Accounting CO_2 emissions from electricity and district heat used in buildings

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Energy performance regulation in buildings

- Controlling and directing the demand change
- How much and which energy is used in buildings
- Straightforward for new buildings, more complicated for existing

- Not directly linked to policies for energy production, however the both are important:
  - Generates the demand change in the existing market with consequences for developments in the production side

- *Buildings account for 41% of primary energy use in EU (Eurostat) being the largest single potential for energy savings*

Energy performance (EP) of buildings

- EP-rating sums up all delivered energy (electricity, district heat/cooling, fuels) into a single rating with relevant weighting factors (EN 15603)
- "Relevant" weighting factors for energy sources (energy carriers) are the key issue for accountable energy performance requirements

Delivered energy	Building A	Building B
Electricity, kWh/(m^2 a)	100	50
District heat, kWh/(m^2 a)	50	100
Total, kWh/(m^2 a)	150	150

- With weighting factors based on CO_2 emissions (conservative example):

Delivered energy	**Building A**	**Building B**
Electricity, kWh/(m^2 a)	**100*2**	**50*2**
District heat, kWh/(m^2 a)	**50*0.8**	**100*0.8**
Total, kWh/(m^2 a)	**240**	**180**

EP $\leq$ 200

CO_2-emissions vs. primary energy concept

- Primary energy use refers to the use of natural resources[1]
- Nuclear energy causes the major difference:
  - Primary energy factor of 2.8…3.0 because of the use of uranium
  - No CO_2-emissions at all (0 kg(CO_2)/MWh)
- For other energy carriers, the weighting factors are very similar independently of the use of primary energy or CO_2 approach

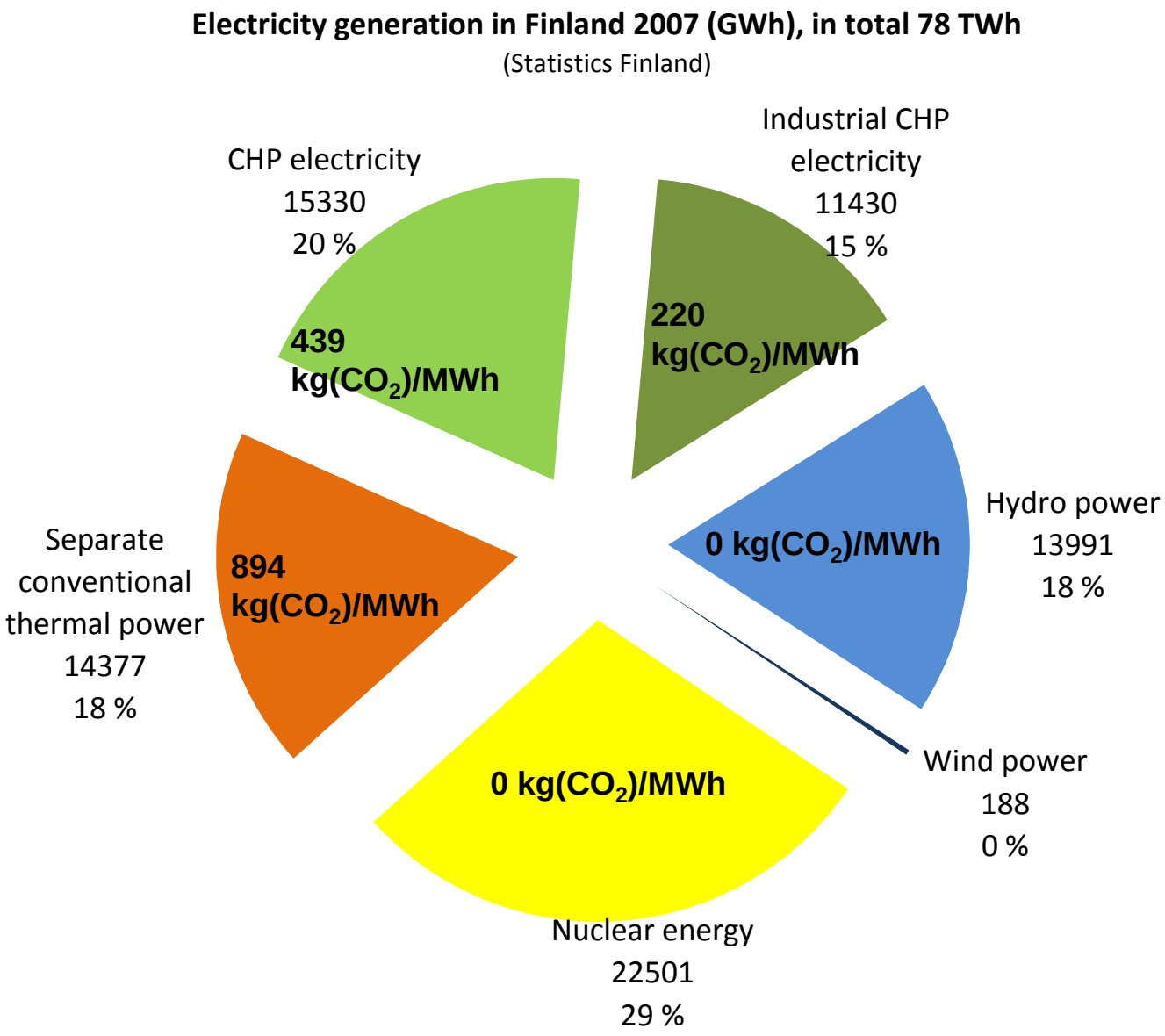
- $\Rightarrow$ somewhat higher weighting factor for electricity if primary energy approach is used (this study focuses on emissions)
- weighting factors more complicated to determine for mix of all production sources as situation in Finland

