Embodied Carbon: Refurbish or Rebuild?
Green Sky Thinking

15th May 2017
SPEAKERS

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Associate & Head of Sustainability
Knowledge exchange between ECD & MSc Sustainability students at Sheffield University

Learning opportunity for students:
• Architectural research skills
• Calculation of embodied energy and embodied carbon
• Work on real, live project (BIM-level 2)
• Professional presentation, report writing skills and communication

Learning opportunity for ECD:
• Usefulness of BIM model for embodied carbon calculations
• Study to inform design practice (material specification + BIM use and management)
• Reflection on process and how to incorporate in practice – i.e. what next?

~150 hrs study, including student learning

Aurora Pelayo de Niz
Zijun Peng (John)
ECD Architects is pleased to invite you to our Seminar: Mapping a changing sustainable approach to high rise retrofit, 1989 – 2014. We will be holding this seminar on two occasions to suit all diaries as follows:

Date: Monday 28 April 2014
Session 1: 10 am to 12 pm
Session 2: 2.30 pm to 4.30 pm
Location: ECD Architects
Studio 3 Blue Lion Place
237 Long Lane, London SE1 4PU

Our seminar will take you to the highs and lows of high rise retrofit, with a whistle-stop tour of the practice’s 25 years of experience retrofitting residential towers. Commencing with Gasherbrum, the ECD Architects’ first high rise retrofit project, through to the successful top to bottom transformation of the iconic Bank House, the practice will undertake a unique journey to provide an offer of value to clients, unmatched in the sector. Our outcomes will be explored by Louise Bolton of ECD Architects, and conclude with our findings from our existing portfolio analysis of our network of Office Houses to Portland House to the BREEAM Standard.

Please let us know if you & your colleagues are able to join us.
E: katrina@ecd2.co.uk T: 020 7119 8644

ECD CHECK UP!
Ways and Means of Undertaking Post Occupancy Evaluations
Please join us at our seminar on June 2nd and 3rd to explore how and why post occupancy evaluations can be undertaken.

Embodied Carbon: Refurbish or Rebuild
GreenSky Thinking 2017

Refurbishment is currently considered a better alternative than demolition due to the embodied carbon associated with the materials used in the building. While low energy refurbishment should be a significant part of any operational energy reductions, what is the associated embodied carbon? Should low carbon, low energy refurbishment and refurbishment be the same thing, or is it a more complex issue? This seminar will explore some of the key issues and challenges for refurbishment and rebuilding.

Please join us for our Green Sky Thinking 2017 Seminar - a discussion of demolition/rebuild vs low energy building refurbishment

Date: Monday, 15 May
Session 1: 10 am - 12 pm
Session 2: 2.30 pm - 4.30 pm
Location: ECD Architects
Studio 3 Blue Lion Place
237 Long Lane, London SE1 4PU

Bringing together and reflecting upon data from the first ECD Project case study and research by others, this seminar will explore the arguments and evidence for and against building demolition and building refurbishment.

This comparative demolition/rebuild versus refurbishment discussion will include:

- An overview of current research and evidence of embodied carbon implications
- An ECD Case study detailing embodied energy and carbon results
- Cost implications and other incentives

Thank you for your interest.

For further information, please contact
E: info@ecd2.co.uk T: 020 7119 8644
HOW TO BUILD AN OPEN CITY
BE GENEROUS
BE PUBLIC
BE ULTRAPRACTICAL
15–19 MAY
Welcome and Introduction
   James Traynor

WHAT? – Background on Embodied Carbon
   Sofie Pelsmakers

HOW? – Methodology, Results, Benchmarking and Lessons Learnt
   Loreana Padron

WHY? – Constraints and Drivers for Embodied Carbon measurement and reduction
   James Traynor

Q&A session
INTRODUCTION
WHAT?
WHAT IS EMBODIED CARBON AND WHY IS IT IMPORTANT?

• **Embodied energy** is the energy used to construct a building and the materials with which it is made. (usually expressed as MJ/kg of material);

• **Embodied carbon** impact is obtained multiplying the energy used to produce the materials by the carbon intensity of the fuel used (kgCO$_2$(e) per kg or per m$^3$ of material). If a manufacturer runs their operations with renewable energy, the embodied carbon of a material is significantly reduced but its embodied energy remains the same.
WHAT IS EMBODIED CARBON AND WHY IS IT IMPORTANT?

Embodied energy & embodied carbon are part of any LCA (Life Cycle Assessment), with other environmental impacts also considered.

