Deliverable D1.5
Environmental performance during the whole life cycle (LCA)

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| CI | Classified, as referred to in Commission Decision 2001/844/EC |
**Document History**

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Publishable summary

Deliverable D1.5 “Environmental performance during the whole life cycle (LCA)” presents the Life Cycle Assessment (LCA) of the whole life cycle of three innovative types of panels – ETICS-like, Cladding and Radiant panels, developed during InnoWEE project. The main objective of the LCA study conducted is to investigate the environmental impacts associated with different life cycle stages of the prefabricated geopolymeric panels made from large fractions of recycled Construction and Demolition Waste (CDW). The LCA study has been conducted in accordance with the principles and framework for LCA, which are defined in the international standard for LCA ISO 14040 and ISO 14044. We have also considered European standard for Environmental Product Declarations (EPD) EN 15804: 12 + A2: 2019, which provides core product category rules (PCR) for Type III environmental declarations for any construction product and construction service. The study consists of four phases: the goal and scope definition, inventory analysis, impact assessment and interpretation phase where optimisations of the production processes and comparisons with commercial products were assessed. We have used Thinkstep Gabi software combined with Ecoinvent and Gabi databases to perform calculations.

LCA impact assessment was conducted with three LCA methods (CML, Recipe and Ecoindicator 99) as well as three different end-of-life methods of calculations of burdens and benefits beyond the system boundary. The comparison of the results of, obtained by using different impact assessment methods shows that at the midpoint there is little, though notable influence of the selection of the impact assessment method. New version of EN 15804 standard and thus new EPDs combine different methods in reporting the parameters. The CML method has been used in the study for final comparisons of the results, obtained for the InnoWEE products and the performance as declared in individual EPDs for established products on the market was done for parameters calculated according to the CML method, because the CML method is mainly used in the EPDs which are the source of the data for the comparison.

From the methodological point of view the direct comparison of the LCA results for two different systems is strongly advised against discouraged because the influences of the calculation rules may be too high. Furthermore, there are always differences such as reference service life, applicability in different climates, a need for repair, cleaning etc. that set different building products and materials apart and thus comparisons are usually very difficult. Therefor comparisons, given in the analysis are informative, only, as it was not possible to do the calculations for the InnoWEE products following the exact same rules as in the case of well-established products.

Deeper analysis of the InnoWEE products has revealed the environmental hot-spots in the whole life cycle of the products that can be used as a guideline during the large scale production set-up. Due to the nature of the production, which is currently established at the pilot line level with sub-optimal transport path lengths, LCA has revealed opportunities to lower the environmental footprint of the production primarily by the optimisation of electricity and secondarily by optimising the transport path, since those are the two most
critical hot-spots. To further explore the environmental potential of the InnoWEE products, four different scenarios for optimizing the environmental footprint of the electricity were studied, showing that significant a reduction of the impact that can be achieved if renewable energy sources, e.g. solar energy, are introduced into the production.

We have studied all life cycle stages of the products namely the production phase, the product use phase, end of life stage as well as benefits and loads beyond the system boundary. Finally, the overall assessment has shown that most of the environmental burdens arise from the production process (A1-A3). Within that, energy use in production process is dominant, but with the transport contribution not negligible. Because of the use of CDW the Indicators related to the use of resources are much more favourable in the InnoWEE products when compared to the competitive products due to the CDW use. In the case of contribution to the global warming the comparison is ambiguous because of different levels of the industrialization. Nonetheless it is shown that after full industrialization and smart use of renewable energy sources also the GWP can be substantially reduced compared to the competitive products.

We can conclude that from the environmental performance point of view confirmed through calculating life cycle assessment all innovative products developed during InnoWEE project are very promising and further research in this direction will be productive and desired. The main point of developing such products is lowering the use of virgin materials and seeking new ways to reuse and recycle demolished building materials that are otherwise landfilled and disposed of. There is a final quantity of virgin materials that Earth can offer and final space that landfilled products can occupy. Attempts to help with this challenges are more that welcome.
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Abbreviations

