic requirements for construction works set out in Annex I of CPR, and those which are listed as predetermined environmental essential characteristics in Annex II of CPR.²

Kit is a product placed on the market by a single economic operator as a set of at least two separate items, none of which needs to be a product itself, intended to be incorporated together in construction works.²

Structural kit means set of structural components to be assembled and installed on site.¹⁰

Life cycle means the consecutive and interlinked stages of a product's life, from raw material acquisition or generation from natural resources, or in the case of products which have previously been incorporated in a construction work, from the latest de-installation from the construction work to final disposal.^{2,7}

End-of-life is the life cycle stage that begins when a product is discarded and ends when the product is returned to nature as a waste product or enters another product's life cycle.⁷

Material (e.g. steel) means any substance, excluding waste, with specific properties that is embedded in the products in a permanent manner.

Constructional material (e.g. constructional steel) is a material used in the construction works.

Structural material (e.g. structural steel) is a constructional material used in the load bearing (structural) components.

Obsolescence is loss of product performance due to changes in the performance requirements.¹⁸

Performance is the degree to which a product or system has certain scalable characteristics.²

Adaptability is the possibility to change or modify a product, system or module to make it suitable for a particular purpose.¹³

Circularity is the degree of alignment with the principles for a circular economy.⁹

Durability is the ability of a product to function as required, under specified conditions of use, maintenance and repair, until a limiting event prevents its functioning.⁷

Load bearing capacity is value or set of values for the loads that can be carried by the component referring respectively to either a single type and direction of loading or to a set of loads in various directions and referring to a defined level of resistance in accordance with EN 1990 and the relevant parts of EN 1993, EN 1994 or EN 1999. For kits the load bearing capacity refers to loads and load combinations the kit can carry that are relevant to the structure for its intended purpose.¹⁰

Recyclability is the susceptibility of a material or product to be effectively and efficiently separated, collected, sorted and aggregated in specific waste streams for the purpose of being recycled into secondary raw materials while minimising the loss of quality or functionality compared to the relevant primary raw material.²

Reliability is the ability of a structure or a structural member to fulfil the specified requirements, including the design working life, for which it has been designed. Reliability is

¹⁸ Based on ISO 15686-1:2011.

usually expressed the probability that a product functions as required under given conditions for a given duration without a limiting event. It covers safety, serviceability and durability of a structure.^{5 10}

Resilience is the ability of a system to endure, resist, adapt to or recover from disruptive events or conditions, whether natural or anthropogenic.

Reusability is the ability of a product, component or system to be used in its original form more than once and maintain its value and functional qualities during recovery to accommodate reapplication for the same or any purpose.¹⁹

Weldability is quality of a material for which a qualified welding procedure can be developed.¹⁰

Product is formed or formless physical item or a kit designed for or utilized with a purpose and placed on the market or put into service.^{9 7}

Component is a product manufactured as a distinct unit to serve a specific function or functions and intended to be incorporated into another product or structure, which may itself be an assembly of several smaller components.^{7 9 13}

Structural component is a component to be used as load-bearing parts of works designed to provide required performance which can be used directly as delivered or can be incorporated into a construction work.^{9 10}

Constituent product is a product used in manufacturing with properties which enter structural calculations or otherwise relate to the mechanical resistance and stability of construction works.^{9 10}

Construction product is a product that is placed on the market, including by means of supply to the construction site, for incorporation in a permanent manner into construction works or parts thereof with the exception of items that need first to be integrated into a kit or another construction product prior to being incorporated in a permanent manner into construction works.²

Custom-made product is a product that, due to the specifications of the client, has a variation in terms of size or material when compared with all other products produced for other clients by the economic operator in question.²

Intermediate product is a product that requires further manufacturing or transformation such as mixing, coating or assembling to make it suitable for end-users.⁷

Permanent product is a product intended to remain in the construction work, or in parts thereof, after the completion of the construction or renovation process.²

Remanufactured product is a product that is not waste or has ceased to be waste in accordance with Directive 2008/98/EC, which has been installed at least once into a

¹⁹ Based on Level(s) <https://ec.europa.eu/jrc/en/publication/levels-common-eu-framework-core-sustainability-indicators-office-and-residential-buildings-part-3>

construction work, and that has been subject to major alteration which is qualified as essential to the product's performance.²

Used product is a product that is not waste or has ceased to be waste in accordance with WFD, and which has been installed at least once into a construction work, and that: (a) has not undergone major alteration so that it can be used for construction purposes without any other pre-processing; or (b) has been subject to a major alteration which, according to the applicable harmonised technical specification, is qualified as non-essential to the product's performance.²

Reused product is a used product installed for at least second time into a construction work.

Resource is an asset (material, component, waste) from which a solution is created or implemented.⁹

Natural resource is a resource occurring in nature.⁹

Virgin resource (or primary resource) is natural resource that is used as the resource for the first time as input in a process or for creating a solution. Virgin resources can be renewable or non-renewable.⁹

Renewable resource is a resource that can be naturally or artificially grown or replenished within a foreseeable time frame by processes found in nature.⁹

Secondary resource (or recovered resource) is resource that is obtained from one that has already been processed or used⁹

Service life is the cumulative time during which the component is in use.¹

Estimated service life (ESL) is the estimated service life of a component.²⁰

Reference service life (RSL) is a service life of a component, which is known to be expected under a particular set (e.g. a reference set) of in-use conditions and which may form the basis of estimating the service life under other in-use conditions.¹⁷

Structure (or structural assembly) is the assembled and organised system of connected structural components designed to carry loads and provide adequate rigidity.^{8 10}

Structural member is physically distinguishable part of a structure, e.g. a column, a beam, a slab, a foundation pile.⁸

Structural system is load-bearing members of a building or civil engineering works and the way in which these members function together.⁸

²⁰ Based on EN 15804

Sustainable development is a development that meets the environmental, social and economic needs of the present without compromising the ability of future generations to meet their own needs.⁹

System is a set of interrelated or interacting elements ⁹

Closed loop system is a system by which products or resources are used and the recovered and turned into new products or resources without losing their inherent properties.⁹

Economic system is a system by which a society organizes and allocates resources.⁹

Circular economy is an economic system that uses a systemic approach to maintain circular flow of resources by recovering, retaining or adding to their value, while contributing to their sustainable development. It involves sharing, leasing, reusing, repairing, refurbishing, and recycling existing materials and products as long as possible.^{9 21}

Linear economy is an economic system where resources typically follow the pattern of extraction, production, use and disposal.⁹

Environmental system is a set of systems of the natural environment that interact, encompassing biotic and abiotic components.⁹

Ecosystem is a dynamic complex of communities of plants, animals and microorganisms and their non-living environment interacting as a functional entity. ⁹

Social system is a system by which human beings are expected to undertake different types of tasks to achieve common goals within a society.⁹

Use

Intended use is the purpose of a product as set out in the applicable harmonised technical specifications or European assessment documents.²

Declared use is the use intended by the manufacturer, including the conditions for usage, as laid out in technical documentation, on labels, in instructions for use, in safety information, or in publicity material.²

Value is gain or benefit from satisfying needs and expectations, in relation to the use and conservation of resources.⁹

Waste (e.g. steel scrap) means any substance or object which is no longer considered to be an asset as it, at the time, provides insufficient value to the holder, or which the holder intends or is required to discard. ^{9 11}

²¹ Based on European Parliament's definition

<https://www.europarl.europa.eu/news/en/headlines/economy/20151201STO05603/circular-economy-definition-importance-and-benefits>

Construction and demolition waste (CDW) is waste generated by construction and demolition activities.¹¹

Hazardous waste is waste that poses substantial or potential threats to public health or the environment. Waste classification is based on the European List of Waste or based on its hazardous properties.¹¹

Reuse of Steel Case Study no. 12

Design for circularity – Petite Maison, Luxembourg



Project summary

Client: University of Luxembourg (UL)
Subsidized by: Esch2022 and frEsch.asbl
Contractors: Annen, CDCL, Gardula, Schreinerei Hoffmann, Mabilux, Prefalux, Reckinger
Architects: Carole Schmit (UL), Dragos Ghioca (UL)
Structural engineers: András Kozma (DESA), Christoph Odenbreit (UL)
Steel fabricator: ArcelorMittal
Engineering: Betic Ingénieurs-Conseils, BIM-Y, Fire Group SECO, DESA Ingénieurs-Conseils, Geri Securite Sante, Icone, Mersch Ingénieurs-paysagistes, Metrico, Paul Wurth – Geprolux, Polaris Architects, Schroeder & Associés
Construction cost (including demolition): N/A

Description of the new building

The Petite Maison building¹, located in Esch-Belval, Luxembourg, was initiated as an architectural project in January 2021 to promote the circularity of construction materials and contribute to the European Capital of Culture Esch2022. The project comprised design, construction, use and deconstruction phases. The structure was specifically designed for disassembling/deconstruction and reuse, incorporating the latest advancements from the European project REDUCE² on demountability and reuse of composite structures.

The main part of the building structure consisted of:

- a steel frame, measuring 10.8 meters (m) × 8.1 m, following a structural grid of 1.35 m,
- modular and prefabricated structural kits³ in standard sizes, including concrete slabs (1.35 m × 5.4 m) with bolted shear connections, adaptable steel connections,
- diagonal bracing systems (roof and wall),
- a timber roof with steel profiled cladding sheets, supported by steel posts,
- timber wall panels, partitions, cladding, and
- prefabricated concrete foundations.

During the use phase, the building was open for guided public visits, workshops, lectures, a cafeteria by Restopolis. A mobile exhibition on deconstruction, designed by Rotor in Brussels, as part of an INTERREG project called FCRBE was hosted in Petite Maison as well and was open to public visit from December 2022 until January 2023.

In August 2023, the deconstruction of the Petite Maison building commenced. QR codes were attached to reusable building components, linking them to a virtual database to facilitate future reuse. Reclaimed materials

and components are presently stored at ArcelorMittal's premises near the building site. Ongoing efforts are underway to transfer these materials to the City of Esch-sur-Alzette with the objective of giving these construction materials a second life.