<table>
<thead>
<tr>
<th>Element</th>
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</tr>
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<td>Climate Change</td>
<td>D</td>
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<td>Water Extraction</td>
<td>E</td>
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<tr>
<td>Mineral Resource Extraction</td>
<td>A</td>
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<tr>
<td>Stratospheric Ozone Depletion</td>
<td>B</td>
</tr>
<tr>
<td>Human Toxicity</td>
<td>A+</td>
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<tr>
<td>Ecotoxicity to Freshwater</td>
<td>A+</td>
</tr>
<tr>
<td>Nuclear Waste (higher level)</td>
<td>B</td>
</tr>
<tr>
<td>Ecotoxicity to Land</td>
<td>A</td>
</tr>
<tr>
<td>Waste Disposal</td>
<td>C</td>
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<tr>
<td>Fossil Fuel Depletion</td>
<td>E</td>
</tr>
<tr>
<td>Eutrophication</td>
<td>B</td>
</tr>
<tr>
<td>Photochemical Ozone Creation</td>
<td>A+</td>
</tr>
<tr>
<td>Acidification</td>
<td>A</td>
</tr>
<tr>
<td>Kg of CO₂ eq. (60 years)</td>
<td>310.0</td>
</tr>
</tbody>
</table>

© The environmental Design Pocketbook
What is embodied carbon and why is it important?

- ~40% of CO₂ emissions associated with the operation and construction of buildings in the UK
- Significant (80% to 95%) CO₂ emission reductions are required to limit global warming to ≤2°C
- UK aiming for 50% reduction by 2025, and 80% by 2050 (Climate Change Act, 1990 baseline)
- 80-90% of UK carbon emissions are caused by the operation of buildings, hence the focus has been on reducing the operational energy use by better fabric standards and on-site renewable technology
- But as buildings become more energy efficient, i.e. their operational carbon reduces, embodied carbon becomes relatively more important (and proportionally greater).
- At present still mostly voluntary requirement though in London Plan might be a Carbon offset
→ Generally, the fabric, foundations, superstructure and envelope have greatest embodied carbon impact. (Building, 28.04, Whole-life carbon: Fabric retention, Mirko Farnetani and Juan José Lafuente of Sturgis Carbon Profiling)

Carbon life cycle phases of a building and their contributions to the overall UK carbon emissions that the construction industry has the ability to influence – from RICS - Methodology to calculate embodied carbon.

BUT! Depending on material build-up, a PassivHaus embodied energy proportion can be as much as 40% (conservatively estimated) of the whole life energy demand. The more detail included, the higher the estimates (and often lack of data means lack of detail) McHendry, 2013
WHAT IS EMBODIED CARBON AND WHY IS IT IMPORTANT?

• ‘Cradle to gate’: encompasses the carbon from energy used to extract, process and manufacture material until the point that it leaves the factory gate. Usually the boundary included in data.

• ‘Cradle to cradle’: additionally includes routine maintenance – replacement of components, future deconstruction and reuse at the end of the material’s life. This is the ideal approach, but often no data.

• Many buildings currently operate on a ‘cradle to grave’ principle as they are simply demolished and landfilled.
WHAT IS EMBODIED CARBON AND WHY IS IT IMPORTANT?

Difference **operational energy/carbon** as opposed to **embodied energy/carbon**

**operational energy/carbon** associated with operation of **building** (regulated/unregulated energy so to heat/cool/ventilate/light/provide hot water)

**Whole life energy/carbon** includes both all carbon impacts over the building’s lifetime.
Relative impact of the consequent life cycle stages on the overall carbon footprint for different types of buildings, calculated over 30 years (the energy results have been based on the Building Regulations) - from RICS - Methodology to calculate embodied carbon

Only 30 years! How realistic? Embodied carbon is small proportion: are all impacts included? What boundaries?
While operational carbon is still much greater than embodied carbon, as we design and build to higher fabric standards, proportionally the embodied carbon will increase as the operational energy use reduces.

The ratio of embodied to operational carbon increases as Building Regulations are revised - from RICS - Methodology to calculate embodied carbon.
• Less than 1% new-build dwellings build a year; demolition and replacement is 1% so retrofit has an important role to play in reducing operational energy demand (and by avoiding demolition, avoiding additional embodied carbon)

• Demolition would likely increase embodied carbon/embodied energy: Most of the building materials in new buildings are newly produced and processed, so new homes use up to 8 times more resources than an equivalent refurbishment (Ireland, 2008; Yates, 2006).

