# Design for low-carbon buildings Focus on embodied GHGs

NORNET LCA
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# STARTING POINT

- Design for low carbon buildings requires

- 1) comparison of design alternatives although complete building data is not available
- 2) the calculation of embodied GHGs gradually over the course of the building design.
- 3) understand the significance of the preliminary calculation in each design stage.

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# OBJECTIVES

- To assess the potentials and drawbacks of the current methods, standards and tools provided as aids for the design for low-carbon buildings
- To assess the significance of different design phases from the perspective of embodied carbon
- To draw conclusions and recommendations on the information, methods and standards needed.

- See also
- Häkkinen,T; Kuittinen, M; Ruuska, A; Jung, N. Reducing embodied carbon during the design process of buildings, J. Build. Eng. 4 (2015) 1–13. doi:10.1016/j.jobe.2015.06.005.

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# METHODS

- a review of relevant literature,
- interviews of principal designers in Finnish architectural offices, and
- a case study of a building.

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# STUDY OF LITERATURE

- AIMS: TO FIND INFORMATION FOR

- a) importance of embodied GHGs
- b) importance of the early stages of design
- c) current approaches for low-carbon design
- d) availability of data
- e) availability of “plans-of-works” for low carbon design.

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# STUDY OF LITERATURE: a) importance of embodied GHGs compared to all GHGs induced by buildings

- The magnitude and share depends on building type, climate, comfort requirements, and local regulations.
- The assessment result depends on methodological choices.
- Recent research emphasises the meaning of embodied GHGs.
- 1) EE and NWEBs use less energy and have lower GHG emissions over their lifetime. The relative importance of the embodied GHGs increases .
- 2) GHGs from materials' production may increase in absolute terms if some materials are used in larger quantities or others have higher CFs.
- 3) The increasing use of renewable energy is expected to lower GHGs from heat and power generation.
- 4) The importance of the construction-phase-related GHGs may be emphasised because of timing and the significant carbon spike.

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# STUDY OF LITERATURE:
# b) The importance of early design stages with regard to embodied GHGs

- Recent research addresses the significance of the preparation phase and early design phases
- Clear target setting with KPIs in the preparation phase
- Selection of energy intensive materials and products at the initial stages of building design
- Design decisions made in the conceptual stage have large impact on the final overall performance of the building
  - On a basis of a survey on 67 buildings 57% of technological decisions were made in the conceptual design stage, compared with only 13% in the detailed design stage.

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# STUDY OF LITERATURE:
# c) Alternative approaches

- 1) Working with practical guidelines may not give holistic results;
- 2) Sustainable rating systems support target setting rather than design parameters;
- 3) The use of LCA in practical building design is highly data-demanding and work-intensive; LCA tools that are well integrated with software used by e.g. architects are still rare
- 4) Simplified tools may be useful but also inaccurate
- 5) BIM compatible tools provide potential to assess CF in a step-by-step way as integrated tools in design process, but there are problems like the availability of carbon information.

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- BIM and design for low carbon buildings:
- The assessment of embodied impacts happens by combining information about material quantities and environmental impacts of materials.
- BIM helps the assessment as it supports the quick assessment of quantities.

- 1) Including LCA information in the BIM objects has been suggested.

- 2) More flexibility is achieved when combining environmental data from external data bases  with information about quantities based on the model using IFC as a data sharing format.
- Most of BIM/CAD tools propose export function to IFC. The resulting IFC exported files then contain IFC objects that can be used for sustainability assessment.

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- Data about GHGs can be rather easily linked:
  - Element level data can be directly linked to information about the quantities of walls, floors etc.
  - Product level data can be linked to information about quantities when the tool supports the definition of the contents of elements
- The database can be included in the tool that makes the calculation.
- The database can be external (like EPD databases).
- ELODIE tool developed in France uses EPDs provided by manufacturers that are stored in an external online database, and uses IFC based data of building components.
- ILMARI tool developed in Finland, also uses IFC-based data on building components, and calculates the carbon footprint with the help of a CF database which is embedded in the tool.