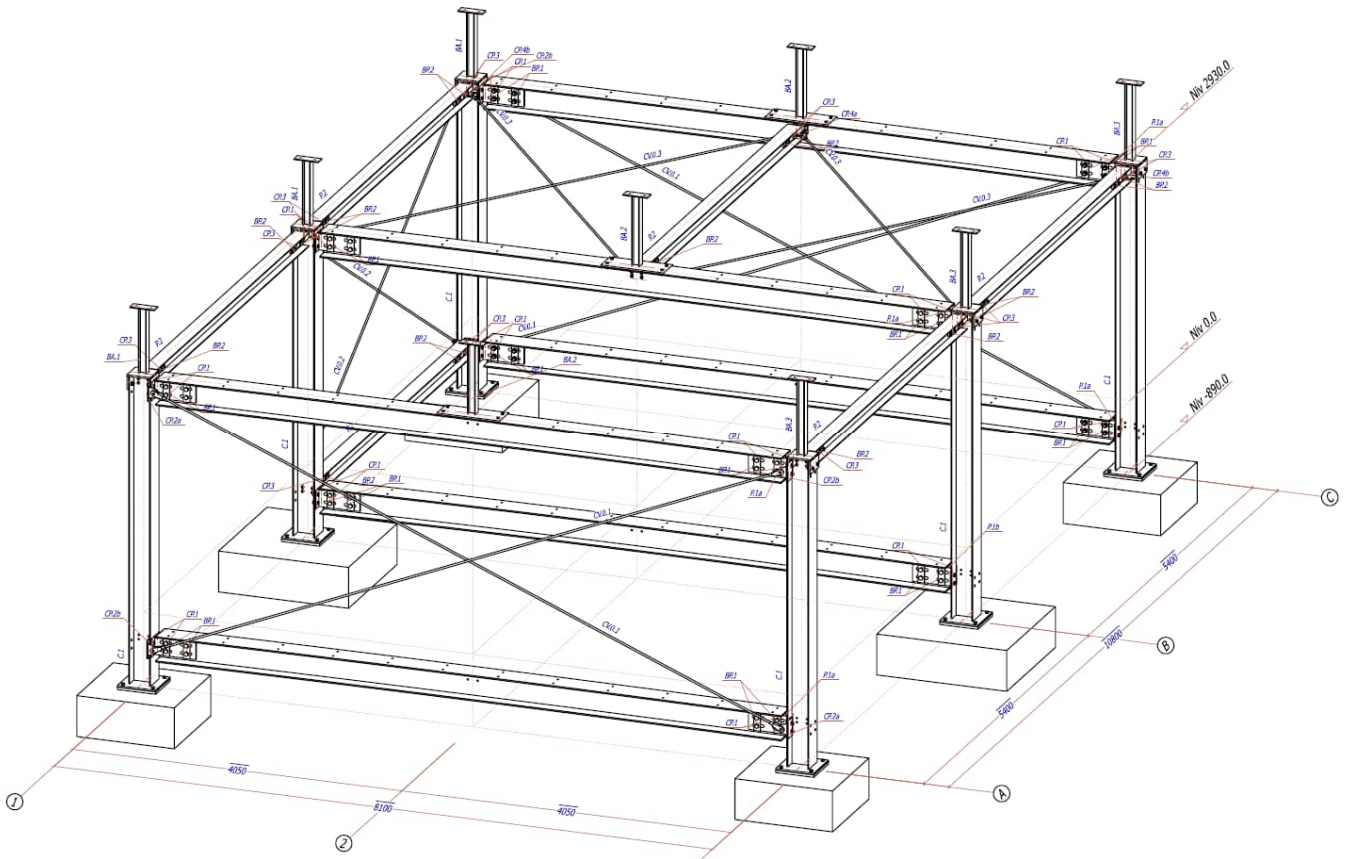
Design process

Several key considerations have been integrated into the design process to enhance sustainability and circularity:

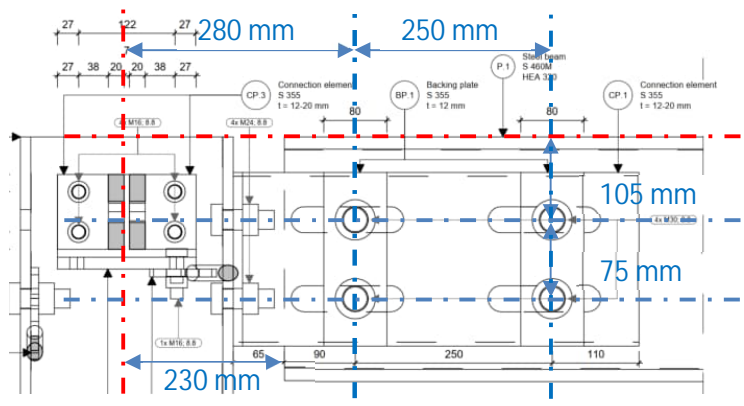
- Carbon optimization:
During the initial design phase, grade S355 steel was chosen for the frame. In the final design, grade S460 steel was adopted to optimize the frame's weight and minimized embodied carbon footprint, which resulted in 24% reduction in weight, decreasing from 17.39 tons to 13.25 tons.
Precambering was applied to equalize deflections. The level of necessary precambering was determined using a model with semi-rigid joints considering the real joint stiffness.
- Prioritization of modular prefabricated elements with standardized details:
Prefabricated concrete slabs have been standardized to conform to a uniform size, while all beams have been standardized in length, aligned with a structural grid of 1.35 meters.
The number of different elements has been minimized. Uniform sections, including identical bolt hole layouts, were used for columns and primary beams. All additional connected members (for example bracing, roof structure, etc.) used the existing pre-drilled holes in beams and columns.
Adaptable steel connections were utilized, featuring standardized midi grids for bolts in endplates and fin plates: the first row of bolts in the fin plate and endplate was 105 mm off the edge of the top flange of the beam, followed by 75 mm spacing for the other rows; the first column of bolts in the fin plate was 280 mm off the centreline of the column, followed by 250 mm for the other columns of bolts.
Concrete foundations are prefabricated, and are designed to be removable and potentially reusable.
- Consideration of member adaptability:
Adaptable steel connections enable secondary beams to connect with primary beams as well as columns of various sizes within the same structural grid, enhancing the adaptability of these beams.
- Designing for disassembly using bolted connections:
Bolted connections have been favored within the structure: demountable shear connections between beam and slab, connections for beams, columns, bracings, and foundations, allowing for easier disassembly compared to welded connections. Welding was kept to an absolute minimum (only the base plate is welded to the column, nothing else).
- Responsible sourcing of materials:
Main building components are new materials with low environment impact inputs where possible, while non-loadbearing timber panels are reused materials; all are sourced from nearby suppliers, thereby minimizing environmental impact.

The design loads and design codes are summarized in the following table (steel structure):

Load (Design code)	Characteristic values (kN/m ²)	
Permanent load (EN 1991-1-1)	Cladding - roof	0.25
	Cladding - wall	0.85
	Technical installations	0.50
Snow (EN 1991-1-3)	Snow load on the ground, s_k	0.60
Wind (EN 1991-1-4)	Peak velocity pressure: q_p	0.75
Imposed load (EN 1991-1-1)	Imposed load on slabs (Cat. C3)	5.00
	Imposed load on roof (Cat. H)	0.40



Drawing of the structure.



Details of a complex joint where multiple members meet³; Standardized midi grids for bolts in endplates and fin plates³.

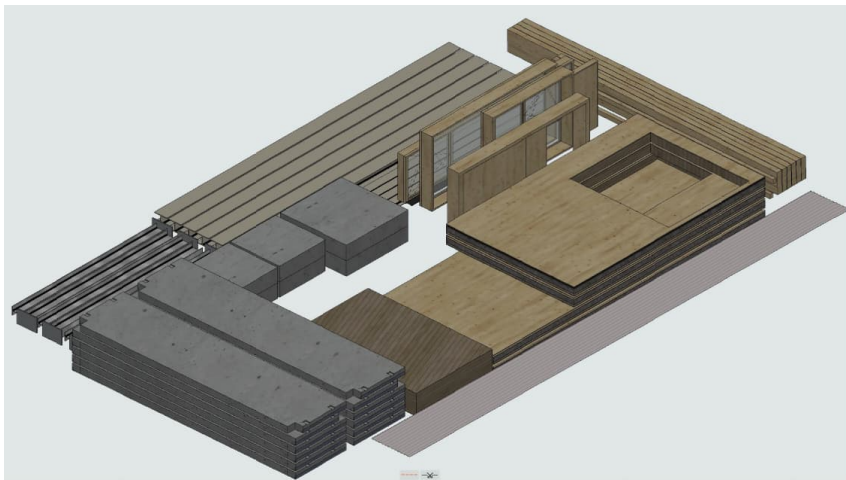
Construction and deconstruction processes

Both digital and printed inventory catalogues are easily accessible. Each construction element underwent after BIM-modelling by the architects, scanning and inventorying, with QR codes attached, linking to a deconstruction platform jointly developed by LIST and BIM-Y. This platform provides detailed information on geometry, technical properties, and manufacturers.



Steel skeleton with prefabricated concrete slabs¹.

The same contractors are responsible for the construction and deconstruction of the building. The deconstruction process closely mirrored the original construction sequence. A deconstruction procedure⁴ and storage plan, devised by Uni.Lu, facilitated efficient handling and organization throughout the deconstruction process.



Storage space measuring 13.5 m × 6 m, estimated by Dragos Ghioca, Uni.Lu.

Schroeder & Associés conducted site visits and surveys to evaluate material and component damage during deconstruction and their potential for reuse. According to their reports and the authors' visit to the storage site:

- Steel sheets were unscrewed from the timber roof frame without any loss, but minor damages were observed in the timber frame at the screw level.
- The elements within the steel frame, including prefabricated concrete slabs and foundations, are well separated and in good condition: there is no visible degradation of galvanization, no signs of rust, and no visible deformation of the profiles. However, local damages have been observed in the concrete foundation blocks. Additionally, the edges of the concrete slabs near the shear connection were protected by steel angles, and no damage could be observed.
- Dismantling the timber frame and partitions revealed challenges with connections between different elements: while the elements remained sufficiently rigid during handling, the screws were deeply embedded, it was necessary to cut notches to access the screw heads.
- Several timber cladding boards were damaged due to nailing fixation; the use of stainless-steel screws would have been more suitable.

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- Salvaged elements were labelled by the contractors after deconstruction.
- Due to the size of the timber partitions, they were temporarily stored at PREFALUX.
- The L plates in the adaptable steel connections with the bolts have been reattached to the beams.
- Bolts, threaded rods, and nuts have been recovered.
- Other salvaged materials included major part of the insulation elements, plastic covering films, etc.



Photo taken during deconstruction © Schroeder & Associés; Timber panels with notches for accessing screw heads during deconstruction.



Reclaimed materials are stored at ArcelorMittal's Differdange site, with steel connections reassembled, and QR codes and labels attached to the main structure components. Local damages to the concrete foundation blocks have been observed.

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Future reuse scenarios

Future reuse scenarios are under consideration for the materials reclaimed from the Petite Maison project:

- Relocation: the plan involves relocating and reconstructing the Petite Maison building using the same materials and components from within the project itself.
- Extension: this approach involves accommodating reclaimed materials and components in the same layout of the original Petite Maison building, with extensions constructed using reclaimed materials sourced from other buildings or projects.
- Adaptation to new layout: the possibility to design a one-family house on an existing empty plot in the city of Esch integrating the reclaimed materials has been studied. More similar elements are needed to complete the design.

Conclusions

The Petite Maison stands as a pioneering demonstration project, illustrating the potential of new building construction to champion material circularity via a system that is de-constructable, modular, and reusable. Following deconstruction, a valuable stock of reusable building elements is generated, with high potential for future reuse. Deconstruction of buildings and salvaging their components are technically feasible, key aspects to this success are:

- Early engagement during the design phase,
- The incorporation of demountable systems alongside prefabricated and standardized elements and details,
- Comprehensive inventory documentation,
- Contractor familiarity with the building's structure,
- Well-structured deconstruction procedure and storage plans.

Acknowledgement

The Petite Maison project was led and coordinated by architect Prof. Carole Schmit, with support from R&D specialist Dragos Ghioca, and in collaboration with Prof. Dr. Christoph Odenbreit at the University of Luxembourg.

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Further information

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This case study was prepared by Jie Yang, José Humberto Matias de Paula Filho from ArcelorMittal, with the support of Christoph Odenbreit, Shahin Sayyareh, András Kozma, and Carole Schmit.

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Funded by the
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Reuse of Steel Case Study no. 13

Reuse of steel sheet piles



Project summary

Project: Remediation of “Schwarze Pumpe” brownfield site,
Spremberg, Germany
Project owner: LMBV GmbH
Design: Arge, CDM Smith
Contractors: Arge Lobbe / Bauer
Steel product: Sheet pile PU 22⁻¹ 14.0 m – 23.0 m S 355 GP 2,000 t
Steel manufacturer: ArcelorMittal
Construction cost: N/A

Reuse of steel sheet piles

Sheet piles can be applied in many fields, such as water transport solutions like quay walls, hazard protection solutions such as dams, mobility infrastructure solutions like rail and road bridges, tunnels, underground car parks, and environmental protection solutions such as polluted soil remediation. The modularity of steel sheet piles facilitates their reuse; they can be extracted from the ground at the end of their service life. In temporary applications, steel sheet piles are often reused multiple times in the same project or for subsequent projects. Steel sheet piles are top choice in [temporary scenarios](#) for example, cofferdams in water, linear excavations, water retention, complicated utilities installation and repairs, and limitation of settlement in nearby structures and services.



