Construção Circular, Neutralidade Carbónica e Cidades Inteligentes

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19/12/2019 VTT – beyond the obvious
GHG emission reduction target for all EU economy: 80% by 2050 compared to 1990 (all industries need to contribute) => After 2035, carbon capture & storage technology would be applied to emissions from industries unable to make substantial cuts (e.g. steel, cement).

EU ETS reduction target: 43% by 2030 compared to 2005
Societal challenges and the impact of the construction sector

climate change, population ageing and urbanisation

Built environment in EU28

- 40% of EU consumption
- 36% of CO₂ emissions
- 97% of the housing stock is inefficient
- 90% of our time indoor
- 75% of EU citizens live in cities

- 1% renovation rate
- 12% of the building stock is protected
- 7% to 12.5% of bridges in bad condition
- 34% municipalities report under-investment in infrastructures

Source: Based on data from BPIE, EC, EIB, Member States
ECTP Strategic Research & Innovation Agenda, 2021-2027
Considerable amounts of natural resources are embodied in the building stock and infrastructure.

Need to focus the sustainability criteria in national building codes on designing resource-efficient buildings and not only on improving energy efficiency and waste recovery.

“IT is essential to take into account the circular economy perspective in the reform of the EU Construction Products Regulation. In addition to responding to the climate challenge, the recycling of construction products opens up a major new product market and, at best, can create millions of jobs in Europe,” Minister of Employment Timo Harakka emphasises.
Resource Efficient Built Environment

- Preserve natural resources
- Better understanding of the end-of-life scenarios of building structures.
- Waste prevention - Support C&D waste reduction,
- Reduce overall the environmental impacts of buildings by encouraging the re-use of the building components.
REDUCE: Space resourcing and Low-carbon materials
Reduction of construction volumes
Increase in the use ratio of unused or poorly used premises

Space as a service
School as a service
Everyday services
City as a service

https://www.archdaily.com/907675/oodi-helsinki-central-library-ala-architects

ISO Omena Service Centre
Making it easier for residents to use everyday services
Urban densification
Infill development and building extensions with timber based solutions

Case-studies
Added values of using timber based solutions:

• In the majority of the plans timber was allowed visual presence in the townscape
• Light weight timber constructions make the suggested building extensions designed using prefabricated spatial modules and parasite volumes attached to old structures feasible

Infill construction is one of the Finnish national goals in regional and land-use development and studied cases show environmental, economic and social benefits of the solution.

Infill development can serve as a financing instrument for building refurbishments.
Low carbon materials supporting circular economy

Urban Timber Buildings

From the circular economy perspective, wood as a construction material is renewable, largely recyclable and may provide closed-loop manufacturing and utilization processes. Wooden buildings and furniture with long life cycles are also carbon storages.

Project Wood Circus, Underpinning the vital role of the forest-based sector in the Circular Bioeconomy: [https://woodcircus.eu/](https://woodcircus.eu/)
Low2now, SITRA, [http://www.low2no.org/](http://www.low2no.org/)

19/12/2019   VTT – beyond the obvious
RECOVER: Demolitions and construction waste
An urban mining resource
Construction and Demolition waste make up one-third of all waste generated in Europe

19/12/2019 VTT – beyond the obvious

Selected material stock (2015) and embodied energy of the City of Melbourne. André Stephan & Aristide Athanassiadis
http://theconversation.com/with-the-right-tools-we-can-mine-cities-87672

Steel stock in residential buildings 1970-2050, global level

Million kg steel

2.00E+07
1.90E+07
1.80E+07
1.70E+07
1.60E+07
1.50E+07
1.40E+07
1.30E+07
1.20E+07
1.10E+07
1.00E+07
0.90E+07
0.80E+07
0.70E+07
0.60E+07
0.50E+07
0.40E+07
0.30E+07
0.20E+07
0.10E+07
0.00E+00


Total high rise buildings
Total apartment buildings
Total semidetached
Total detached

Stocks in the cities are expected to grow as well as the material flows. At a certain level of welfare, the stocks saturate.

Utilization of waste requires careful management and a lot of knowledge of the materials:

In demolition work it is important to ensure safe waste materials (non-contaminated) for recycling them into new products.

Safe demolition includes removal of hazardous material from material loop and controlled management of waste containing hazardous materials.
Pre-demolition audits a new, voluntary measure for mapping out the materials and hazardous substances in buildings to be demolished.

The decision comes before demolition

EU Guidelines
Published in 2018

National Guidelines

Electronic reporting
Finland’s objective is to reach the target of 70 per cent material utilisation set for construction and demolition waste in the EU Waste Directive by next year (2020).

More emphasis should be placed on the role of demolition as a project preceding new builds.

