Impact of dynamic CO₂ emission factors for the public electricity supply on the life-cycle assessment of energy efficient residential buildings

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Specific greenhouse gas emissions of the German electricity mix in g CO₂-eq./kWh
Agenda

1. Introduction and scope
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   a. Dynamic CO₂ emission factors for the German electricity mix
   b. Adaptation of the building LCA method
   c. Modelling of future emission factors
3. Case study
4. Conclusion and outlook
1 Introduction and scope

- Anthropogenic climate change globally threatens the livelihood of millions.

- German *Energiewende* is aiming on the decarbonisation of all sectors of energy consumption by
  - increasing efficiency and/or reducing energy demand, respectively
  - increasing the share of renewable energy sources in power supply, building sector and mobility

- Volatile character of future power generation as well as power demand are increasing

![Graph showing GHG emissions and reduction targets](image)

Source: BMUB (2016): Climate Action Plan 2050; Own illustration
2 Methodology

- The **goal** is the adaptation of established methods for environmental and life-cycle assessment (LCA) to reflect
  - dynamics of future power generation
  - patterns of energy consumption in buildings

- The **basis** is the established LCA for buildings according to the standard DIN EN 15978, for instance as implemented in the DGNB certification

<table>
<thead>
<tr>
<th>Building life cycle</th>
<th>Benefits and loads beyond the system boundary (D)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Product (A1-3)</td>
<td></td>
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<tr>
<td>Construction (A4-5)</td>
<td></td>
</tr>
<tr>
<td>Use (B1-6)</td>
<td></td>
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<tr>
<td>End of Life (C1-4)</td>
<td></td>
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</tbody>
</table>

*Source: Own illustration (based on EN 15978)*
Dynamic CO$_2$ emission factors for the German electricity mix

- Processing of data on power generation from ENTSO-E transparency platform for 2017 and calibration to federal statistics

- Mix of electricity generation technologies and energy carriers in each time step (temporal resolution: 15 minutes)

**Net power generation and load in GW**

![Graph showing net power generation and load in GW for Winter and Summer periods.](image)

**Source:** Wörner et al. (2019): Dynamische CO2-Emissionsfaktoren für den deutschen Strom-Mix
Dynamic CO$_2$ emission factors for the German electricity mix

- Mean specific emissions per unit of electric energy supplied for each energy carrier and plant type from PROBAS database

Specific greenhouse gas emissions of the German electricity mix in g$_{CO2-eq.}$/kWh

Source: Wörner et al. (2019): Dynamische CO2-Emissionsfakten für den deutschen Strom-Mix (Illustration adapted)
Adaptation of the building LCA method

The building LCA is modified regarding the use phase (Module B) to allow for

- a higher time resolution when assessing the energy demand ($q_i$)
- an implementation of dynamic greenhouse gas emission factors ($f_{GHG,i}$)

\[
q_{GHG,i} = q_i \times f_{GHG,i}
\]

- The calculation of total emissions over lifetime

\[
c_{total} = c_{annual} \times n_{years} = \sum_i c_{GHG,i} \times n_{years}
\]

$n_{years}$: estimated service life of the building

$i$: timestep (from 1 to 35,040 for one year)
Modelling of future emission factors

- Future emission factors are calculated on the basis of a 80 % GHG reduction scenario from Gerbert et al. 2018: “Klimapfade für Deutschland“

- Profiles for power generation are derived from 2017 load profiles

<table>
<thead>
<tr>
<th></th>
<th>2017</th>
<th>2030</th>
<th>2050</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Annual power generation (in TWh)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Net annual production</td>
<td>619.4</td>
<td>578</td>
<td>627.1</td>
</tr>
<tr>
<td>Photovoltaics</td>
<td>39.3</td>
<td>70</td>
<td>100</td>
</tr>
<tr>
<td>Wind-Onshore</td>
<td>87.6</td>
<td>136</td>
<td>188</td>
</tr>
<tr>
<td>Wind-Offshore</td>
<td>17.6</td>
<td>63</td>
<td>208</td>
</tr>
<tr>
<td>Biomass</td>
<td>46.7</td>
<td>46.8</td>
<td>36.8</td>
</tr>
<tr>
<td>Other renewable</td>
<td>26.3</td>
<td>27.2</td>
<td>27.3</td>
</tr>
<tr>
<td>Conventional fossil</td>
<td>401.9</td>
<td>235</td>
<td>67</td>
</tr>
<tr>
<td><strong>Consumption weighted annual GHG emission factor for the public electricity supply (in gCO₂-eq./kWh)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>direct</td>
<td>524.5</td>
<td>340.6</td>
<td>77.6</td>
</tr>
<tr>
<td>incl. upstream chains</td>
<td>594.1</td>
<td>401.4</td>
<td>119.6</td>
</tr>
</tbody>
</table>

3 Case study

- Residential building model in accordance with German Energy Saving Ordinance (EnEV)*

- Dynamic building simulation using IDA ICE 4.81

*cf. Klauß 2010, Weißmann 2017 for further input parameters

**Source:** Own illustrations derived from IDA ICE 4.81
### Case study

- Simulation gives load profiles and resulting GHG emissions are calculated (temporal resolution: 15 minutes)

- Calculation of the specific GHG emissions of products (A1-3) and the operation phase (B1-7)
Case study

- Comparison of LCA results for
  - 2017, 2030 and 2050 electricity mix
  - static and dynamic LCA approach

Key findings

1) Considerable reduction of GHG emissions

![Graph showing specific GHG emissions for different years and approaches.](source: Own illustration)
### Case study

- Comparison of LCA results for
  - 2017, 2030 and 2050 electricity mix
  - static and dynamic LCA approach

#### Key findings

1. Considerable reduction of GHG emissions
2. Higher GHG emissions when using dynamic GHG emissions factors
3. Increasing assessment gap if share of renewable energy sources increases

*Source: Own illustration*
4 Conclusion and outlook

- Renewable energy technologies and energy efficient buildings support the achievement of GHG emission reduction targets until 2050
  - GHG emissions of the construction phase must be reduced as well or compensated by other sectors, respectively
  - LCA results based on dynamic demand inputs and emission profiles suggest that an additional effort is necessary to limit climate change

- A higher degree of dynamic inputs may be used to further enhance LCAs and achieve more realistic assessments
  - LCAs with annually decreasing emission factors/profiles in the cause of a buildings’ service life
  - Impact of decarbonisation trends on most important construction materials and building components
Thank you for your attention!

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Literature


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