Temporary applications, such as excavation pits, have shorter life cycles, often under 2 years. Contractors commonly employ sheet piles for such purposes, with sections sometimes reused up to 10 times. Symmetric U-sections are particularly suitable for reuse due to their compactness and high stiffness. After each use, a portion (≤ 50 cm) is typically removed if deformations or damages from the installation process are observed at the head or toe. In addition, it is becoming increasingly accepted by project owners to install used sheet piles in permanent applications. After long service lives, the sheet piles can still be extracted from the soil, being recycled and serve as input for the newly produced steel. This establishes a perfect cycle for the infinite use of steel, without any degradation of material properties.

Reuse of steel sheet piles in temporary applications

[Decontamination of polluted soils:](#)

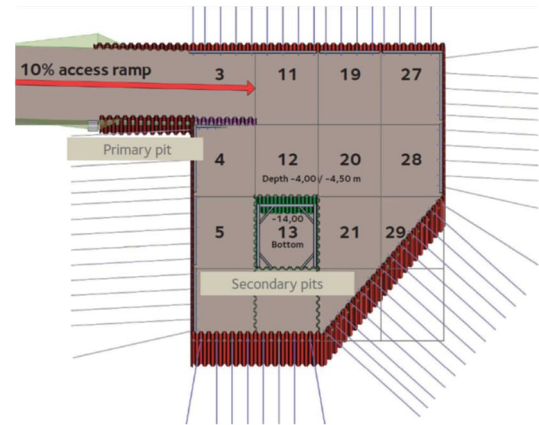
Soil decontamination projects involve enclosing contaminated areas with steel sheet pile walls. The procedure typically includes surrounding the area with an impervious sheet pile wall, excavating contaminated soil, treating

it off-site or on-site, returning treated soil, and removing and reusing the sheet pile wall. This process can be done in one phase or in smaller sequential cells, the latter allowing for multiple reuses of the sheet piles. Once removed, no waste remains on-site.

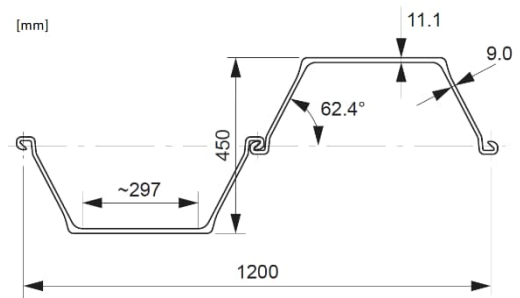
[Remediation of "Schwarze Pumpe" brownfield site, Spremberg, Germany¹](#)

Established in 1955 as the VEB Gaskombinat Schwarze Pumpe, the Schwarze Pumpe Industrial Park initially focused on brown coal energy and briquette production. By 1992, modernization efforts aligned with environmental standards led to the dismantling of old facilities and the construction of new power plants. Remediation efforts began in 2017, processing 430,000 tonnes of contaminated soil using soil treatment processes to purify segments contaminated with benzene and phenols. Heavily polluted areas were excavated, thermally treated, and restored, with an on-site soil cleaning plant constructed to reduce transport requirements.

The adoption of a sheet pile solution was motivated by its modularity and potential for multiple reuses on-site. The primary pit enclosure was first executed with anchored sheet piles. Secondary pits were then executed within the enclosed areas. Specifically, PU 22⁻¹ profile was selected for its robustness and reusability. The profile was rolled with a 1 mm reduced thickness compared to the standard profile (PU 22) to optimize the total weight of piles while maintaining sufficient bearing capacity for the project needs. Sheet pile lengths were optimized to suit various application areas, ranging from 14.0 m to 23.0 m, with considerations for length reduction due to repeated use already factored into the determination process. After each use, the sheet piles were cleaned, decontaminated, and they were stored for reuse in future secondary pits.



Plan view of the pits¹



PU 22⁻¹ profile

[Cofferdams in water:](#)

Steel sheet piles can have good watertightness as well as high resistance to hydraulic pressures, and are reclaimable after use. In scenarios like constructing bridge piers within a river, sheet piles can serve as formwork, with some left in position within the cofferdam to protect the concrete foundation.

[Steel sheet pile wall, Vienna tube extension](#)

A 4.6 km extension at the northern end of the Vienna U-Bahn line U1 was opened in 2006, serving a population of more than 90,000 people and easing traffic congestion in the city. The U1/3 Großfeldsiedlung section near the end of the extension is 1.76 km long, with 1.3 km designed as a cost-effective cut-and-cover tunnel, 10 m deep, and 5 m underwater. A watertight cast-in-situ concrete box section, constructed inside temporary sheetpiling cofferdams, was selected for the tunnel. The works were split into short sections approximately 70 m long, and the cofferdam was relocated as the works advanced. The cofferdam sidewalls were AU 20 double piles, with double PU 25s for the transverse walls; they were held back by a layer of struts. AU 20 sheet piles were chosen as the most cost-effective solution because (i) they can be reused several times with good driving performance suitable for



Sheet pile wall with struts

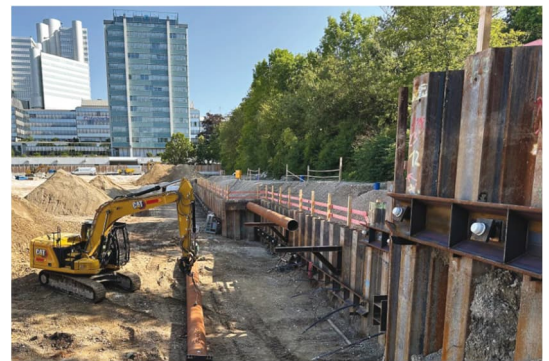
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the compact gravel of the Danube valley, (ii) compared to the 600 mm wide PU piles, there was a 10% saving on the volume of steel, and in addition, the number of interlocks was reduced, resulting in improved watertightness. Before reuse, the piles were inspected to ensure they were in good condition (the piles were not significantly deformed despite being driven into compact soils); the interlocks were then cleaned and filled with fresh sealant. This procedure was especially economical for the 750 mm wide AU 20 piles, as it minimized the number of piles being driven, extracted, and inspected, as well as the number of interlocks requiring treatment.

[Steel sheet pile wall, New Headquarters of the Bayerischen Versorgungskammer \(BVK\) in Munich¹](#)

The new BVK headquarters is under construction at the former Siemens site on Richard-Strauss-Strasse 76 (RS76) in Munich. Züblin Spezialtiefbau GmbH was commissioned for the excavation pit project. A total of 188,300 m³ of soil will be excavated. Temporary sheet pile constructions were erected on the south and east sides of the construction site for excavation support in 2023. The contractor chose EcoSheetPile™ Plus Series Sheet Piles, produced in Luxembourg with 100% recycled steel and 100% renewable electricity (solar and wind). The installed sheet piles were in profile PU 28⁻¹, S 355 GP, range in length from 15.20 to 22.20 meters, totalling 798 tonnes and a sheet pile surface area of 4,850 m². The RS76 excavation project has been awarded a certificate for "Sustainable Building Site" by the German Sustainable Building Council, DGNB. In addition to initiatives such as extensive noise protection, further use of demolition material, and tree protection, sustainability contributions from the sheet pile construction are twofold: the sheet piles are XCarb® recycled and renewably produced, and they are rented and returned to ArcelorMittal's rental warehouse for future reuse after this project. ArcelorMittal Träger und Spundwand GmbH has begun transitioning all sheet pile warehouses' rental stock to EcoSheetPile™ Plus Series in the fourth quarter of 2022.



Sheet pile wall shoring of the excavation pit
© Züblin Spezialtiefbau

Reuse of steel sheet piles in permanent applications

[Reinforcing the Gorinchem - Waardenburg dyke with steel sheet piles, the Netherlands²](#)

While used steel sheet piles are often employed in temporary applications, they are less commonly reused in permanent structures such as dyke reinforcement. However, for the project alliance Graaf Reinald Alliantie, they proved to be the ideal solution for over 6 km of the 23 km dyke project, offering crucial support and reinforcement against hydraulic failure by piping. With Dutch tendering procedures now incorporating environmental impact considerations, Graaf Reinald Alliantie deliberately opted for used sheet piles to minimize environmental effects. To safeguard the dyke against piping, the length of the seepage path must be extended to prevent the occurrence of the phenomenon. A sheet pile wall perfectly fulfils this function, and in this application, a used sheet pile section performs just as effectively as a new one. The reinforcement of the Gorinchem-Waardenburg dyke has a theoretical lifespan of 100 years. Given the minimal corrosion of sheet piles embedded in the dyke body, they can be extracted at the end of the dyke's life. Some removed sheet piles may be reused or repurposed in other projects, while others may be directly recycled in an Electric Arc Furnace for new products.



Dyke reinforcement in Wolferen-Sprok NL²

Business models

Given the reusability and modularity of steel sheet piles, there are several business models:

- rental for a short period,
- purchase and re-sale after use,
- purchase with a buy-back option at the end of the project, or
- purchase followed by storage for future works.

[Widening of the railway tracks at the Belval train station, Luxembourg](#)

The Luxembourgish railway company CFL rehabilitated the train station at 'Belval – Mill' in Luxembourg (2008-2009), choosing steel sheet piles for the new quay structure. Despite compact marl in the soil, installation proceeded smoothly due to careful selection of the sheet pile sections and the driving method. The PU 18⁻¹ section, selected for its high stiffness, allowed for deeper driving and minimal wall deflection. The existing sheet piles, in excellent condition, could be easily extracted and the reclaimed sheet piles were kept by the contractors for future projects.



Conclusions

Steel sheet piles are versatile, modular, and reusable. In temporary scenarios, sheet piles are frequently reused multiple times, while acceptance of their reuse in permanent applications is growing. The reuse of steel sheet piles emphasizes cost-effectiveness and sustainability in construction projects.

Further information

¹F. Fohl, *Neue Zentrale der Bayerischen Versorgungskammer in München – Fokus Spundwandverbau*. *Geotechnik*, 2023, vol. 46, no. 3, pp. A16-17.

²F. Fohl, O. Hechler, *Reuse of Steel Sheet Piles – Best Practice*.

In: L. Bragança, M. Cvetkovska, R. Askar, V. Ungureanu (eds) *Creating a Roadmap Towards Circularity in the Built Environment*, Springer Tracts in Civil Engineering, 2024. Springer, Cham.

https://doi.org/10.1007/978-3-031-45980-1_3.

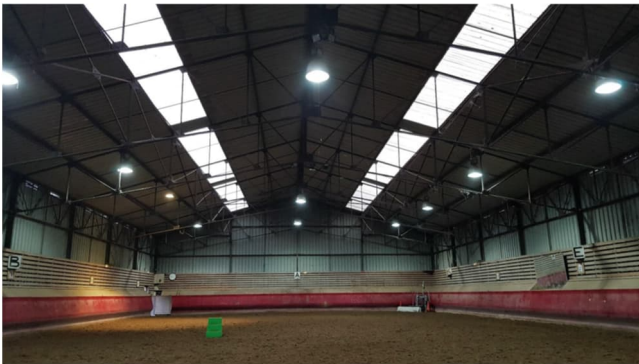
This case study was prepared by Jie Yang, José Humberto Matias de Paula Filho from ArcelorMittal, with the support of François Fohl, Cécile Prüm and João Martins.