The purpose of the surveys is to create good conditions for the appropriate use of demolition materials while preventing environmental and health risks and ensuring a high-quality demolition process in all demolition projects.

Finnish pre-demolition audit is based on EU initiated audit procedure. This guide is part of a series of three guides aimed at improving the quality of demolition projects. The other two guides deal with the procurement of demolition work and the implementation of the demolition process as a whole.
<table>
<thead>
<tr>
<th>Building owners</th>
<th>Demolition companies</th>
<th>Recycling companies</th>
</tr>
</thead>
<tbody>
<tr>
<td>- A correct material inventory at the start of the tender process, so that a correct and detailed cost estimation can be made.</td>
<td>- A correct material inventory at the start so that a realistic price can be offered.</td>
<td>- High-grade material streams allow a more cost-effective recycling process and more high-grade recycling applications.</td>
</tr>
<tr>
<td>- High-grade material outputs and a legal and sustainable end market for the material streams.</td>
<td>- Health security in waste handling when hazardous materials are identified and treated properly.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Lower unexpected works</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- A higher quality of the material streams</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Avoiding penalties and landfilling costs.</td>
<td></td>
</tr>
</tbody>
</table>

19/12/2019 VTT – beyond the obvious

https://www.vtt.fi/sites/PARADE/
REUSE: Reusable buildings and components
Demolition or deconstruction?

Photo credits: Paul Kamrath
What is reuse?
Products designed to survive harsh conditions in several lifecycles or management of industrial waste?
Vision for the future reusable buildings

**High end-of-life value**
Future owners aware of the value of their property at its end of life. Supply chain actors actively offering reusable components for sale before the deconstruction.

**Reusable BIM**
BIM objects for the new building design equally sourced from the product manufacturers and second-hand material dealers.

**Reversible and scalable design**
Buildings will be designed for deconstruction and reuse. The evolution of future building requirements (e.g. relocation loads, thermal insulation) will be anticipated.
Focus on single-storey steel buildings
Broad applicability (industrial, commercial, sports, exhibition, warehouses), suitable for reuse and viable for circular-economy business models. The results will be extendable to other materials and building typologies.

Existing and future buildings
Reuse of existing building stock is challenging and only marginally profitable.
Steel reuse

-Reusing is the (environmentally) best solution
- Carbon footprint of steel can be further reduced, waste can be prevented
- **Steel has existing supply chain from recycling activities**
- Steel is reusable multiple times
- Facility owners already know that metals have end-of-life value and should be collected
- Although steel is being reused, systemic solution is missing
- Business models need to be developed for the whole value chain
- The whole sector will benefit from implementation of steel reuse. Once the circular economy is established in constructional steel, it is easy to extend it to the other materials and products
Documented case studies
Drivers and facilitators of reuse cases
Deconstruction and reassembly of a steel structure in a new location

The owner of the retail stores chain decided to replace a building in Tampere with a larger one. At the same time, the need for a new grocery store emerged only 60 km away creating the opportunity for relocated reuse.

New design was based on available building frame

Main features

- Degree of reuse of steel frame (columns, main girders, cross girders) and roof profiles 100% reused.
- In-situ fire protection of frame with intumescent coating
- New plinth and wall structures, new bay for the small storage part.
- About 10% saving in total construction costs due to reusing of steel structures

Photo credits: Ruukki
Realistic building case

Environmental potential for reusing components
Steel reuse model: gradual increase from 10% in 2018 to 50% in 2050

Implementing constructional steel reuse of 50% by 2050 may keep the new steel demand at the 2018 level.

However, new business opportunities will open in the supply chain of reused products (product manufacturers, re-certification, deconstruction, trading etc.).
Documented business models

Reuse of the whole primary structure (CZ)

Reuse of the reconditioned steel sections (UK)

Supply chain, new roles, place for new players
Testing protocol and re-certification

Non-destructive testing
- XRF spectrometer
- Hyperspectral camera
- Hardness testing

Minimum-invasive testing
- strength and ductility
- impact toughness
- weldability

Standard coupon tests
On-line trading platform

Find steel buildings scheduled for demolition
Find used steel sections
Sell structural steel
Upload as-built BIM model

Image credits: SCI
# Design for future reuse

## Technical reusability (similar to BRE or DGNB Design for Deconstruction)

<table>
<thead>
<tr>
<th>Component</th>
<th>( r = \sum \rho_i w_i )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Performance assessment result (%)</td>
<td>Weighting factor for each performance category (%)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Building</th>
<th>( R = \frac{\sum m_i r_i}{\sum m_i} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Component mass (t)</td>
<td></td>
</tr>
</tbody>
</table>

