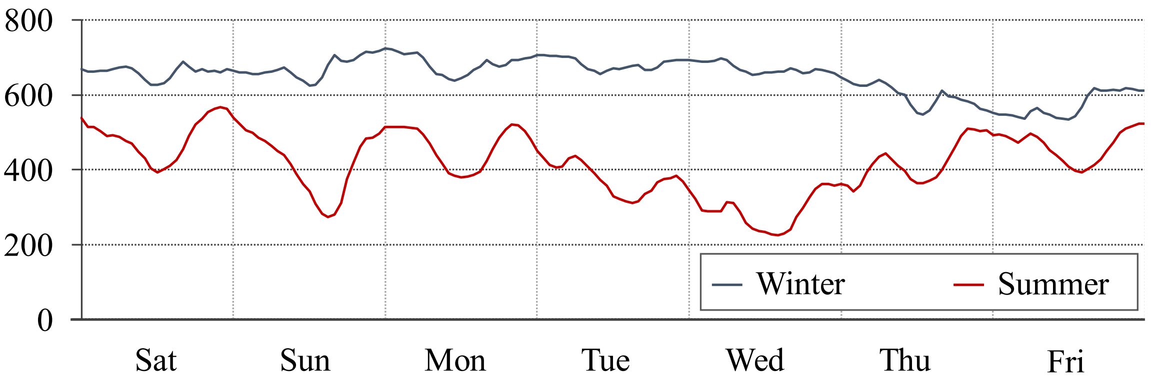
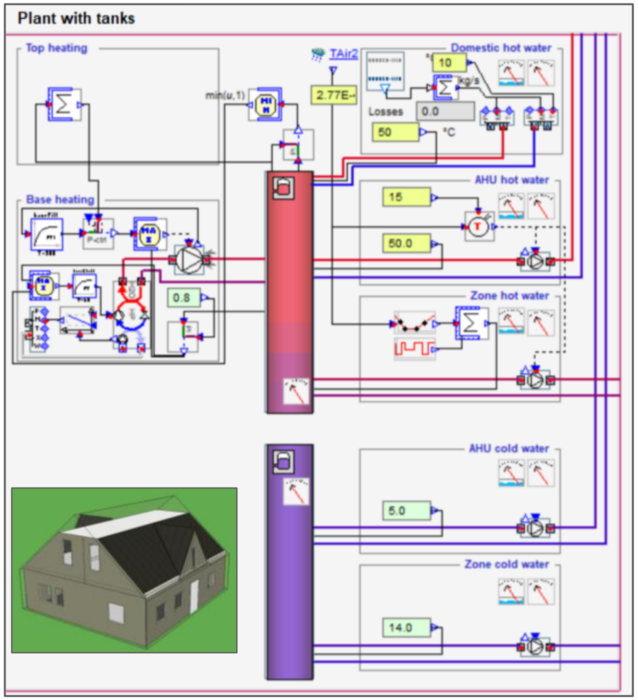
Impact of dynamic CO_2 emission factors for the public electricity supply on the life-cycle assessment of energy efficient residential buildings

André Müller, M.Sc. & Patrick Wörner, M.Sc.

Specific greenhouse gas emissions of the German electricity mix in $g_{CO2\text{-}eq.}$/kWh