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Reuse of Steel Case Study no. 14

The deconstruction and reassembly of a hall with truss structure



Project summary

Client:	SYTEVOM
Contractor:	VIRY – FAYAT GROUP
Architect:	ER ARCHITECTURE
Structural engineers:	ALBYR, ICS BOIS
Steel fabricator:	VIRY – FAYAT GROUP
Original steelwork:	1970s

Description of the existing building

The original building was situated in Gennevilliers in the north of Paris. The building served as indoor riding ring. It has been designed as a frame structure with hot rolled IPE sections used for the columns and truss girders. The truss girder was composed of equal leg angle sections of different sizes: L50x5 used for the upper chord, L60x6 used for the lower chord, L40x4 used for the uprights and diagonals in the centre of the truss and again L50x5 used for the truss elements near the columns. The connection between truss elements and upper and lower chord may be seen as specific feature as these connections are welded.

In total nine frames form the hall.

During the initial inspection of the existing building several members were observed to have suffered from buckling. These trusses were not re-usable and therefore they had been separated from trusses planned to be reused. Nonetheless, these trusses were kept in order to be used for the reassessment of material properties of the structural steel elements.



Deconstruction and Construction processes



Before the deconstruction, the steel structure has been initially inspected in order to identify elements that are not suitable for re-use and to identify main features as the connections between the elements.

Then truss girder were disconnected from the columns and moved to ground with a mobile crane. For transporting, the truss girders had to be separated in two halves. As the truss elements were welded this had to be done by grinding (mechanical cutting). Finally, all elements were transported to the plant of steel construction company VIRY situated in the vicinity of the new structure to be erected.

Reassessment of existing elements

In order to limit the amount of destructive testing, testing groups have been created with the help of surface hardness measurements. After having confirmed the testing groups, several tensile tests and tests for the determination of the chemical composition have been performed. The specimens were extracted from the trusses that could not be re-used due to excessive deformation of some elements. The results of the destructive tests showed homogenous results for the testing groups.

For IPE sections, a safe estimation of the yield strength has been done based on product standards applicable at the time of erection of the existing structure.

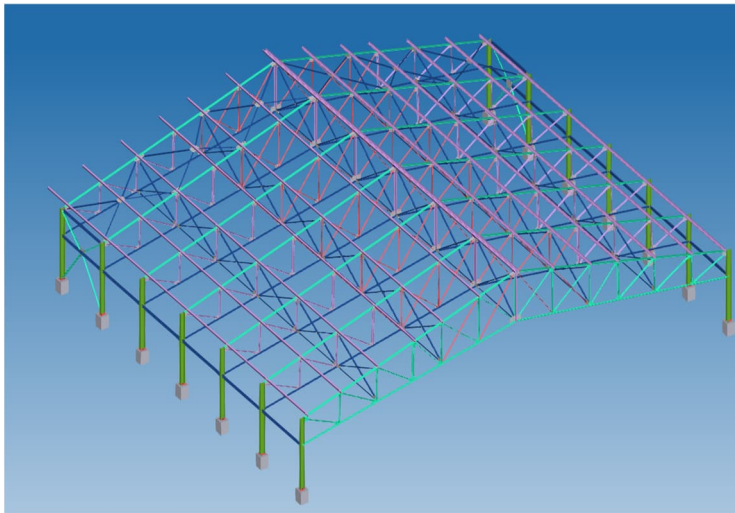
The welds have been assessed by visual inspection only, because there were exposed to limited stresses in the original building and they will also be exposed to limited stresses in the future structure.



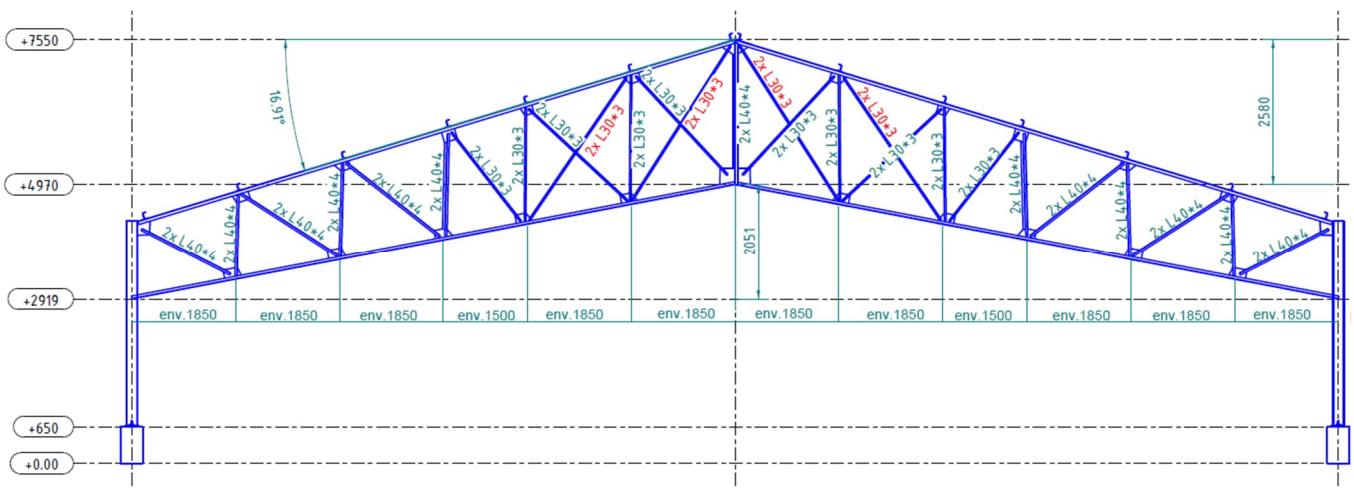
Design of the new building

The hall has been desconstructed and will be reused as canopy for a waste sorting centre situated in Epinal in the eastern of France. Due to increased loads it became necessary to redesign the structure. As a result, it was decided to reduce the distance between the frames. Additionnaly, during the inspection of the existing building several members were observed to have suffered from buckling. These trusses were not re-usable and therefore they had been clearly identified and seperated from the elements to be re-used.

A 3D image of the new structure and the design of the frame is shown in the next Figures.



The overall design of the new structure is identical with donor structre: The frame is constituted of the reclaimed hot-rolled section columns and a truss rafter. Additionnaly, to the reduction of the distance between the frames, it was necessary to add additional diagonals in the centre of the truss in order to account to the increased loading. These elements are indicated in red in the Figure below.



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Conclusions

The following key aspects of the process have been identified:

- Nearly the whole structure could be re-used including truss elements that have not been separated to their constituent sections.
- A rigorous planning of the deconstruction process is necessary to ensure limit problems and delays. In particular, the aspect of joints with mechanical fasteners may give indications on the ease of loosening of the bolts. In the present project, during the deconstruction it had to be decided to cut some connection because it was too difficult to loosen the bolts.
- Weld assessment is of importance. Based on a risk analysis, visual inspection has been estimated as sufficient in the present project, but for more critical connection with higher stress state more detailed non destructive testing will be necessary.

This case study was prepared by André Beyer and Amor Benlarbi, CTICM, with the support of Emile Seta, VIRY.



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Reuse of Steel Case Study no. 15

Deconstruction and relocation of four standard kit modules in a new complex of buildings in Râmnicu Vâlcea, Romania



Project summary

Client: S.C. CCS IMOB CONSTRUCT S.R.L.
Structural engineers: S.C. BON STEEL S.R.L.

Description of the existing building

A standard kit solution was developed in 2006 to build steel structures adaptable for different locations (climatic/seismic conditions) and applications, in different locations in Romania. The structure of standard kit was designed as 6 bays of 6.0 m, with a single span of 15.0 m and a height at eaves of 7m, with the possibility to connect several such kits for longer lengths.

Buildings from four construction sites, implemented between 2008 and 2010 in Baia Mare (A), Râmnicu-Vâlcea (B), Târgu Mureș (C), and Cluj-Napoca (D) were disassembly, relocated and integrated in a new

complex in Sibiu, Romania in 2019. The secondary structure consists of cold-formed steel purlins and side rails. The 3D views of the relocated structures are presented in Figure 1.



Baia Mare

Râmnicu Vâlcea

Târgu Mureș

Cluj-Napoca

Fig. 1. 3D view of the initial structure (structural model)



Fig. 2. Components of the existing structures

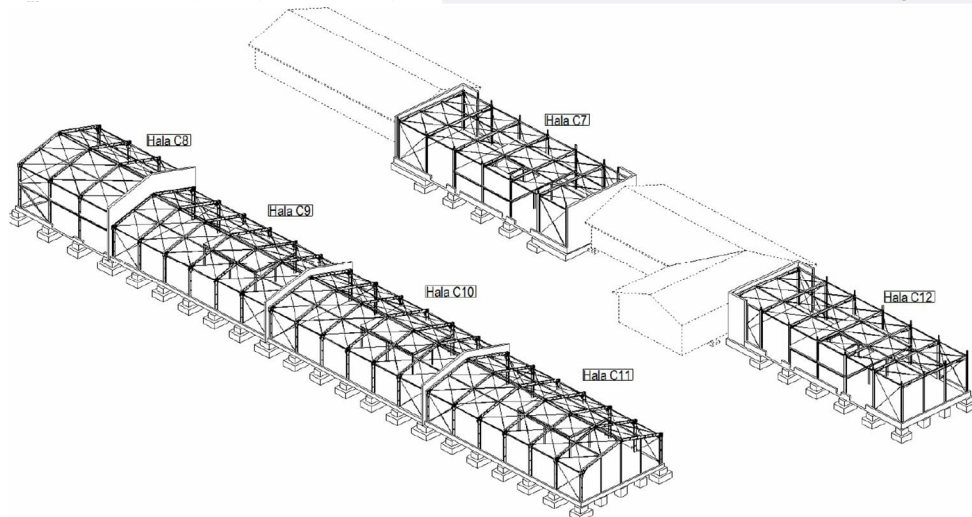
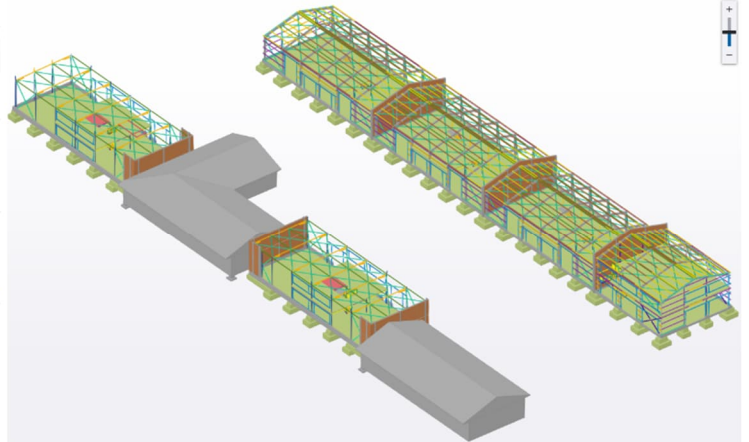
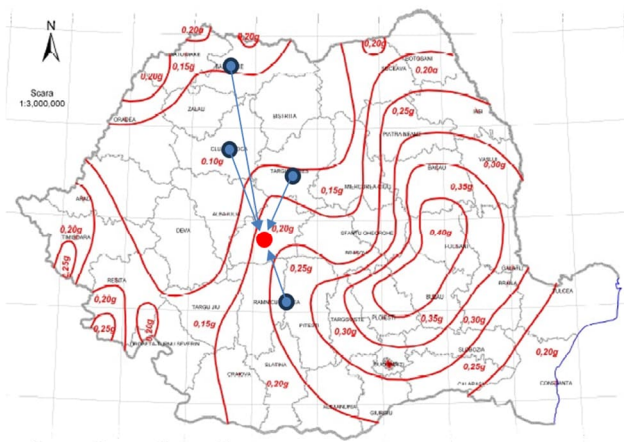


Fig. 2. Seismic map and the location of the new structure + 3D view of the new complex (structural model)

A new complex of buildings made from standard kit modules was implemented by the client. The industrial complex consists of two existing masonry structure buildings and six steel structure buildings. Four of these were deconstructed and relocated to Sibiu (buildings C8 - C9 - C10 - C11), while the other two steel structures are new.

