Integration of Energy and Material Performance of Buildings: I=E+M

S.M. van Hulten, E.A. Alsema, D. Anink, G. Donze, A. Meijer, A. Straub

W/E Consultants Sustainable Building
OTB Research Institute, Delft University of Technology
The Netherlands
Why an integration of methods?

- **2020**: Net Zero Energy Buildings
- **2013**: Material performance introduced in Dutch building regulations
- **Energy**: Improvement by factor 10-100 since 1970’s
- **1995**: Energy performance introduced in Dutch building legislation

Increasing impact of materials and embodied energy
Material vs Energy performance

For example: effect of solar panels + extra insulation:

- Positive effect on energy performance
- Negative effect on material performance

How to balance materials and energy performance?
MPG: legislation and certification

- MPG methodology in National Building Legislation
- National, LCA based product database
- ‘Shadowprice’ in €/m²/year
- Tools / certification
### MPG: generic/specific LCA product database

<table>
<thead>
<tr>
<th>Product</th>
<th>Schaduwprijs</th>
<th>Aantal</th>
<th>Dimensie 1</th>
<th>Dimensie 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kalkzandsteen lijmblokken</td>
<td>1.58</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kalkzandsteen elementen</td>
<td>1.61</td>
<td>39.8 m²</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Cellenbeton casco panelen (Xella-Ytong)</td>
<td>1.8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cellenbeton casco panelen (Xella-)</td>
<td>1.81</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cellenbeton verdiepings hoge panelen (Xella-Ytong)</td>
<td>1.81</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cellenbeton blokken (Xella-Ytong)</td>
<td>1.85</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cellenbeton wandplaten (Xella-He…</td>
<td>2.45</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
MPG: material and embodied energy impact
Integration: framework

**MPG**
- Material performance indicator
- National standard Dutch building legislation
- Considers whole life cycle (LCA)
- System boundary = global economy.

**EPG**
- Energy performance indicator
- Based on EPBD standard (legislation)
- Considers building use phase
- Materials’ embodied energy not included
- System boundary ≈ building perimeter

**MPG + EPG**
- integral environmental impact from operational energy consumption and materials use expressed in €/m²/year

**EPG**

**IPG**
GPR Building: assessment tool
Case: Net Zero Energy Building

- 3 variants in solar energy installation
- effects on total environmental impact of building
IPG: Integral environmental impact

Residential building, *present* standard: EPC=0,40

<table>
<thead>
<tr>
<th>Integral environmental impact performance (IPG) (€/m²/year)</th>
<th>-1</th>
<th>-0.5</th>
<th>0</th>
<th>0.5</th>
<th>1</th>
<th>1.5</th>
<th>2</th>
<th>2.5</th>
<th>3</th>
<th>3.5</th>
<th>4</th>
<th>4.5</th>
<th>score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy performance</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1,16</td>
</tr>
<tr>
<td>Material performance</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0,39</td>
</tr>
<tr>
<td><strong>Totaal</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>1,55</strong></td>
</tr>
</tbody>
</table>

**NZEB** Residential building: EPC= -0,04

<table>
<thead>
<tr>
<th>Integral environmental impact performance (IPG) (€/m²/year)</th>
<th>-1.5</th>
<th>-1</th>
<th>-0.5</th>
<th>0</th>
<th>0.5</th>
<th>1</th>
<th>1.5</th>
<th>2</th>
<th>2.5</th>
<th>3</th>
<th>3.5</th>
<th>4</th>
<th>score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy performance</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-0,22</td>
</tr>
<tr>
<td>Material performance</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>0,57</strong></td>
</tr>
<tr>
<td><strong>Totaal</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>0,35</strong></td>
</tr>
</tbody>
</table>
Conclusions

• IPG gives an integrated assessment of environmental performance

• For **entire building life cycle**, from resource winning to use phase and final decommissioning

• Based on **existing**, standardized calculation methods, familiar to building community

• **Level playing field**
Discussion and outlook

• Extension to other countries requires:
  • reassess **system boundaries** (energy)
  • establish national **LCA database** (materials)