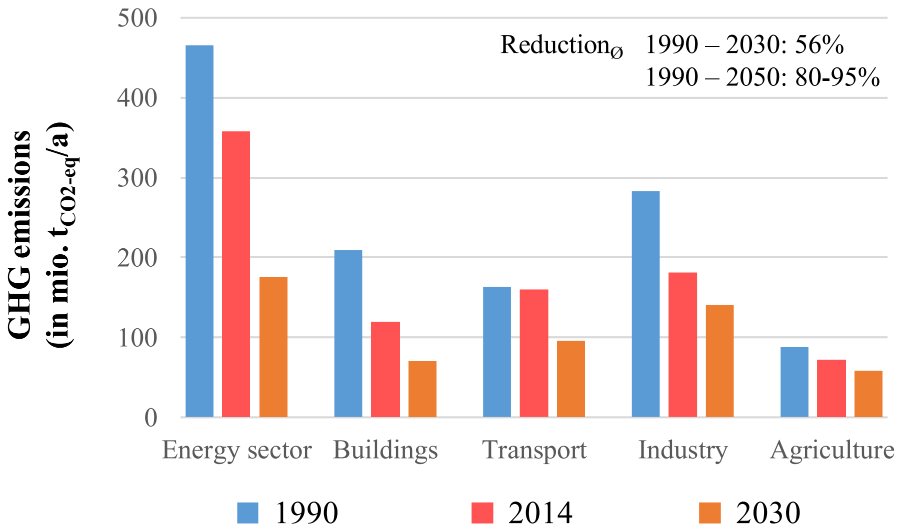


Agenda

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



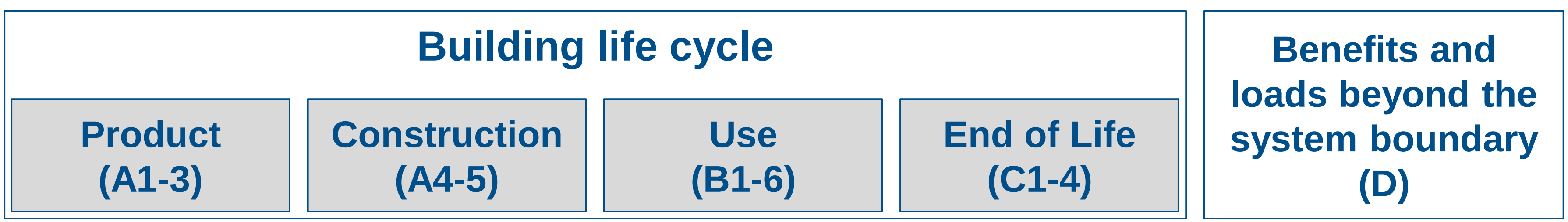
Source: BMUB (2016): Climate Action Plan 2050; Own illustration

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

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



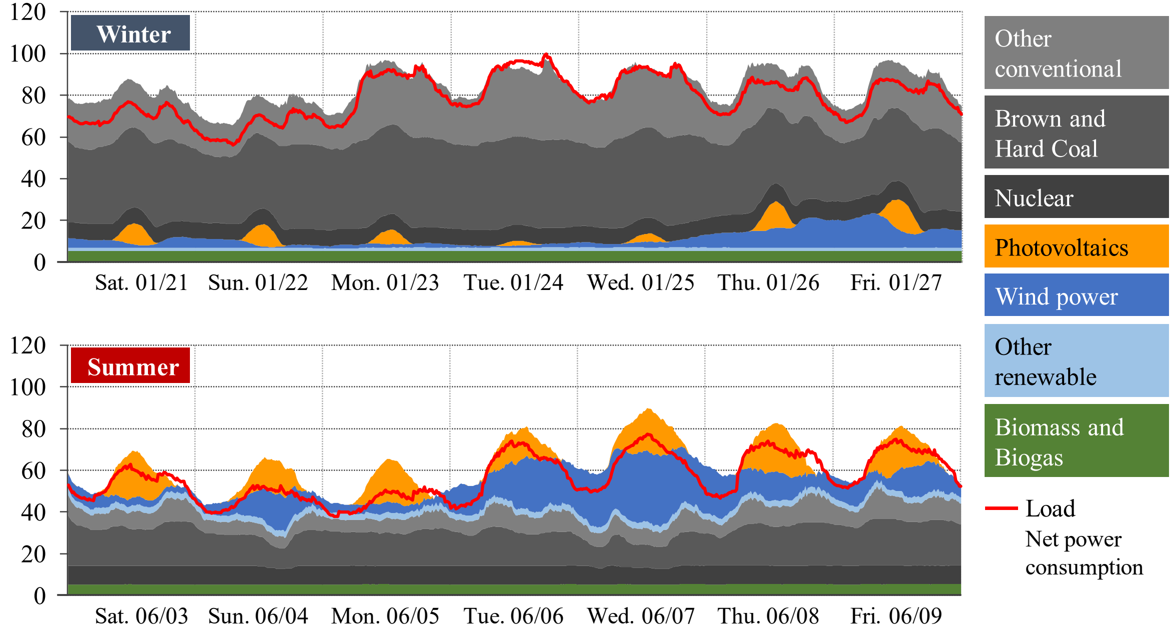
Source: Own illustration (based on EN 15978)