Design process

The new building had to be redesigned with the idea of partially employing the elements recovered from the old buildings and adding a new floor for building C8 and partial floor for building C10.

The most important aspects for designing the new structure were:

- change of location, which imply new loading conditions (snow, wind, seismic actions);
- evolution of design codes (from 2006 to 2019)

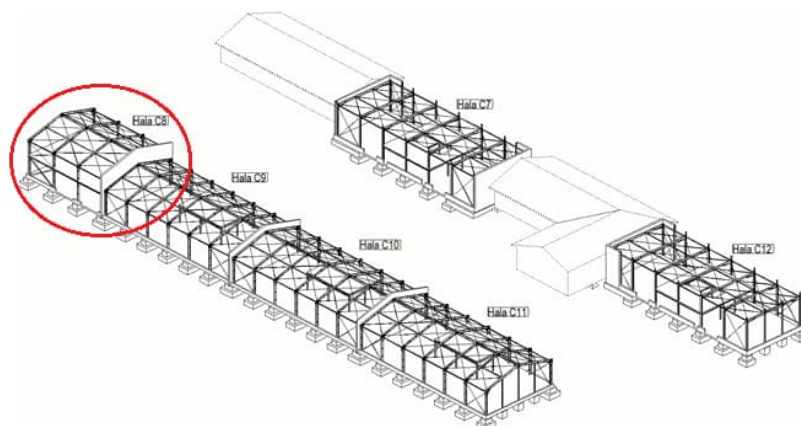
Loads Characteristic values	Characteristic values 2007 Design Codes				Characteristic values 2019 Design Code	max %
	Baia Mare	Cluj- Napoca	Târgu Mureş	Râmnicu Vâlcea	NEW SIBIU	
Snow load, $S_{0,k}$ kN/m ²	2.0	1.5	1.5	2.0	1.5	--
Wind pressure, q kN/m ²	0.5	0.4	0.4	0.4	0.6	↑25% - 50%
Peak ground acceleration for seismic action, a_g	0.12g	0.08g	0.12g	0.20g	0.20g	↑167% - 250%

Deconstruction and Construction processes

The project was divided into three contractual phases:

- (1) inspection of the existing structure and identification of available documentation; deconstruction process; inspection of the elements from the deconstruction of the existing building to assess their potential for reuse; experimental investigation of the mechanical properties of the steel components;
- (2) preparation of the new site and other groundworks;
- (3) new construction.

C8 structure



For this structure, an intermediate floor was introduced. In such conditions, the new loads lead to over-stresses in some elements, which required interventions to strengthen them. Some elements such as the longitudinal beams and vertical braces were not reused. Figure 3 presents the initial structure model and the new, indicating in red and blue the positions of the element and the strengthening.

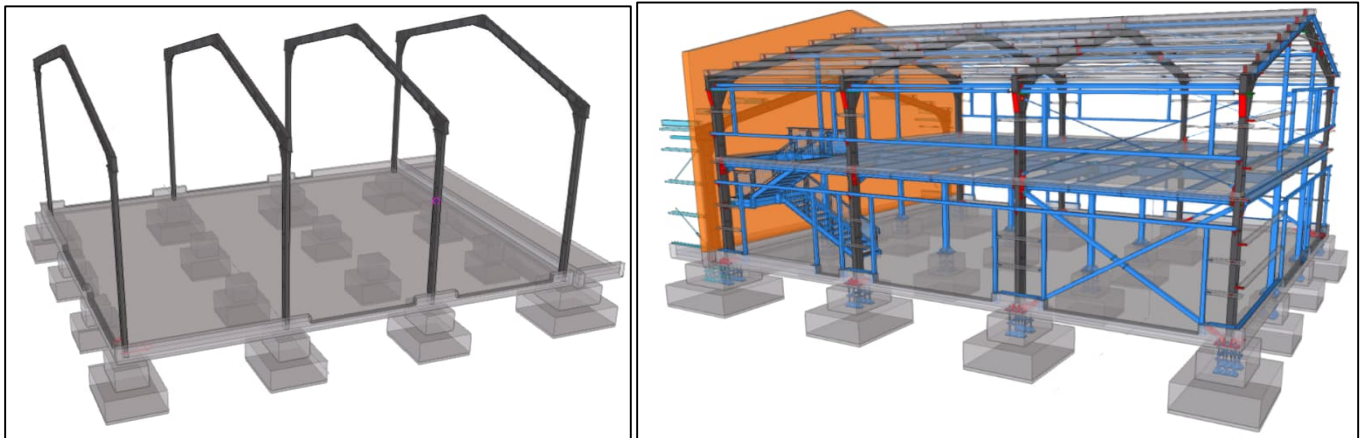


Fig. 3.

The pinned column base connection was changed into a rigid connection. The connection strengthening was done using a larger base plate, vertical stiffeners and 6 anchoring bars of 36 mm in diameter.

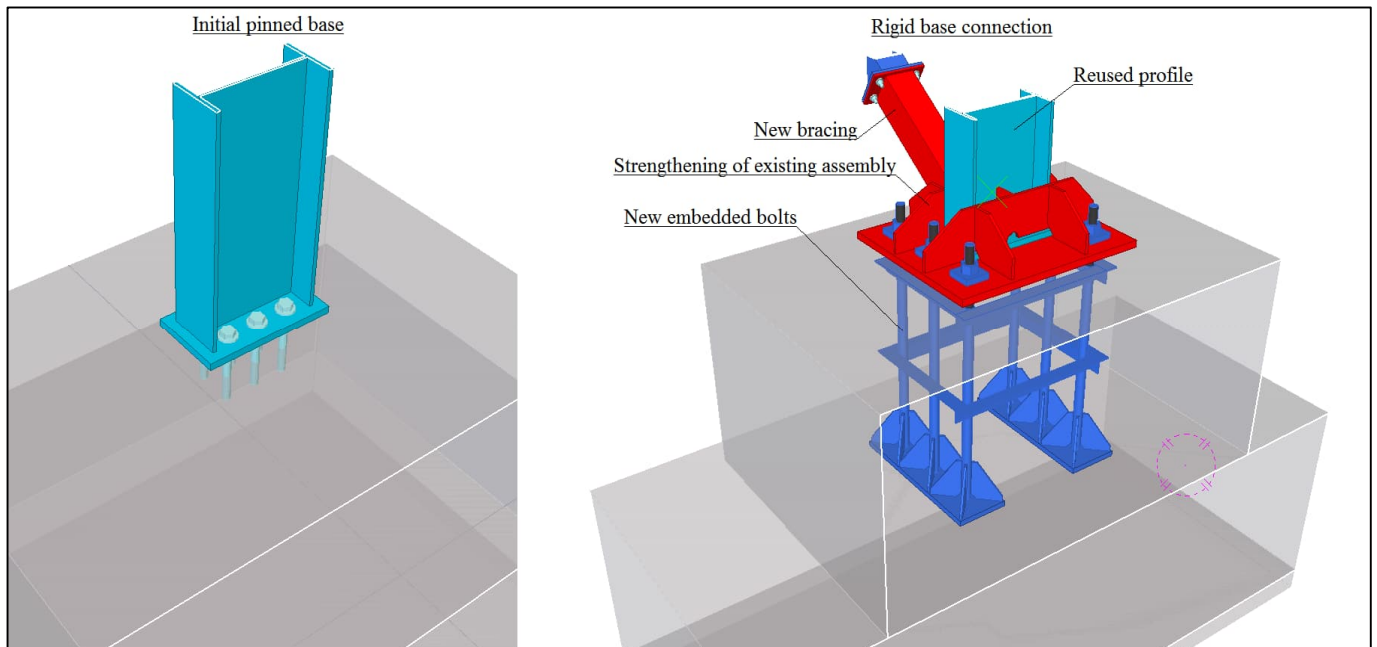


Fig. 4.

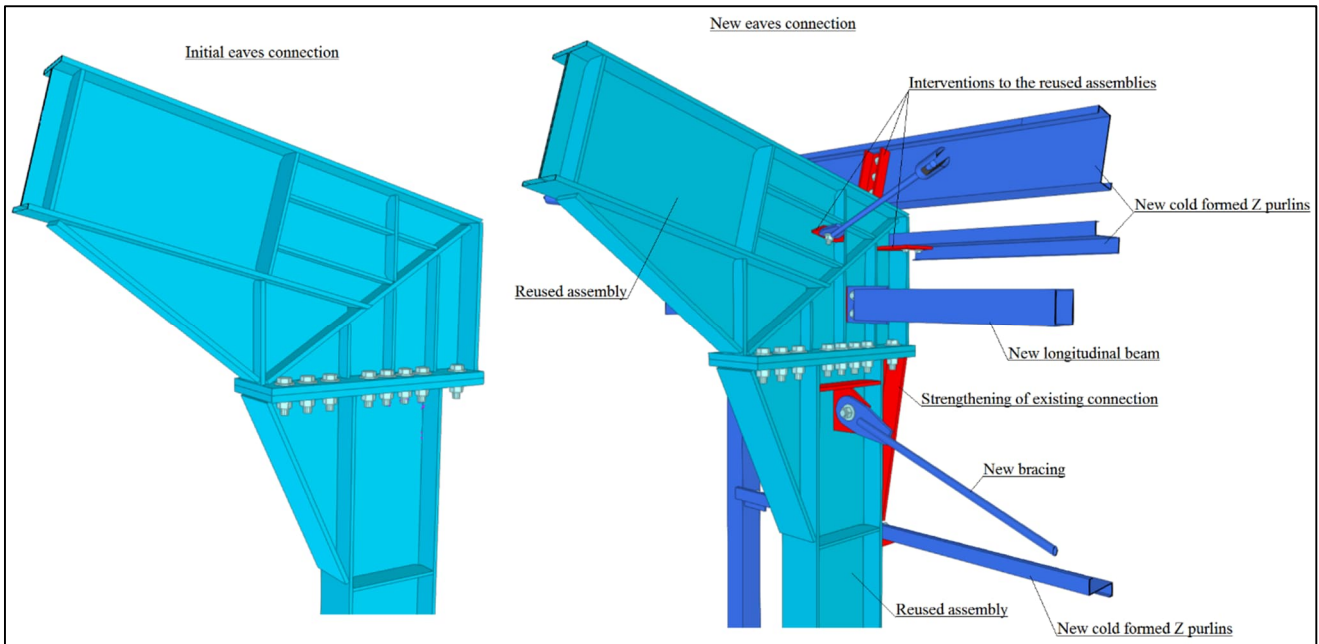


Fig. 5.