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# STUDY OF LITERATURE:
# d) Availability of data for low-carbon design

- Availability
- Access
- Suitability
  - similar product category rules
  - generic, specific (EPDs)
- Usability

# STUDY OF LITERATURE:
# d) Availability of “plans-of works” for low-carbon design

- Design tasks for low carbon buildings could be integrated into existing design procedures by addressing
  - the subtasks to be implemented in each phase
  - the use of tools in different phases.
- The current Finnish process description for architectural design does not describe any sub tasks for sustainability assessment. It mentions one single task of the assessment of LC impacts within Generic design and provide no further details.
- The British RIBA plan of work includes steps for formulating sustainability aspirations, sustainability strategies and for sustainability check-points.

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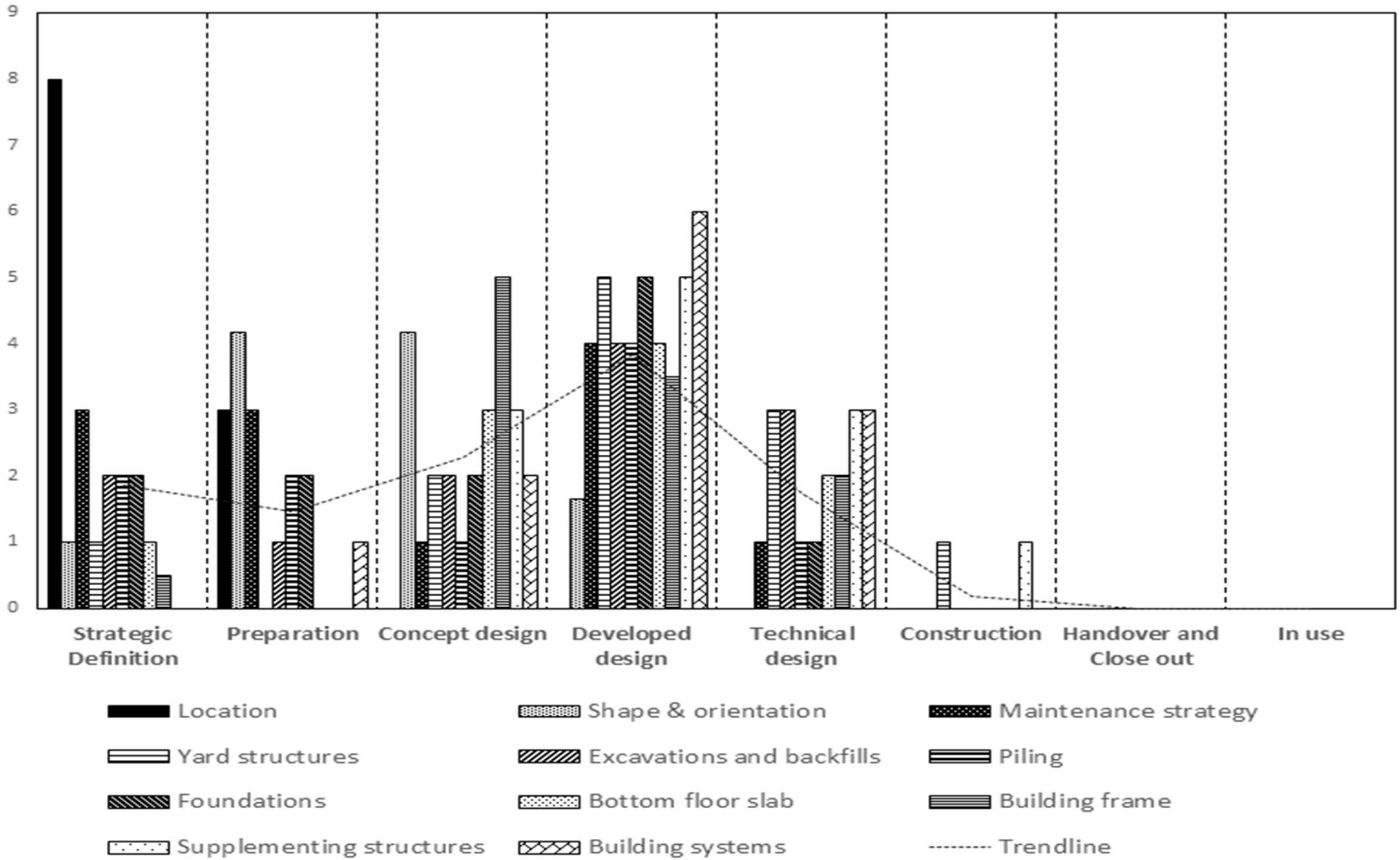
# INTERVIEWS - AIM: To find out the most important design phases with regard to the selection of materials