2 a

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

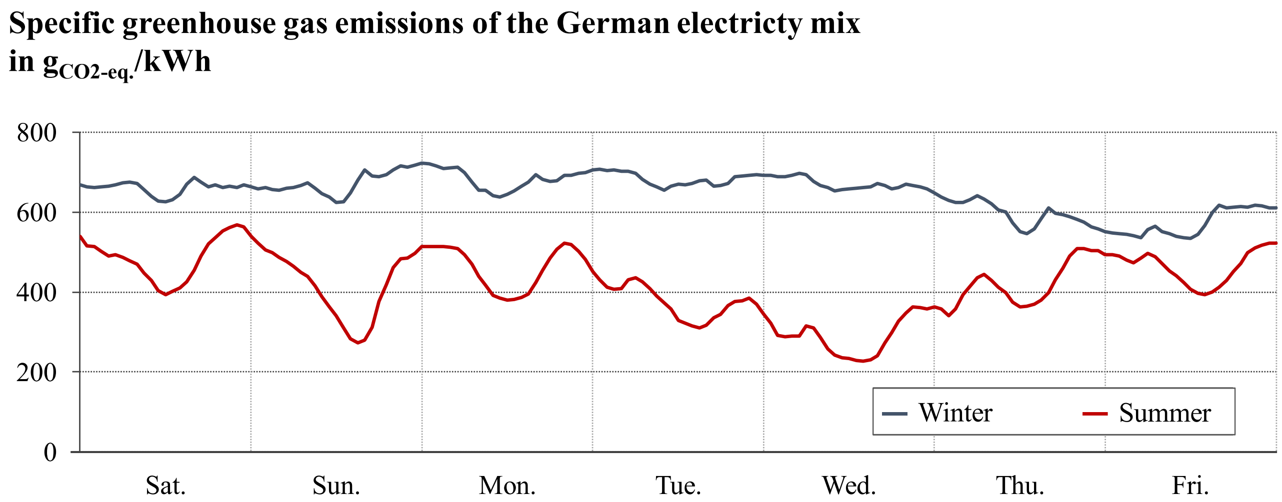


Source: Wörner et al. (2019): Dynamische CO2-Emissionsfaktoren für den deutschen Strom-Mix

2 a

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



Source: Wörner et al. (2019): Dynamische CO2-Emissionsfaktoren für den deutschen Strom-Mix (Illustration adapted)

2 b 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 grenhouse gas emission factors ($f_{\text{GHG},i}$)

(1) $$c_{\text{GHG},i} = q_i * f_{\text{GHG},i}$$

c_{GHG}	greenhouse gas emissions caused by a buildings' energy demand (in $g_{\text{CO2-eq.}}$)
q	energy demand (in kWh)
f_{GHG}	specific greenhouse gas emissions ($g_{\text{CO2-eq.}}$/kWh)
i	timestep (from 1 to 35,040 for one year)

- The calculation of total emissions over lifetime

(2) $$c_{\text{total}} = c_{\text{annual}} * n_{years} = \sum_i \left(c_{\text{GHG},i}\right) * n_{\text{years}}$$