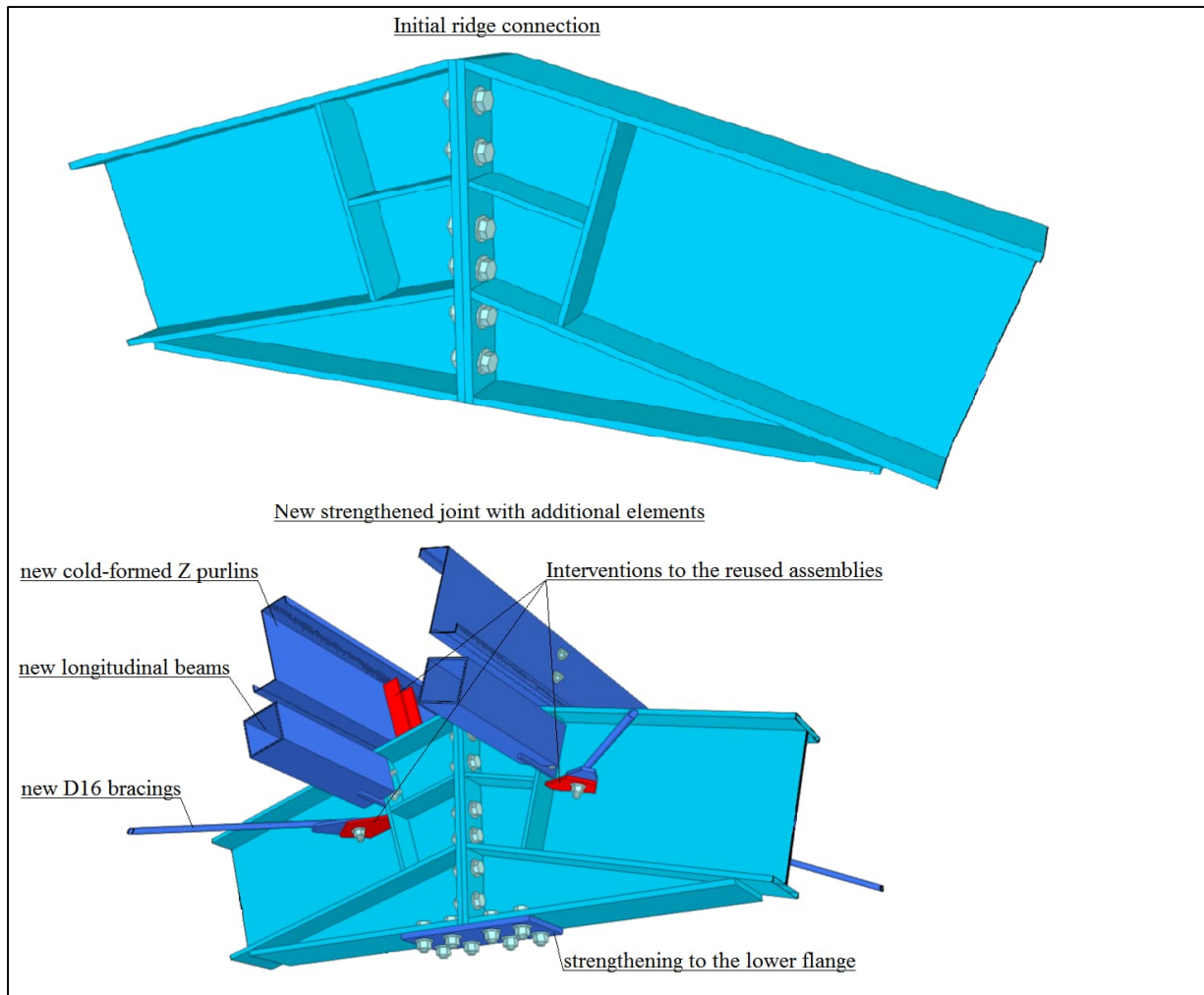


Fig. 6.

In order to accommodate the new floor, additional plates welded on the web of the columns at the intermediate beams were introduced.

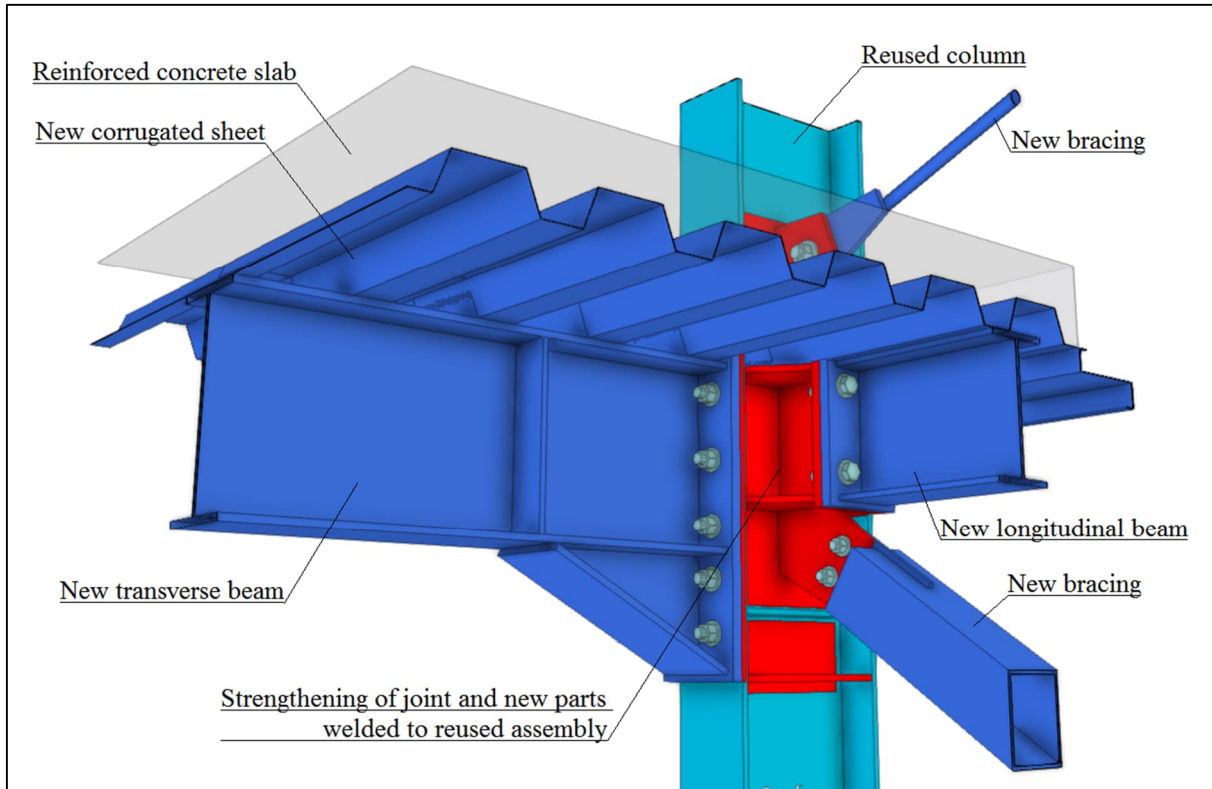
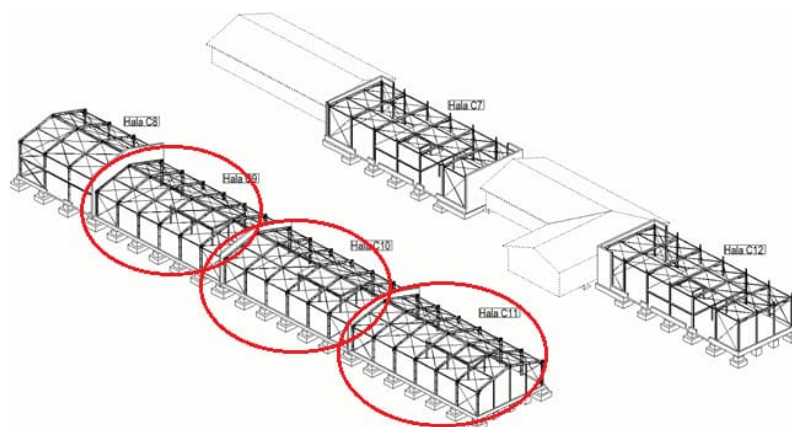


Fig. 7.

C9, C10, and C11 structures



The solution for a minimum intervention to the structure is based on the reduction of the initial bay from 6.0 m to 5.1 m. In this case, the longitudinal elements cannot be reused in a convenient manner. In addition, the decision was to change the column base from a pinned support to a fixed support, similar to the intervention presented for structure C8.

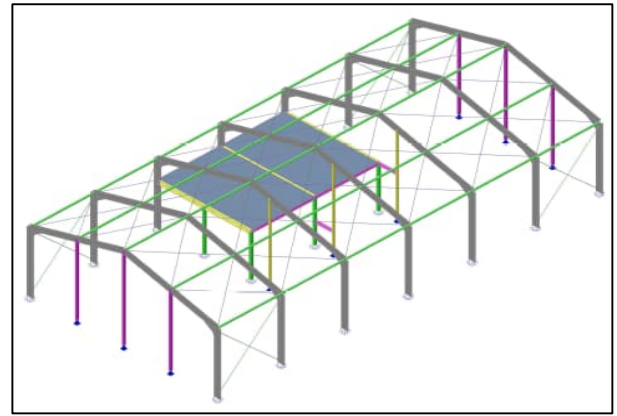
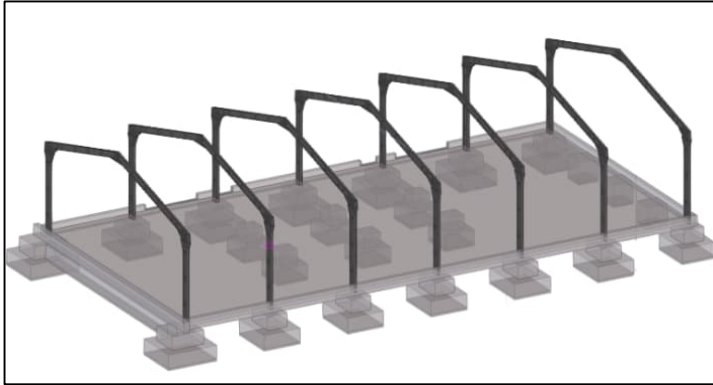


Fig. 8

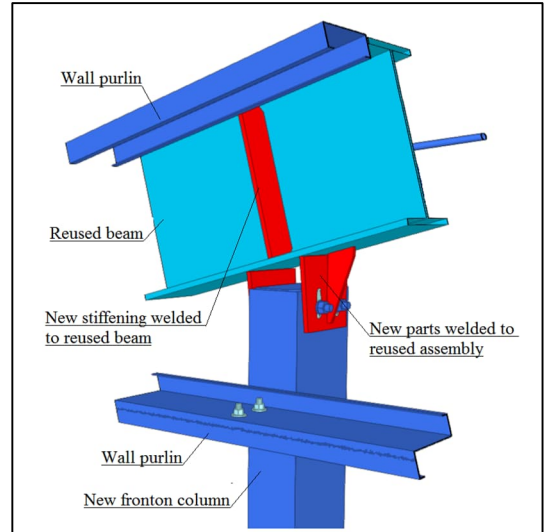
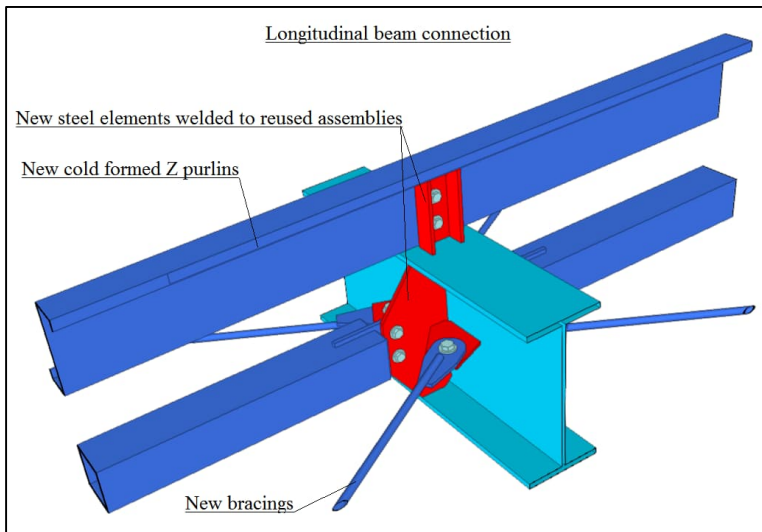


Fig. 9

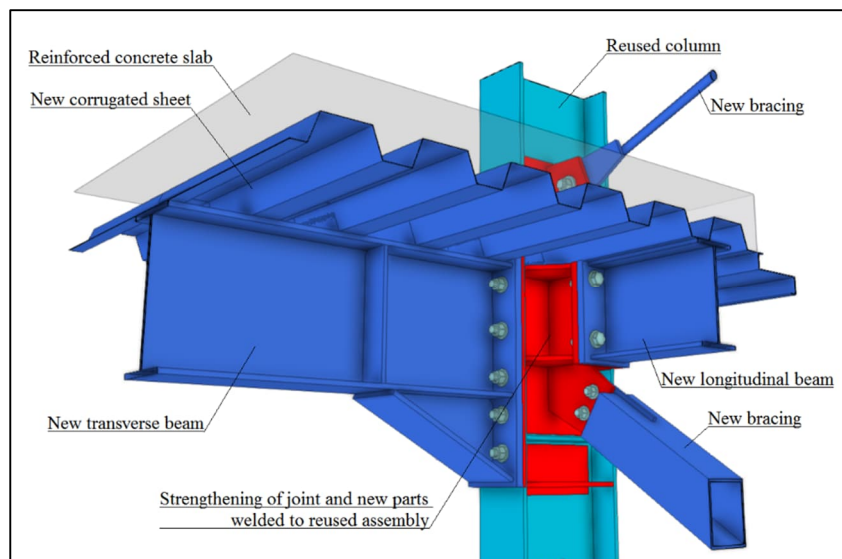


Fig. 10

Finally, the C8 – C11 structures of the new building complex are presented in Fig. 11, where the elements in red are reused elements and blue elements are new elements. The bracing system for both structures was changed by replacing the steel rods with tubular sections (SHS profiles). Also, for all structures, the cladding was mounted on Z200 purlins at the roof and Z150 side rails in the walls, which also required other elements for connecting to the structure.