## Economic prospect (complementary score)

<table>
<thead>
<tr>
<th>Component</th>
<th>( e = P(c_1 \cap c_2 \cap \ldots \cap c_n) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Criteria (e.g. span, height, floor area)</td>
<td>Number of new buildings in the selected area and time span</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Building</th>
<th>( E = \frac{\sum m_i e_i}{\sum m_i} )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Comparison of different scenarios

<table>
<thead>
<tr>
<th>Overall reusability index ( R )</th>
<th>Sections</th>
<th>Components</th>
<th>Assemblies</th>
<th>Whole steelwork</th>
</tr>
</thead>
<tbody>
<tr>
<td>Complete relocation</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frames separately</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Only sections</td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

Supply chain, new roles, place for new players
Good practice: Building information modelling
Good practice: BIM + augmented reality
Conversion of the former heat and power plant of RWTH Aachen University into a seminar building
Process of reusing concrete elements

deconstruction
storage
reassembly
supplementation
cutting
transport
insulation
finished

Satu Huuhka, Tampere University of Technology

All photos © Claus Asam, courtesy of the photographer
Contemporary reuse of timber

Satu Huuhka, Tampere University of Technology

Photo 1 courtesy of General Architecture; Photo 2 © Mikael Olsson; Photo 3 courtesy of 3RW Architects; Photo 4 © diephotodesigner.de; Photo 5 courtesy of Georg Grotenfelt; Photo 6 courtesy of PAVE Architects

VTT 2018
To do list …

- **Remove barriers** in legislation & standardization, keep balance between demands for product safety and reusability (e.g. CE marking & CPRs, end-of-waste process, construction permit procedures etc.);

- **Set targets** for reuse (e.g. sectorial level, regional level, company goals, etc …)

- **Facilitate deconstruction** over demolition by incentives and pre-demolition audits (e.g. request working out a reuse plan);

- **Develop competences** in the whole circular economy chain;

- **Design for reuse** (e.g. public projects);

- **Assess the impact and maximize** the residual value at end-of life of new construction;
Methods for the whole life carbon assessment of buildings
From Carbon footprint to Carbon handprint

Carbon handprint
A Positive Indicator

An indicator of climate change mitigation potential. Describes the GHG emission reduction in a customer’s activities that occurs when the customer replaces a baseline solution with a handprint solution.

Carbon footprint

The sum of GHG emissions and removals in a product system expressed as CO2 eq. and based on an LCA using the single impact category of climate change (ISO 14067: 2018).

Download in:
A low-carbon building has a low carbon footprint and a big carbon handprint

Carbon handprint
A Positive Indicator
The carbon handprint analysis incorporates the net benefits of climate impact that would not arise if there were no construction project. These might be the building’s carbon storages and sinks, the extra renewable energy produced during the building’s life cycle, and the benefits gained from the reuse and recycling of the construction products.

Carbon footprint
A carbon footprint analysis covers a building’s entire life cycle. It includes the manufacture and transportation of the products used in a construction project, the worksite, the use and maintenance of the building, its demolition, and recycling.

Download in:
https://julkaisut.valtioneuvosto.fi/handle/10024/161796
Example of a single industrial hall

- Pre-designed steel hall from PRECASTEEL\(^1\)
- EPD data from Ruukki Construction\(^2\)
- LCA includes steelwork, concrete slab and foundations, envelope, windows and doors\(^3\)

\(^1\) [http://www.unav.es/Precasteel/](http://www.unav.es/Precasteel/)
\(^2\) [https://cdn.ruukki.com/docs/](https://cdn.ruukki.com/docs/)
\(^3\) S. Vares, P. Hradil, M. Sansom, V. Ungureanu, Economic potential and environmental impacts of reused steel structures, Structure and Infrastructure Engineering, September 2019
Smart and Sustainable Cities
Perspectives from the Construction Sector
Cross-cutting domains and sector synergies

- **Digitalization** in enabling new services and innovation as well as more efficient systems
- Integrated and **cross-sectoral planning and management** is essential
- Cities have many stakeholders; value-chains and changing and new ecosystems are emerging
- Importance of energy management at building and district level increases as well as the increased use of low carbon energies
- **New services**, e.g. mobility as a service, **building as a service**, energy as-a-service, X-as-a-service.
- Importance of **resiliency, safety and security** is highlighted
- Upgrading existing infrastructure asks for new business concepts including new models for ownership
## CIB Smart City Roadmap and Vision