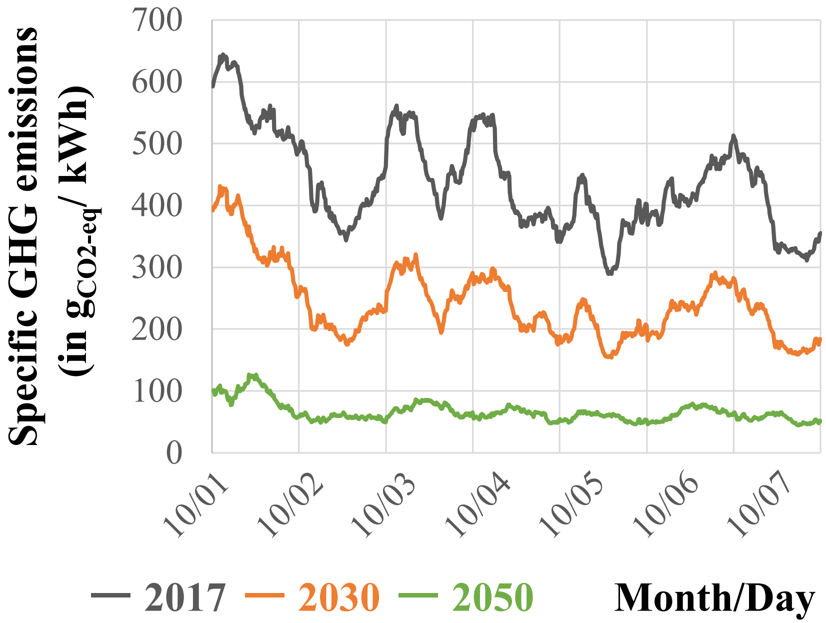
n_{years}	estimated service life of the building
i	timestep (from 1 to 35,040 for one year)

2 c 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

	2017	2030	2050
Annual power generation (in TWh)			
Net annual production	619.4	578	627.1
Photovoltaics	39.3	70	100
Wind-Onshore	87.6	136	188
Wind-Offshore	17.6	63	208
Biomass	46.7	46.8	36.8
Other renewable	26.3	27.2	27.3
Conventional fossil	401.9	235	67
Consumption weighted annual GHG emission factor for the public electricity supply (in $g_{CO2\text{-}eq.}$ /kWh)			
direct	524.5	340.6	77.6
incl. upstream chains	594.1	401.4	119.6

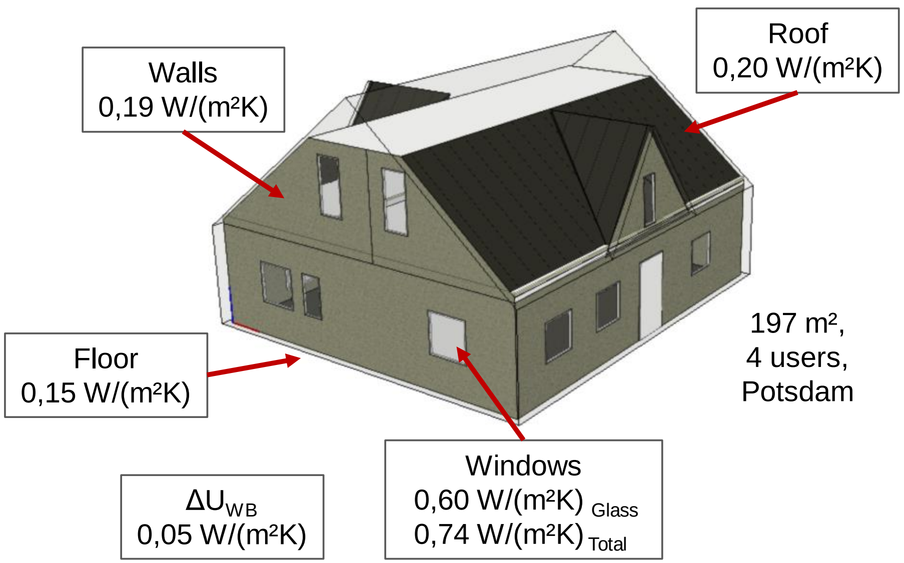
Source: 2017 – Wörner et. al 2019; 2030 & 2050 – Gerbert et al. 2018