• Given it is the fabric, foundations, superstructure and envelope with greatest embodied carbon impact, retaining these where possible, will reduce refurbishment embodied carbon impact (Building, 28.04, Whole-life carbon: Fabric retention, Mirko Farnetani and Juan José Lafuente of Sturgis Carbon Profiling)

• Retrofit leads to “significant environmental and financial savings” (Building, 28.04, Whole-life carbon: Fabric retention, Mirko Farnetani and Juan José Lafuente of Sturgis Carbon Profiling)
• Further embodied carbon impact reductions can be found from limited demolition and landfilling and processing of waste (Building, 28.04, Whole-life carbon: Fabric retention, Mirko Farnetani and Juan José Lafuente of Sturgis Carbon Profiling)

• Financial benefit also from retention and reduced local pollution/dust/noise associated with demolition and new-build

• Future-proof buildings now to allow for deconstruction to reduce future embodied carbon impacts

• Lack of financial incentives for retention due to 20% VAT for refurbishment
19% decrease in the building’s embodied energy due to the reduced quantity of materials needed to meet the Building Regulations standard, but increased operational energy need. Andreou, E., (2015) (50 year lifespan)

In PassivHaus, a large % of the whole life building energy use impact is likely attributable to the insulation quantity.
WHY BOTHER?

Clients + architects
- to identify ways to reduce environmental impacts & reduce use of resources/associated pollution
- to assess compliance with environmental legislation

Clients:
- to gain a competitive edge
- to engage consumers to choose such products over those that are less 'environmentally friendly'

from RICS - Methodology to calculate embodied carbon, showing typical embodied carbon associated with different elements, and reduction potential
• Lack of appropriate data

• Parties involved in the design, construction and operation of a building are segregated in the delivery chain.

• The definition of a building’s lifespan will have a considerable impact on the outcome (environmental impact calculated over 20, 30 or 60 years or longer?)

• Buildings will usually end their prescribed definition of “life” before the end of its physical life. This is known as “obsolescence”.

• Some impacts are difficult, if not impossible to compare

• NEVER MIX different embodied or LCA sources: they use different boundaries and assumptions and make data not comparable.

• ALWAYS use country specific data as manufacturing processes differ globally.

• Architype/Sweet Group web-based building simulation platform [http://rapiere.net/who-we-are/](http://rapiere.net/who-we-are/) *(Rapiere)*

• **Butterfly** - Life-Cycle Costing tool, free LCC software for UK housing professionals, from [www.blpinsurance.com/added-services/life-cycle-costing/](http://www.blpinsurance.com/added-services/life-cycle-costing/) - limited access

• **Open LCA**, free LCA software, [www.openlca.org](http://www.openlca.org)

• **IMPACT** (Integrated Material Profile and Costing Tool) is an IES LCA/LCC plug-in utilising BIM generated quantities - [http://www.impactwba.com/](http://www.impactwba.com/)

• **Inventory of Carbon and Energy (ICE)**

**International – licensed**

• **SimaPro & EcoInvent**  
  [http://www.simapro.co.uk/](http://www.simapro.co.uk/)

• **Gabi (& Ecoinvent)**  
• BS 15978 – covers both operational and embodied CO₂ - basis for assessing impacts

• UCL (2014), Demolition or Refurbishment of Social Housing? A review of the evidence

• London assembly (2015), Knock it Down or Do it Up? The challenge of estate regeneration

• Savills Research Report to the Cabinet Office (2016), Completing London’s Streets, How the regeneration and intensification of housing estates could increase London’s supply of homes and benefit residents


• Green Guide to Specification http://www.bre.co.uk/greenguide/podpage.jsp?id=2126

Inventory of Carbon and Energy (ICE) – www.circularecology.com

- ICE database has many features and a wealth of information on embodied energy and carbon, including:
  - Over 400 values of embodied energy/embodied carbon broken down into approx. 170 different (building) materials
  - A detailed material profile for over 30 main material classifications (i.e. Aggregates, Aluminium, Concrete, Steel...etc) - Mostly mainstream construction materials
  - For each type of material, the database provides measures of the embodied energy (i.e. MJ) and kgCO₂ emissions, which are related to specific unit quantities of the material. Calculations are made by multiplying a mass(or area) quantity for the material by the appropriate factors.
  - Boundary is typically ‘cradle-to-gate’ only; some rule of thumb estimates.
  - Needs updating

Inventory of Carbon & Energy (ICE)  
Version 2.0

Prof. Geoff Hammond & Craig Jones
Sustainable Energy Research Team (SERT)  
Department of Mechanical Engineering  
University of Bath, UK

This project was joint funded under the Carbon Vision Buildings program by:  
www.bath.ac.uk/mech-erg/sert/embodied

© University of Bath 2011
HOW?
General assumptions:

• All data is from cradle to gate, as specified in the ICE database. Operational Carbon emissions are not included in this study.