| Building | Building Type and use | Location | Project type | Floor area ($m^2$) | Designer |
| --- | --- | --- | --- | --- | --- |
| Entteri School | School | Sipoo, Finland | New building | 4150 | K2S Architects |
| Kindergarten Kalkunvuori | Daycare center | Tampere, Finland | New building | 2400 | Gylling-Vikström Architects |
| YTHS Hospital | Hospital | Helsinki, Finland | New building | 1500 | Sanaksenaho Architects |
| Toukoniitty | Residential building, block of flats | Helsinki, Finland | New building | 11500 | ARK-House |
| Kuilden | Concert Hall | Kuilden, Norway | New building | 16000 | ALA Architects |
| Otaniemi Metro | Subway station | Espoo, Finland | New building | 15000 | ALA Architects |
| Kuopio Theatre | City Theater | Kuopio, Finland | Renovation and extension project | 10000 | ALA Architects |
| Lappeenranta Theater | City Theater | Lappeenranta, Finland | New building | 7500 | ALA Architects |
| Isokuusi | Residential Building, block of flats | Tampere, Finland | New building | 9000 | PuustaInnovations |
| Saarijärvi | Residential Building, block of flats | Saarijärvi, Finland | New building | 2200 | PuustaInnovations |
| Tervakukka Passive house | Detached house | Tampere, Finland | New building | 198 | Kombi Architects |
| Syysviiru | Senior home | Lohja, Finland | Renovation project | 1900 | Kombi Architects |




- Importance of each design phase with regard to each design consideration
- The scale on Y axis presents the number of points out of one (1.0) given for different design considerations in different project. Columns show the decisions that are made in each design phase for each design consideration

- The most of the decisions that affect the selection of building materials and parts are done in the developed design phase.
- Preparation and concept design phases are also very important, especially when projects are commissioned by large construction companies in design-build projects who have pre-defined structure types and concepts.
- The preparation and concept design phases are crucial in public building projects. The goal-setting in these matters would be of high importance if the goal was to optimise the CF of the building.
- Architects, structural engineers and representatives of the owners have the main role in the decision making process when it comes to defining building parts.
- Depending on the case, owners of the building may make most of the decisions.
- The role of city planners was important as well
  - their decisions affect the need for excavations, piling and even façade materials in some countries.

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# CASE STUDY: Importance of different phases

| The source of GHG emission: Building component or energy consumption in different phases | Relative share of GHG-emissions of the Case-building* (Building component specific material related GHG-emissions of the case-building in total are 1670t of CO2-equ.) | Design phase based on RIBA and ARK12 ** |
|---|---|---|
| Yard structures, foundations, piling, excavations and backfills, bottom floor slab | 16 % | Strategic definition & Preparation |
| Building Frame | 35 % | Concept & developed design |
| Supplementing structures | 16 % | Concept & developed design |
| Construction, renovation and demolition work | 14 % | Concept & developed design |
| Building Systems | 2 % | Technical design |
| Renovation and refurbishment | 17 % | Technical design |

- Building components and their share of total building-level GHG-emissions and timing of decisions relative to design phases impacting GHG emissions.