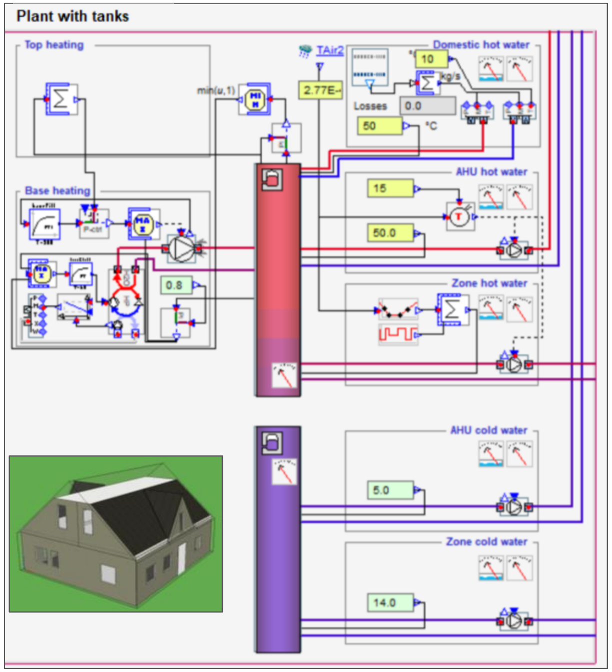


3 Case study

- Residential building model in accordance with German Energy Saving Ordinance (EnEV)*
- Dynamic building simulation using IDA ICE 4.81

Heat generation	
Air-to-water heat pump	
Nominal power	9.28 kW
COP / Annual performance ratio	3.5 / 2.95
Heat transfer	
Floor heating	
Room temperature	
Heating period	min. 20 °C
Cooling period	max. 26 °C



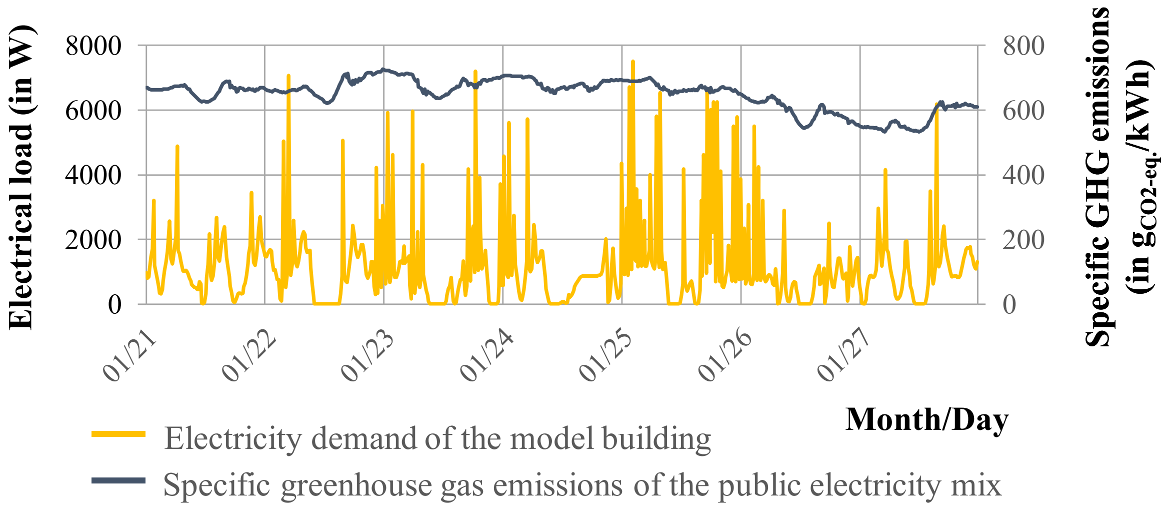


*cf. Klauß 2010, Weißmann 2017 for further input parameters

Source: Own illustrations derived from IDA ICE 4.81

3 Case study

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



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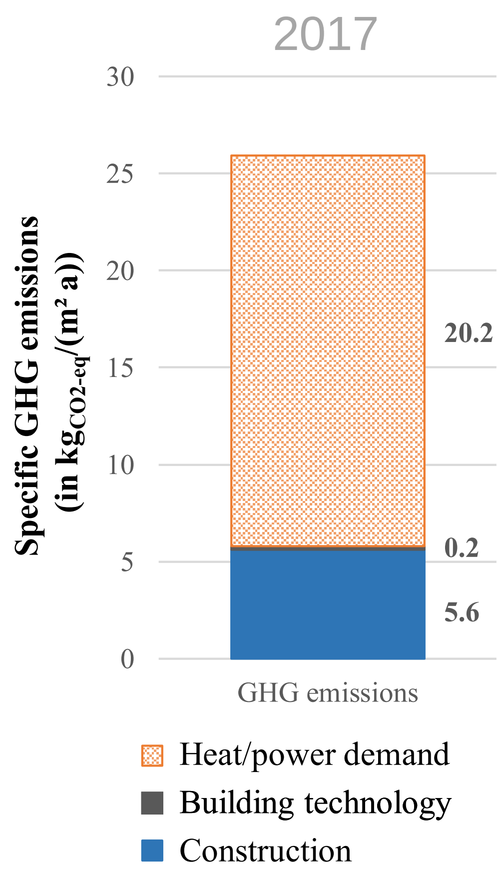