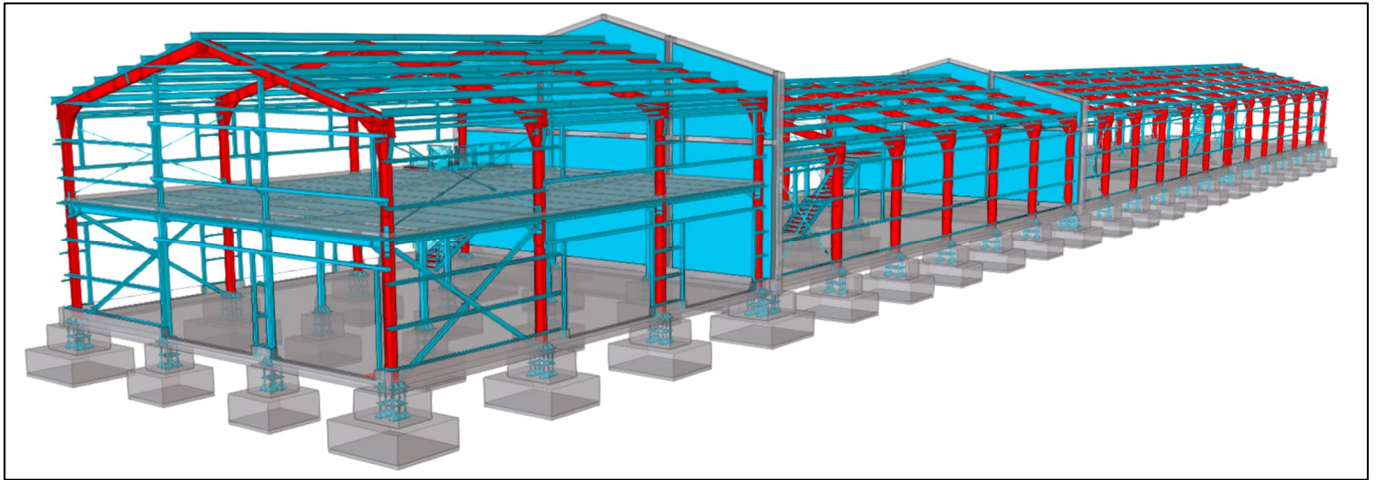


Fig. 11

Cost assessment

The table below shows the type and quantity of elements used for the structure of the C9 hall:

C9 Hall structures		Quantity [kg]
Reused elements	Columns	5622
	Beams	8581
New elements	Anchor bolts	1771
	Parts for strengthening reused assemblies	2491
	Longitudinal beams	2223
	Roof bracings	535
	Wall bracings	227
Structure for mezzanine and stairs		5856
Secondary structure for wall openings		862
Purlins for walls and for roof	Walls	957
	Roof	2223
Total weight of steel structure		31348
Concrete infrastructure		255 m ³

All the below prices are without VAT, at the level of year 2019. The reused steel structure was purchased for a price of 0.57€/kg. For the reused elements the interventions mentioned above were necessary, so an additional 4000€ cost for sandblasting and painting were also added. For the dismantling of existing halls and reuse of the assemblies, an expertise was needed, the cost of which was 800€.

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The detailed prices can be seen in the table below:

2019	Price [€]
Design and verification	2000
Reused elements	8100
Technical expertise	800
Interventions to existing assemblies	3000
Sandblasting and painting	4600
New steel elements (incl. intermediate floor)	22000
Infrastructure	36000
Transport and assembly of steel structure	4700
TOTAL	81200

Comparative cost study: hall with reused elements vs. hall with new elements

In order to be able to choose the wright solution, a comparison in terms of prices between the partial reuse of existing structures and the construction of the structures with new elements was done. It was necessary to design halls with the same characteristics, but with new profiles.

For the C9 structures, HEA300 columns were used instead of IPE400 and IPE330 beams instead of IPE360. The beam-to-column connections were considered rigid in this case as well, but their geometry differs from the initial variant. Also, the ridge connection is different.

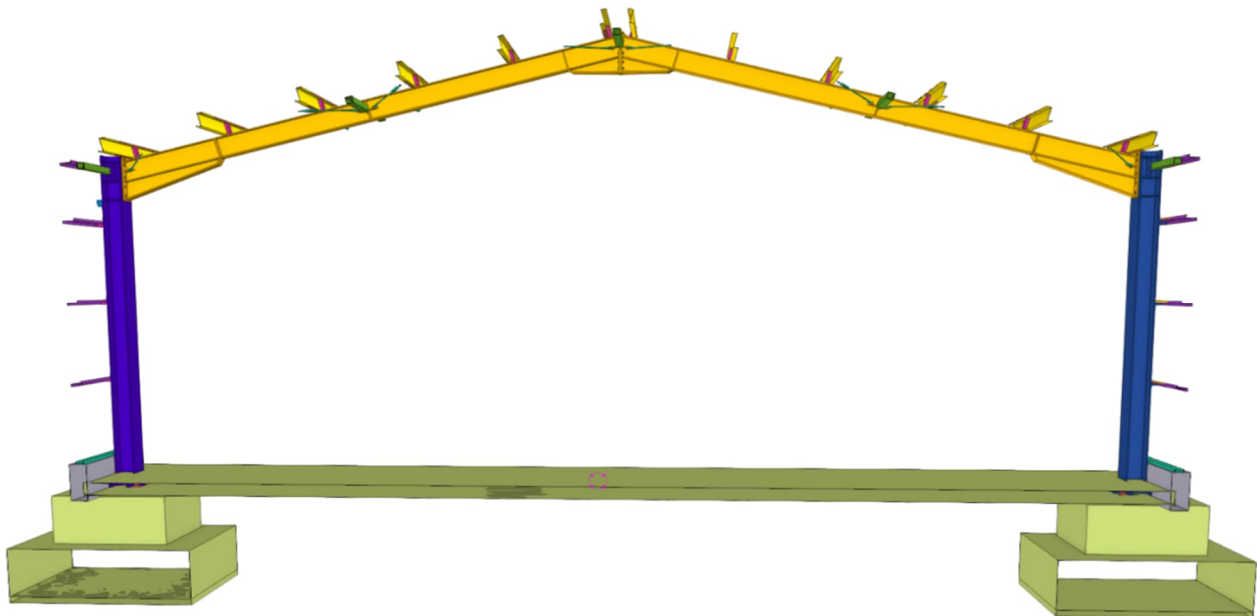


Fig. 12

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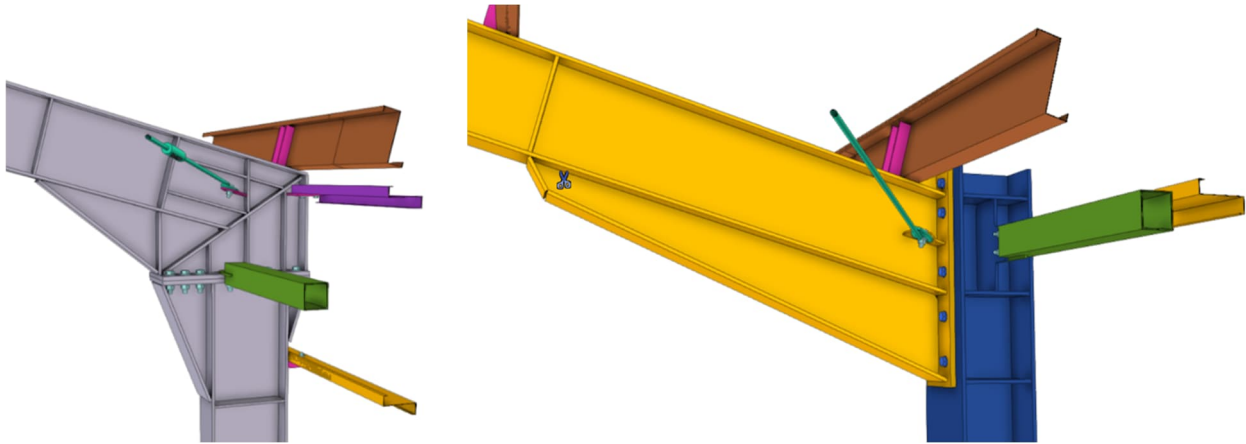


Fig. 11. Old solution vs. new solution

	Reused [kg]	New [kg]
Column assembly	550.7	641.0
Beam assembly	635.8	518.1
Transverse frame	2373.0	2309.0

The material considered in the design of the structure with new elements was also S235 to have similar conditions, and the longitudinal elements, bracings and purlins were kept the same in both cases. The transverse frame weight is close in both cases, however the frame with new elements has a weight 64 kg lower.

For this hypothetical case the table of type and quantity of elements and price centralization are shown below:

C9 hall structures		Quantity [kg]
New elements	Columns	8974
	Beams	7253
	Anchor bolts	1771
	Parts for strengthening reused assemblies	0
	Longitudinal beams	2223
	Roof bracings	535
	Wall bracings	227
Structure for mezzanine and stairs		5856
Secondary structure for wall openings		862
Purlins for walls and for roof	Walls	957
	Roof	2223
Total weight of steel structure		30881
Concrete infrastructure		255 m ³

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	Case: reused Price [€]	Case: new Price [€]
Design and verification	2000	2000
Reused elements	8100	0
Interventions to existing assemblies	3000	0
Sandblasting and painting of reused assemblies	4600	0
Expertise	800	0
New steel elements (sanded and painted)	22000	46500
Infrastructure	36000	36000
Transport and assembly of steel structure	4700	4700
TOTAL	81200	89200

d

The result of this hypothetical comparison shows that there is a cost difference of approximately 8000 € between two halls of the same size and close weight of the structure, one with reused profiles and one with new profiles, the one with reused profiles being obviously cheaper. However, price differences may be greater when using a different type of material and reducing the overall weight of the structure. This price study was conducted for conditions as close as possible to see the most unfavourable scenario.

The total value of the economy for the four halls with transverse frames from reused elements was 35000 €.

Conclusions

Further information

This case study was prepared by Viorel Ungureanu, from the CMMC Department of the Politehnica University of Timisoara.