[1]*Definition (for a building): **Non-renewable primary energy** is the non-renewable energy used to produced the energy delivered to the building. It is calculated from delivered energy amounts of energy carriers, using conversion factors (EN 15603:2008).*

Case Finland

- Study of CO_2-emissions from electricity generation and district heat production:
  - Hourly data of specific emissions from 2000-2007
  - Demand change analyses for electricity use
  - Demand change analyses for district heating use
  - Coupling with new capacity – scenarios
  - Derivation of **energy carrier weighting factors** based on demand change analyses to show how much one energy carrier is more valuable than another on emission bases

Electricity generation in Finland



Electricity generation, average specific emission 2000-2007: **273 kg(CO_2)/MWh**

District heat production, average specific emission 2000-2007: **217 kg(CO_2)/MWh**

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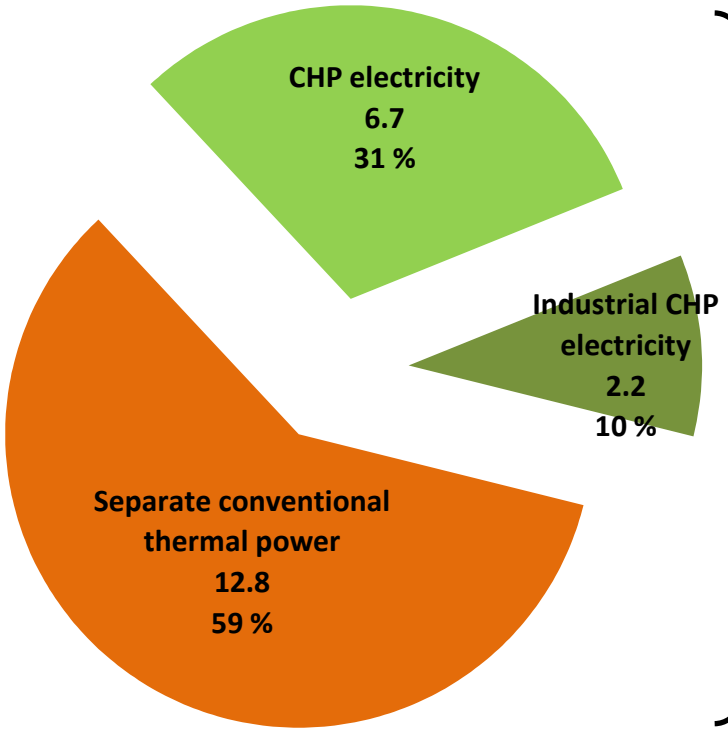
Emissions of heat and power production
(calculated with benefit allocation method)