• Only Architectural and Structural elements were included (no data from services or additional systems at the time).

• All the aluminium is taken as primary and rolled.

• Glass is taken as worst case scenario (100% primary with no recycled content).

• There are more detailed assumptions related to the Refurbished and New Build scenarios (included in the full study).

Source of diagram: UKGBC - Tackling embodied carbon in buildings
METHODOLOGY

TOOLS

BIM (Autodesk Revit)
1. Model the building
2. Create schedules of elements: walls, floors, roofs, windows, etc.
3. Calculate the area of each element and provide general thickness information
4. Export schedules into an Excel format

ICE DATABASE (Inventory of Carbon and Energy)
5. Find the density and Embodied Carbon factor of each material

EXCEL
6. Create tables with quantities, areas and thicknesses from the Revit schedules
7. Calculate the embodied carbon per material and building element
8. Calculate totals per floor, building and squaremetre

BIM – Building Information Model

BIM has several implementation levels:

• Level 0: CAD using 2D drawings, lines, arcs, text, etc.

• Level 1: generally 3D models for concept work, and 2D for drafting of Production Information with basic levels of data sharing.

• Level 2: each discipline has its own BIM model that it’s combined into a federated model plus COBie datadrops, as per the EIRs. This is the method of working that has been set as a minimum target by the UK government for all public-sector work, from 2016.

• Level 3: in a simplified way it’s when all disciplines use a single, shared project model which is held in a centralised location.
BIM – THE DIMENSIONS

Level 2 BIM – Sharing Models for Coordination Review

- Site/Civil Model
- ARCH Model
- STRUCT Model
- Services Model
- Federated Model

METHODOLOGY

- 4D Sequencing
- 5D Cost Control
- 6D Sustainability Analysis
- 7D Facilities Management
METHODOLOGY

BIM – THE DIMENSIONS

Level 2 BIM – Sharing Models for Coordination Review

Site/Civil Model
ARCH Model
STRUCT Model
Services Model
Federated Model

Embodied Carbon?  Operational Carbon?

CO₂

4D Sequencing
5D Cost Control
6D Sustainability Analysis
7D Facilities Management
METHODOLOGY

TOOLS

INVENTORY OF CARBON & ENERGY
[ICE] Version 2.0
Annex B: Methodologies for Recycling
Prof. Geoff Hammond & Craig Jones
January 2011

ECD Architects
ENERGY CONSCIOUS DESIGN
Ideally, the density and EC factor should be a parameter within each Revit family so that the EC can be automatically calculated.
Approach to cradle-to-gate carbon calculations: a cavity wall is broken down to its components

### METHODOLOGY

### CALCULATION BY COMPONENT

**Volume (m³) = area (m²) x thickness (m)**

**Mass = volume (m³) x density (kg/m³);**

![Compressing the formulas for each element](image)

![Compressing the formulas for each element](image)
**METHODOLOGY**

**CALCULATION BY COMPONENT**

<table>
<thead>
<tr>
<th>Type</th>
<th>Area (m²)</th>
<th>Volume (m³)</th>
<th>Mass (kg)</th>
<th>EC (kgCO₂)</th>
<th>LE (kgCO₂)</th>
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</table>

**Embodied Carbon (kgCO₂) = Mass (kg) x ICE Embodied carbon factor (kgCO₂/kg)**

**SUMMARY:**

- Volume (m³) = area (m²) x thickness (m)
- Mass = volume (m³) x density (kg/m³);
- Embodied Carbon (kgCO₂) = Mass (kg) x ICE Embodied carbon (kgCO₂/kg)
LESSONS LEARNED

RIBA STAGES (too early or too late?)
Stage 1: not enough information regarding materials
Stage 2/3: too late for inform big decisions like demolish or refurbish
Stage 4: too late for changing main materials such as structure or cladding

BIM
It was useful for extracting schedules of amounts but we did not have a fully detailed model when the research started. The model was between Stages 2 and 3.

ICE DATABASE CONTENT
Basic in the sense that it is difficult to get non-typical EC factors, such as materials with recycled content

Source: UKGBC, Embodied Carbon: Developing a Client Brief
WHY?
Constraints for Embodied Carbon measurement and reduction

• Lack of clarity in standardized measurement (note: RICS methodology published 2017)
• Lack of incentive for measurement and reduction
• Benchmarking accuracy
• Lack of skills and training
Drivers for Embodied Carbon measurement and reduction

• nZEB (2020) increasing attention on Embodied Carbon
• Clients with strong sustainability objectives
• Increasing project data through BIM
• London Plan (2019). Likelihood of Embodied Carbon being offset against carbon tax?
Q&A
Thank you.

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