• EU level:
  • **eco-efficiency program** and **energy directive**
  • product specific **European LCA database** would be a great advantage for producers of building materials
Thank you for your attention

More information:
www.tki-kiem.nl (in Dutch)
or in the paper (in English)

We gratefully acknowledge the financial support from the research program
TKI ENERGO of the Dutch Ministry of Economic Affairs
### MPG method (2)

<table>
<thead>
<tr>
<th>Environmental impact categories</th>
<th>Equivalent unit</th>
<th>Weighing factors [€ / kg equivalent]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Depletion of abiotic resources (excluding fossil fuels) – ADP</td>
<td>Sb eq</td>
<td>€ 0.16</td>
</tr>
<tr>
<td>2. Depletion fossil fuels – ADP</td>
<td>Sb eq</td>
<td>€ 0.16</td>
</tr>
<tr>
<td>3. Global warming – GWP 100 j.</td>
<td>CO₂ eq</td>
<td>€ 0.05</td>
</tr>
<tr>
<td>4. Depletion ozone layer – ODP</td>
<td>CFK-11 eq</td>
<td>€ 30</td>
</tr>
<tr>
<td>5. Photochemical oxidant creation – POCP</td>
<td>C₂H₄ eq</td>
<td>€ 2</td>
</tr>
<tr>
<td>6. Acidification – AP</td>
<td>SO₂ eq</td>
<td>€ 4</td>
</tr>
<tr>
<td>7. Eutrophication – EP</td>
<td>PO₄ eq</td>
<td>€ 9</td>
</tr>
<tr>
<td>8. Human toxicity – HTP</td>
<td>1,4-DCB eq</td>
<td>€ 0.09</td>
</tr>
<tr>
<td>9. Fresh water aquatic eco toxicity – FAETP</td>
<td>1,4-DCB eq</td>
<td>€ 0.03</td>
</tr>
<tr>
<td>10. Marine aquatic eco toxicity - MAETP</td>
<td>1,4-DCB eq</td>
<td>€ 0.0001</td>
</tr>
<tr>
<td>11. Terrestrial eco toxicity – TETP</td>
<td>1,4-DCB eq</td>
<td>€ 0.06</td>
</tr>
</tbody>
</table>

#### 1-points score

- **Raw materials**
- **Emissions**
GPR Building: Sustainable building assessment tool

GPR Building v.4

Energy
- Energy performance
- Complementary energy measures

Environment
- Water
- Environmental care
- Materials

Health
- Noise
- Air quality
- Thermal comfort
- Light and visual comfort

User Quality
- Accessibility
- Functionality
- Technical Quality
- Safety

Long term value
- Adaptability and future amenities
- Flexibility
- Perceived value

Other factors:
- Environmental care
- Air quality
- Thermal comfort
- Light and visual comfort
- Accessibility
- Functionality
- Technical Quality
- Safety
- Adaptability and future amenities
- Flexibility
- Perceived value
System boundaries for EPG and MPG

System boundary for Energy Performance of Buildings (EPG)

System boundary for Energy Performance of Buildings

System boundary for Material Performance of Buildings (MPG)

Biomass production and transport abroad
Natural gas winning and transport abroad
Coal/oil winning and transport abroad
Electricity production and transport abroad

Waste production in Netherlands
Biomass production and distribution in Netherlands
Gas winning and distribution in Netherlands
Electricity production and distribution in Netherlands

Electricity production and distribution in project (collective)

Heat production and distribution in city or region
Heat production within building
Electricity production in or on building
Electricity production and distribution in project (collective)

Final consumption of energy (space heating, domestic hot water, household appliances)

Gas, Biomass, Coal

Project boundary

Building boundary / boundary energy metering

Heat production and distribution within project (collective)
Gas, Biomass

System boundary for energy distribution in Netherlands

Coal/oil winning and transport abroad
Gas winning and distribution in Netherlands
Biomass production and transport abroad

Electricity production and transport abroad

Gas, Biomass

System boundary for energy distribution in Netherlands

Natural gas winning and transport abroad
Coal/oil winning and transport abroad
Electricity production and transport abroad

Gas, Biomass

2017 Sustainable Built Environment Conference