The authors are grateful for the information and images provided by



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Reuse of Steel Case Study no. 16

The deconstruction and reassembly of steel hall in a new location



Picture 1 Deconstruction of steel frame hall in Hakaniemi, Finland

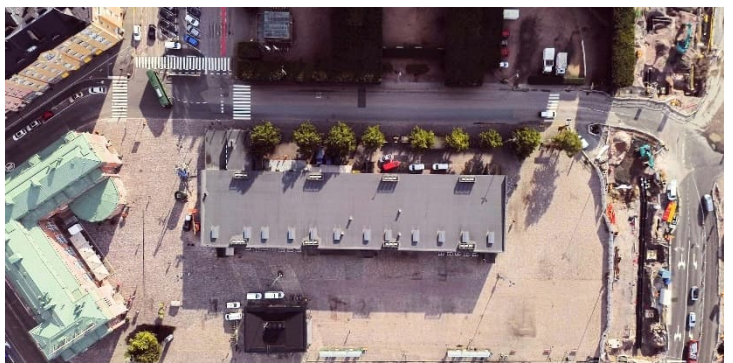
Project summary

Location: Helsinki, Finland
Owner of hall: City of Helsinki
New Owner: Veljekset Keskinen Oy
Contractor / client of demolition work: Lehto Tilat Oy
Demolition contractor: Purkupiha Oy
Deconstruction time: Fall 2023
Auction sale price of hall: 440 000€

Description of the existing building

The project deals with dismantling Market Hall building in Hakaniemi district, Helsinki. The building located on Hämeentie 1 Helsinki, Finland was located in the heart of Helsinki metropolitan area. It was designed by Lehto Group. The Market Hall was also known as "The Glass Hall." It opened as temporary market hall opened in January 2018 to enabled the continuation of activities from old historical building market hall building throughout its entire 5-year renovation period. The Glass Hall operated for 5 years before dismantling. Deconstruction begun in fall 2023. The old Hakaniemi Market Hall is a well-known building, and this temporary market hall also became very popular among citizens.

The Glass Hall is one-story hall and was built on a pile foundation. The size of the building is about 2 300 square meters (the main building was approximately 92 meters long and 23 meters wide). The load-bearing structure of this 2300 m² hall is a steel frame assembled with



Picture 2 In the middle is the temporary market hall and on the left side is the old Market Hall

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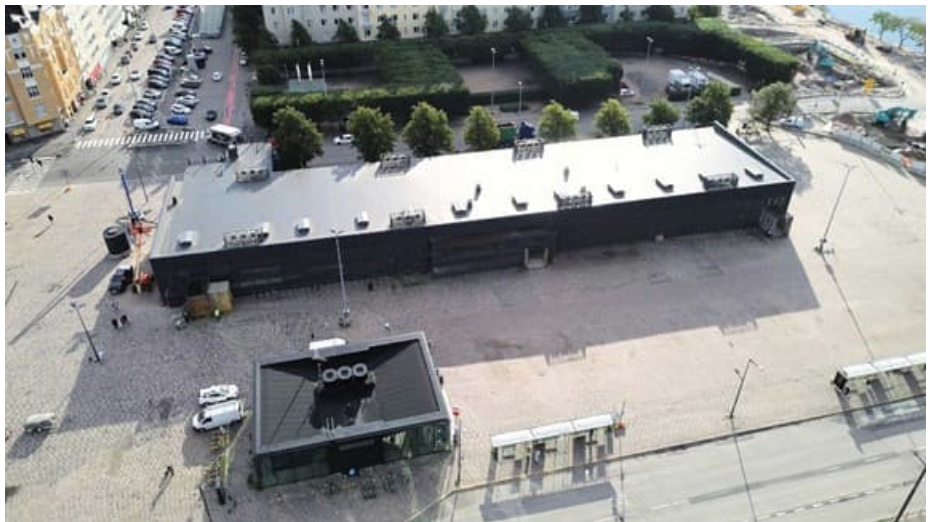
Picture 3 Temporary market hall in Helsinki before deconstruction

bolted connections. The facade of the hall consisted of glass elements and wood cladding. The technical facilities of the building and the social facilities were containerized. About 140 companies operated in the hall.

Design process

The planning of the renovation project and temporary facilities was the responsibility of the construction of the urban environment (Helsinki city) in cooperation with the wholesale market. The goal of the Glass Hall was to use the aid temporarily. During the spring of 2023, the retailers moved back to the renovated premises after the renovation.

Originally the Glass Hall was planned to be temporal and mobile. This aspect was already taken into consideration in the design phase. However, the further use of the hall was not clear to owner, city of Helsinki. A few different alternatives have been presented for the further use of the hall. Different option and alternatives were considered at earlier phase. One option was that the hall would remain in its current location but for another purpose. Another option and the most likely option, the hall was thought to be moved to use as temporary facilities at somewhere else, in different location in Helsinki.



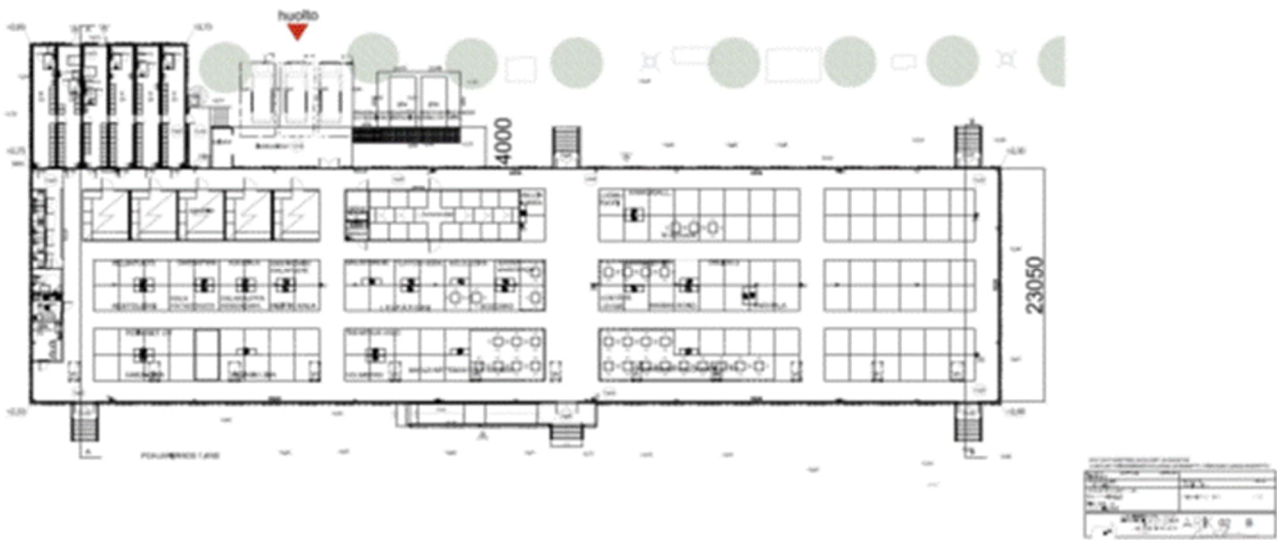
Picture 4 Temporary market hall building of Hakaniemi in Helsinki, Finland (2023)

Since the hall was designed for a temporal use, elements of hall were also designed for easy and possible transport. Elements were design to fit in the trucks.

Deconstruction and Construction processes

The City of Helsinki owned the temporary Market Hall. In the end, the owner decided to sell the temporary hall and it was auctioned because they could not reuse it themselves. The hall was put up for sale in huutokauppa.com and the auction took place between 5.6.-14.6.2023. The highest bid won. A sales brochure and

six attachments contained basic information and structural drawings of the market hall. Additional information from the sales brochure: *"The property will be sold in the condition and equipment it is in the advertisement and at the time of the sale. Before submitting an offer, the bidder is obliged to familiarise himself with the object and documents before making a binding offer. The purchaser cannot subsequently rely on a circumstance that could have been detected during the preliminary inspection or from the documents. A separate visit to the object must be agreed in advance with the seller's representative."*



Picture 5 Structural drawings of market hall from the sales brochure

The highest tender offer was submitted by Vesa Keskinen (Veljekset Keskinen Oy). Keskinen has said in public that the buying decision was made in less than an hour before auction was closing and that the decision might sound an impulse purchase, but it is a deliberate purchase. Keskinen is well-known Finnish public figure who owns Finland's largest and best-known village shop in Tuuri. Tuuri Village Shop is a tourist attraction and an experience destination. The Glass Hall was sold in 6.7.2023.

Deconstruction contract was put out to tender and Purkupiha Oy was chosen as the demolition contractor for the temporal market hall.

The nine-week-long deconstruction programme was carried out in the fall of 2023. Deconstruction begun with the internal strip-out. Deconstruction of the facade involved removal of the wooden cladding panels followed by careful removal of the glass facade elements. After removing the roof elements and ceiling elements and partially dismantling the floor, the steel roof truss elements were dismantled.



Picture 6 Temporal market hall during its deconstruction in fall 2023

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The dismantled parts of the hall were carefully protected for transfers. Due to the limited space and congested location of the hall, logistics required careful planning in terms of scheduling, transportation and the protection of the dismantled parts. The largest elements were transported from the site at nighttime as daytime relocation was not possible. The elements were transferred to the nearby Malmi Airport logistics centre, from where the elements were transported to Tuuri, about 350 kilometres to the north of Helsinki. One estimation is that there were 50 truckloads.



Picture 7 The Market Hall reassembly in Tuuri 2023-2024

Purkupiha cooperated with various parties during and after the deconstruction processes. The protection and transport of the dismantled elements were carried out in cooperation with Purkupiha, the new owner of the Glass Hall, and a logistics company. Purkupiha helped and gave information to the new owner of the hall and helped them for example marking elements during deconstruction and helped with loading and logistics planning. Purkupiha has helped the new owner in the necessary parts even after the deconstruction work.

In Tuuri, the temporal market hall reassembly started soon after its deconstruction. The construction work was completed already in spring 2024. In Tuuri, the Hakaniemi Glass Hall was given a new life as the Village's Fashion Outlet and its opening ceremony was held in 24.2.2024.

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Picture 8 Temporary Market Hall in its new location and in the new context as Village's Fashion Outlet in Tuuri 2024

Conclusions

The following key aspects of the process have been identified:

- Hall was originally planned for temporary use, so the hall was designed to being able to deconstruct and it must had been moveable and transferable.
- Helsinki City could not further use the temporary hall itself and they decided to sell it. Selling the hall made it possible to reuse and reassembly the hall instead of demolishing and recycling it.
- Because the hall was designed to deconstruct the building was simpler and easier to deconstruct compared to permanent buildings, and also the hall was quickly reassembled.
- Transports of elements were thought in the design process because elements fit to the trucks.
- The availability of drawings to buyers
- Right timing of different phases is important to enable reuse: decision of the further use vs. selling, arranging auction, allocate time for dismantling.
- Good communication with all parties included in deconstruction and reuse process.
- Demolition contractors had previous experience of deconstruct of the same designers' buildings and therefore were familiar with this type of hall, which made the deconstruct process even more secure.

In conclusion, the design of this steel frame hall significantly contributed its reuse possibility and offers a model for other projects.

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Further information

References:

- Sales brochure of hall and attachments
- Purkupiha Oy: employee and site manager
- Agenda and Minutes of Helsinki City:
 - o [AAE3B889-0022-CC4E-8F9B-892B86500000.pdf \(hel.fi\)](#)
 - o <https://paatokset.hel.fi/fi/asia/hel-2023-008579/819e9ac0-6598-42d0-9375-cece0d950577>
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 - o [5D43695A-41A1-C465-B248-8CF798700009.pdf \(hel.fi\)](#)
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