Source: Own illustration

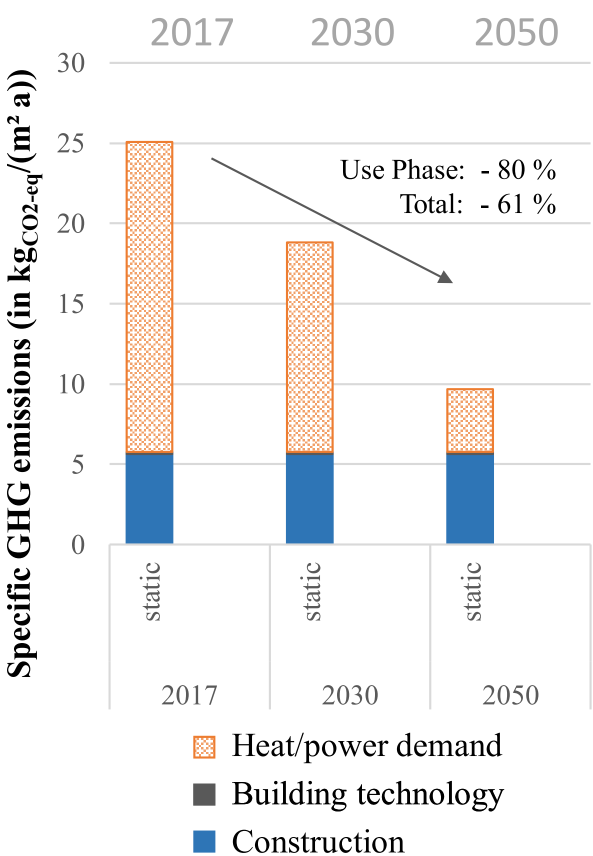
- Calculation of the specific GHG emissions of products (A1-3) and the operation phase (B1-7)

3 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



Source: Own illustration

3 Case study

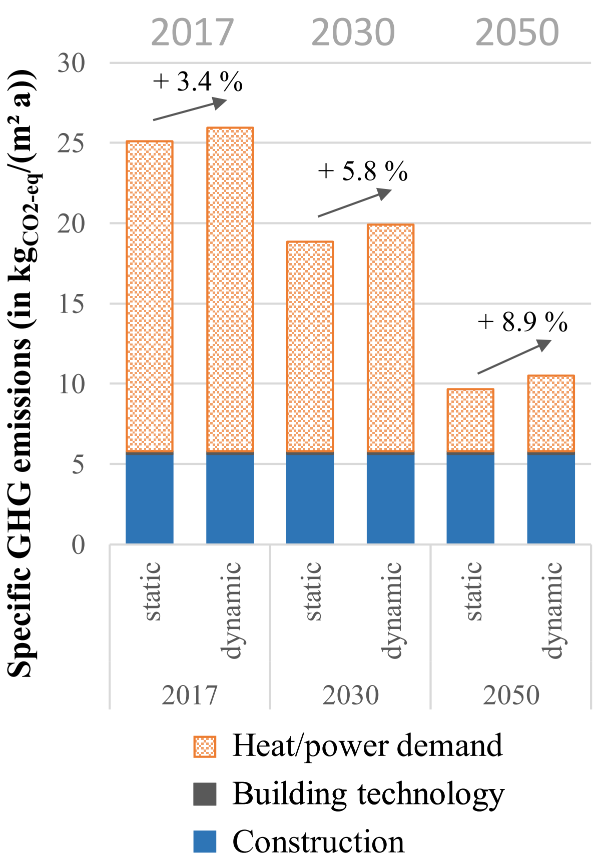
- Comparison of LCA results for
  - 2017, 2030 and 2050 electricity mix
  - static and dynamic LCA approach

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

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Thank you for your attention!

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