ADP el. Abiotic depletion (elements)
ADP fos. Abiotic depletion (fossil)
AP Acidification potential
CDW Construction Demolition Waste
DALY disability adjusted life years
E The specific emissions and resources consumed per unit of analysis
e Specific emissions and resources consumed per unit of output
ED Damage to ecosystem quality
EERAfterEOWIn Specific emissions and resources consumed per unit of analysis arising from combustion of secondary fuel entering from a previous system
EERAfterEOWOut Specific emissions and resources consumed per unit of analysis arising from processing and combustion of secondary fuels in a subsequent system after the end of waste status
EERAverage Specific emissions and resources per unit of analysis that would have arisen from specific current average substituted energy source: heat and electricity
EERBeforeEoWOut Specific emissions and resources consumed per unit of analysis arising from processing of waste destined to be used as material for energy recovery of a subsequent system before the end of waste status
EF Environmental Footprint
EINC Specific emissions and resources consumed per unit of analysis arising from incineration of waste
ELF Specific emissions and resources consumed per unit of analysis arising from landfill
eModuleA specific emissions and resources per unit of output for modules A1–A3
eModuleA* specific emissions and resources per unit of output for modules A1–A3 including incineration and co-incineration of waste (gross value)
eModuleC specific emissions and resources per unit of output for module C
eModuleD specific loads and benefits per unit of output for module D
eModuleD1 specific loads and benefits per unit of analysis for module D related to the export of secondary materials
eModuleD2 specific loads and benefits per unit of analysis for module D related to the export of secondary fuels
eModuleD3 Specific loads and benefits per unit of output for module D related to the export of energy as a result of waste incineration (for R1<60% and R1>60%)
EMRAfterEoWIn Specific emissions and resources consumed per unit of analysis arising from material recovery (recycling and reusing) processes of the previous system after the end of waste status
EMRAfterEoWOut Specific emissions and resources consumed per unit of analysis arising from material recovery (recycling and reusing) processes of a subsequent system after the end of waste status
<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
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<tbody>
<tr>
<td>EMRBeforeEoWOut</td>
<td>Specific emissions and resources consumed per unit of analysis arising from material recovery (recycling and reusing) processes of the current system until the end of waste status is reached</td>
</tr>
<tr>
<td>EOL</td>
<td>End-Of-Life</td>
</tr>
<tr>
<td>EP</td>
<td>Eutrophication potential</td>
</tr>
<tr>
<td>EPD</td>
<td>Environmental Product Declaration</td>
</tr>
<tr>
<td>ePE</td>
<td>Specific emissions and resources per unit of output arising from energy consumption coming from primary sources</td>
</tr>
<tr>
<td>EPS</td>
<td>Expanded Polystyrene</td>
</tr>
<tr>
<td>ESEEic</td>
<td>Specific emissions and resources consumed per unit of analysis that would have arisen from specific current average substituted energy source: electricity</td>
</tr>
<tr>
<td>ESEHeat</td>
<td>Specific emissions and resources consumed per unit of analysis that would have arisen from specific current average substituted energy source: heat</td>
</tr>
<tr>
<td>ETICS</td>
<td>External Thermal Insulation Composite System</td>
</tr>
<tr>
<td>EVMIn</td>
<td>Specific emissions and resources consumed per unit of analysis arising from acquisition and pre-processing of primary material in the production of the product</td>
</tr>
<tr>
<td>EVMSubOut</td>
<td>Specific emissions and resources consumed per unit of analysis arising from acquisition and pre-processing of the primary material</td>
</tr>
<tr>
<td>FAETP</td>
<td>Freshwater aquatic ecotoxicity potential</td>
</tr>
<tr>
<td>GHG</td>
<td>Green House Gas</td>
</tr>
<tr>
<td>GWP</td>
<td>Global warming potential</td>
</tr>
<tr>
<td>GWP excl. biog. carbon</td>
<td>Global warming potential excluding biogenic carbon</td>
</tr>
<tr>
<td>HDG</td>
<td>High Density Geopolymer</td>
</tr>
<tr>
<td>HH</td>
<td>Damage to Human health</td>
</tr>
<tr>
<td>HTP</td>
<td>Human toxicity potential</td>
</tr>
<tr>
<td>ILCD</td>
<td>International Reference Life Cycle Data System</td>
</tr>
<tr>
<td>LCA</td>
<td>Life Cycle Assessment</td>
</tr>
<tr>
<td>LCI</td>
<td>Life Cycle Inventory</td>
</tr>
<tr>
<td>LCIA</td>
<td>Life Cycle Impact Assessment</td>
</tr>
<tr>
<td>LCT</td>
<td>Life Cycle Thinking</td>
</tr>
<tr>
<td>LHV</td>
<td>Lower heating value of the material</td>
</tr>
<tr>
<td>M</td>
<td>Amount of material used for each material flow</td>
</tr>
<tr>
<td>MAETP</td>
<td>Marine aquatic ecotoxicity potential</td>
</tr>
<tr>
<td>MERIn</td>
<td>Amount of material entering the product system that has reached the end of waste status before incineration in a previous system and enters the product system as secondary fuel</td>
</tr>
<tr>
<td>MEROut</td>
<td>Amount of material leaving the product system where it has reached the end of waste status before incineration and leaves the product system as secondary fuel</td>
</tr>
<tr>
<td>MINCIn</td>
<td>Amount of waste generated by a previous system that has been incinerated with efficiency of energy recovery lower than 60 % or that is used for energy recovery with energy efficiency greater than 60 % but has not reached the end of waste status</td>
</tr>
<tr>
<td>MINCOut</td>
<td>Amount of waste that will be incinerated with efficiency of energy recovery lower than 60 % or that is used for energy recovery with energy efficiency greater than 60 % but which has not reached the end of waste status</td>
</tr>
<tr>
<td>MLF</td>
<td>Amount of material in the product that will be landfilled</td>
</tr>
<tr>
<td>MMRIn</td>
<td>Amount of input material to the product system that has been recovered</td>
</tr>
</tbody>
</table>
(recycled or reused) from a previous system

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>MMROut</td>
<td>Amount of material exiting the system that will be recovered (recycled and reused) in a subsequent system</td>
</tr>
<tr>
<td>MVMIn</td>
<td>Amount of input material to the product system that has been obtained from primary materials</td>
</tr>
<tr>
<td>ODP</td>
<td>Ozone layer depletion potential</td>
</tr>
<tr>
<td>PCR</td>
<td>Product Category Rules</td>
</tr>
<tr>
<td>PEF</td>
<td>Product Environmental Footprint</td>
</tr>
<tr>
<td>PENRT</td>
<td>Primary energy from non-renewable resources</td>
</tr>
<tr>
<td>PERT</td>
<td>Primary energy from renewable resources</td>
</tr>
<tr>
<td>POCP</td>
<td>Photochemical ozone potential creation</td>
</tr>
<tr>
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