**TG88**

### New and existing *infrastructures*

<table>
<thead>
<tr>
<th>Standards &amp; Policies</th>
<th>Integrated Operations Management</th>
<th>Products &amp; Technologies</th>
<th>Planning &amp; Design</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sectorial approach, separate standards &amp; policies for various infrastructure assets</td>
<td>Common semantics for interoperability and service enabling. Privacy regulations and accountability</td>
<td>Cost-efficient sensors and asset management platforms</td>
<td>Framework for integrated LCC/LCA of urban infrastructure planning</td>
</tr>
<tr>
<td></td>
<td>Data exchange protocols for monitoring and system optimisation</td>
<td>Wireless networks embedded in infrastructure networks</td>
<td>Integrated land use/infrastructure planning including resource efficiency</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Integration of wireless infrastucture networks with energy system and consumer services</td>
<td>Full integration of infrastructure management in urban energy and service planning.</td>
</tr>
</tbody>
</table>

**Current** | **Short term 2020** | **Medium term 2030** | **Long term 2050**

**Climate adaptive and resource efficient infrastructure enabling real-time services.**
Existing and new buildings

- Standards & Policies
  - Lack of semantics and data exchange standards. Missing smart renovation integration policies. Data privacy not regulated in monitoring services.
  - Common semantics for interoperability and connectivity. Life-cycle performance based renovation incentives.
  - Regulations for integration of smart technologies into existing building. Cyber-security.
  - Standardised communication and protocols to machine data exchange. Using IoT/cloud services.

- Integrated Operations Management
  - Forecasting demand-response actions. BIM based operations management tools.
  - Smart, personalised energy monitoring and indoor env. control. Integration with district management.
  - Shared efficiency gains → fully integrated building controls.

- Products & Technologies
  - Smart products and technologies rarely integrated to city systems and validated in large scale.
  - Cost-efficient sensors and energy management platforms. Prefabrication integrating RES and smart solutions.
  - Big data in energy management, real-time services. Smart materials.
  - Cost efficient and multifunctional industrial solutions. Digital models integrated to city services.

- Planning & Design
  - Lack of decision support tools for city planning and modelling tools for existing buildings.
  - Resource-efficient requirements. Modelling and scanning tools for retrofitting.
  - Collaborative design with green performance combined to smart solutions.
  - Full integration to existing stock rehabilitation. Model and life-cycle based contracts.

Current | Short term 2020 | Medium term 2030 | Long term 2050

19/12/2019 VTT – beyond the obvious
Final words
Approach all aspects of sustainability equally as well as all aspects of the major building materials

- REDUCE – REUSE – RECOVER
- From footprint to carbon Hand-Print
- Pre-demolition audits and recertification
- Digitalization as catalyzer
- “Fridays 4 future” are the future customers
- Investments in Research, development and innovation, including in research infrastructures are critical.
VTT’s R&D infrastructure – an essential part of the national research infrastructure

VTT’s research environments are world-class. They enable product development from basic research to piloting and even small-scale production.

- **Bionukki**
  The largest bioeconomy pilot and research facility in the Nordic-countries.

- **Biotechnology and food research piloting environment**
  Offers unique facilities for the development and customisation of bio and food industry technologies.

- **Micronova**
  World-class cleanroom facility, fully equipped for the fabrication of silicon, glass and thin film-based microsystems.

- **VTT MIKES Metrology**
  Is the National Metrology Institute of Finland and performs high-level metrological research and develops measuring applications in partnership with industry.

- **Engine and vehicle laboratory**
  Enables research on passenger cars as well as heavy-duty vehicles up to 63 metric tons to develop energy efficiency, emissions reduction and use of 2nd generation biofuels.

- **PrintoCent**
  World’s first pilot factory for printed intelligence industrialisation.

- **ROVIR**
  Remote Operations and Virtual Reality Centre for the development of remote operations and virtual reality technology in industry.

- **A pilot-scale research environment for fibre processes**
  Enables the development of novel products and supports the renewal of the pulp and paper industry.

- **Centre for Nuclear Safety**
  For nuclear technology safety research.
# Further Information

**Design for Reuse:**

Petr Hradil: Petr.Hradil@vtt.fi  
https://www.vtt.fi/sites/reuse/en  
https://www.vtt.fi/sites/progress/project-consortium  
https://www.steelconstruct.com/eu-projects/progress/eu-policies/  
Economic potential and environmental impacts of reused steel structures:  

**ECTP Strategic Research and Innovation Agenda 2021-2027**


**Pre-demolition audits and Construction Waste:**

Margareta Wahlström: Margareta.Wahlstrom@vtt.fi  
https://ec.europa.eu/growth/content/eu-construction-and-demolition-waste-protocol-0_en  
https://www.vtt.fi/sites/PARADE

**Method for the whole life assessment of buildings**

https://julkaisut.valtioneuvosto.fi/handle/10024/161796