- Electricity generation in Finland 2007: **78 TWh**
- District heat and industrial steam production 2007: **95 TWh**

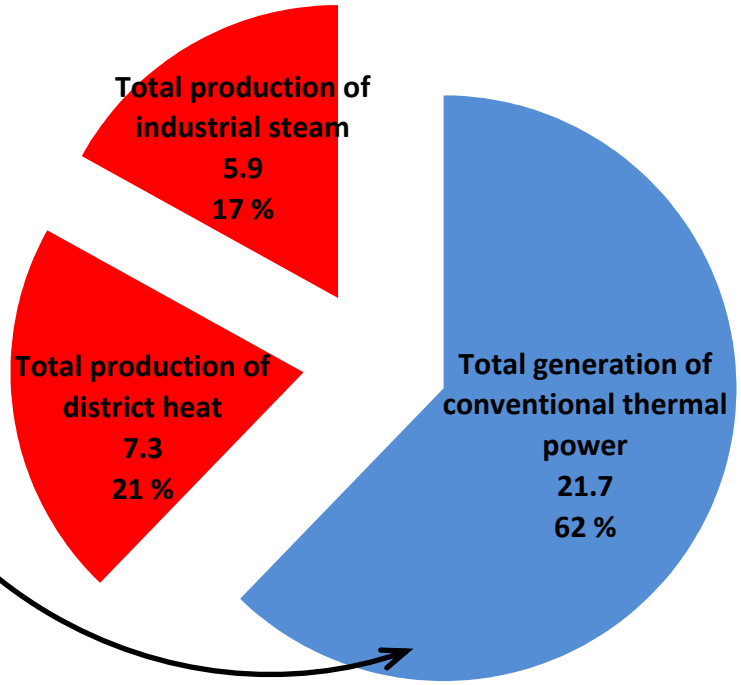
Total emissions of electricity generation 2007 (milj.t CO_2), in total 21.7 milj.t CO_2

(Statistics Finland)