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| | 0 Strategic Definition | 1 Preparation | 2 Concept Design |
|---|---|---|---|
| Objectives | • Identify client's needs | Develop project objectives: Outcome, quality, sustainability, feasibility etc. | • Prepare concept design<br>• Develop project strategies<br>• Issue final brief |
| Typical deliverables | • Strategic Brief | • Initial Project Brief | • Concept Design<br>• Project Strategies: Sustainability, Cost, Maintenance etc.<br>• Final project brief |
| Milestones | • Identify the potential of carbon efficiency in the project | • Include CF target in sustainability strategy<br>• Set assessment and monitoring methods for design phase<br>• Set CF "as required" (Target value) | • Estimate CF of alternative designs<br>• Data: Generic<br>• Calculate values for CF (Standard value) and compare to Target value |

| 3 Developed Design | 4 Technical Design | 5 Construction | 6 Handover 7 Use |
|---|---|---|---|
| • Prepare developed design<br>• Outline building services and structural design | • Prepare technical design | • Construct the building as planned | • Handover and inspect the finished building<br>• Begin maintenance |
| • Developed design<br>• Preliminary cost information | • Completed technical design<br>• Bills of quantities<br>• Tendering documents | • Revise documents to ”as built” status | • Maintenance documentation |
| • Estimate CF of alternative designs<br>• Data: Generic<br>• Calculate values for CF (Standard value) and compare to Target value | • Estimate CF ”as designed”<br>• Data: EPD´s + general<br>• Calculate values for CF (Quantified value) | • Calculate the CF value (Specified value) and compare to Target value<br>• Give feedback about how proposed changes would affect to CF | • Calculate CF ”as built” according to EN 15978<br>• Data: EPD´s + possible site documentation of construction work |

<table>
<tr><th></th><th></th><th>0 Strategic Definition</th><th>1 Preparation</th><th>2 Concept Design</th></tr>
<tr><td rowspan="5">Roles and responsibilities for ensuring carbon efficiency</td><td>Client</td><td rowspan="2">Consider if low CF can result in taxing, funding, marketing or bring other benefits<br>Set criteria for green public procurement of design (if applicable)</td><td>Approve CF goals</td><td rowspan="2">Supporting role</td></tr>
<tr><td>Project manager</td><td rowspan="2">Define preliminary quantitative CF goals<br>Define assessed indicators<br>Select system boundaries and databases</td></tr>
<tr><td>Architect</td><td></td><td>Assess preliminary CF with help of main building materials, floor area and nr. of occupants<br>Study the CF-efficiency of alternatives for reaching the functional requirements.</td></tr>
<tr><td>Structural engineer</td><td></td><td>Supporting role</td><td>Supporting role</td></tr>
<tr><td>HVAC engineer</td><td></td><td>Develop alternative energy concepts</td><td>Develop chosen energy concept</td></tr>
</table>

<table>
<tr><th></th><th>3 Developed Design</th><th>4 Technical Design</th><th>5 Construction</th><th>6 Handover7 Use</th></tr>
<tr><td>Client</td><td rowspan="2">Supporting role</td><td rowspan="2">Approve CF as designed<br>Compare outcome to original goals<br>Set criteria for green public procurement of construction work and products</td><td>Supporting role</td><td rowspan="2">Approve final CF calculations<br>Compare to goals<br>Document ”lessons learned”</td></tr>
<tr><td>Project manager</td><td>Approve changes to CF caused by changes in materials</td></tr>
<tr><td>Architect</td><td rowspan="2">Iterate preliminary CF for base floor, floors, roof, walls, windows and doors, frame</td><td rowspan="3">Ensure the consistency of calculations<br>Make final CF calculations<br>Consider the results of maintenance planning<br>Save information for reference for construction phase</td><td>Supporting role</td><td>Calculate CF as built (Specified value)</td></tr>
<tr><td>Structural engineer</td><td>Supporting role</td><td>Supporting role</td></tr>
<tr><td>HVAC engineer</td><td>Make final energy calculations</td><td>Supporting role</td><td>Update energy certificate ”as built”</td></tr>
</table>