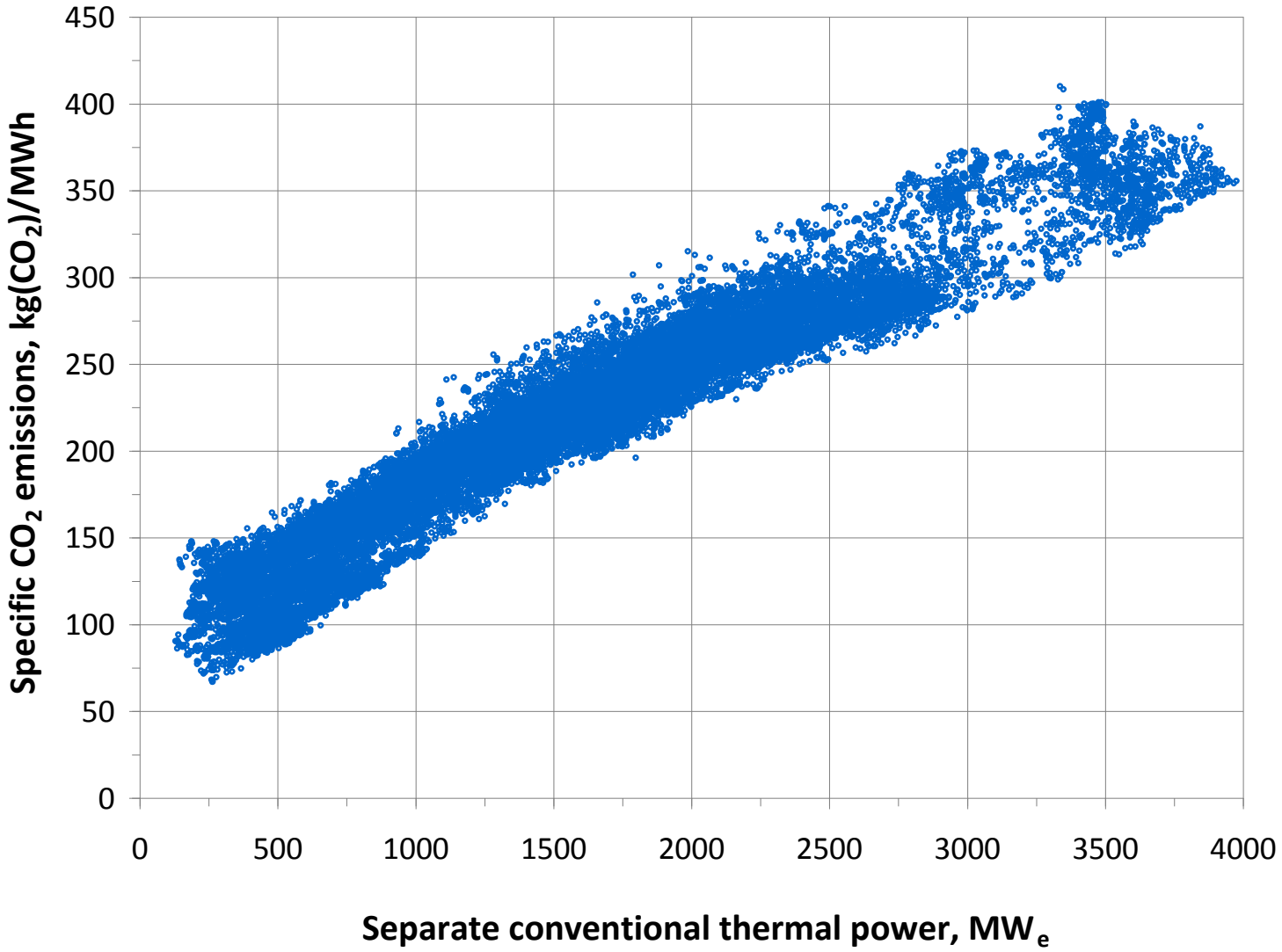


Total emissions of electricity and district heat production 2007 (milj.t CO_2), in total 34.9 milj.t CO_2

(Statistics Finland)



Specific CO_2 emissions of total electricity generation as a function of conventional thermal power 2006–2008



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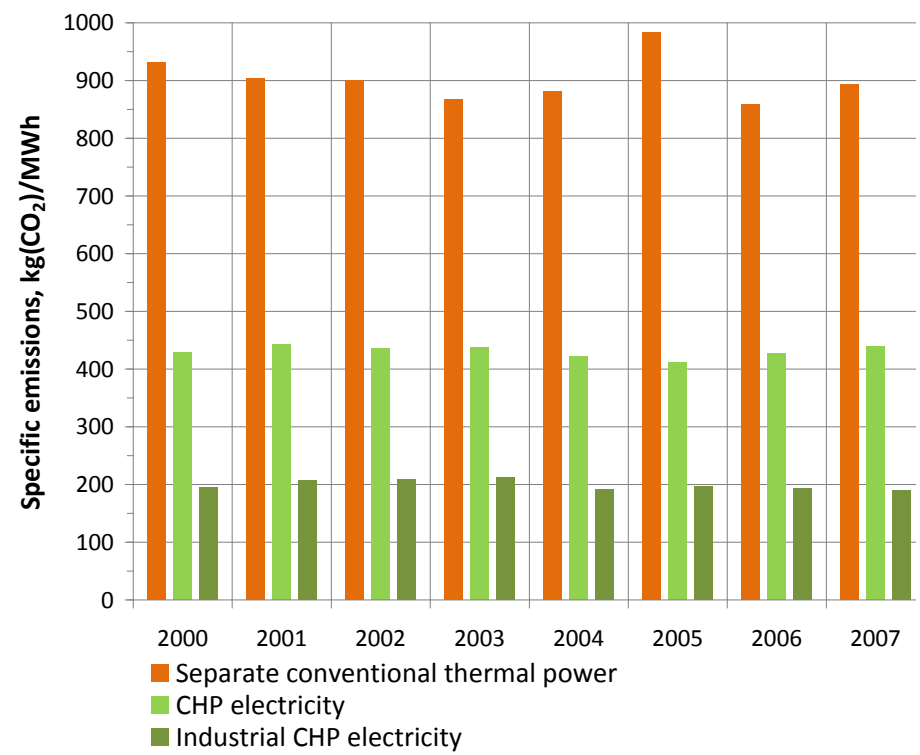
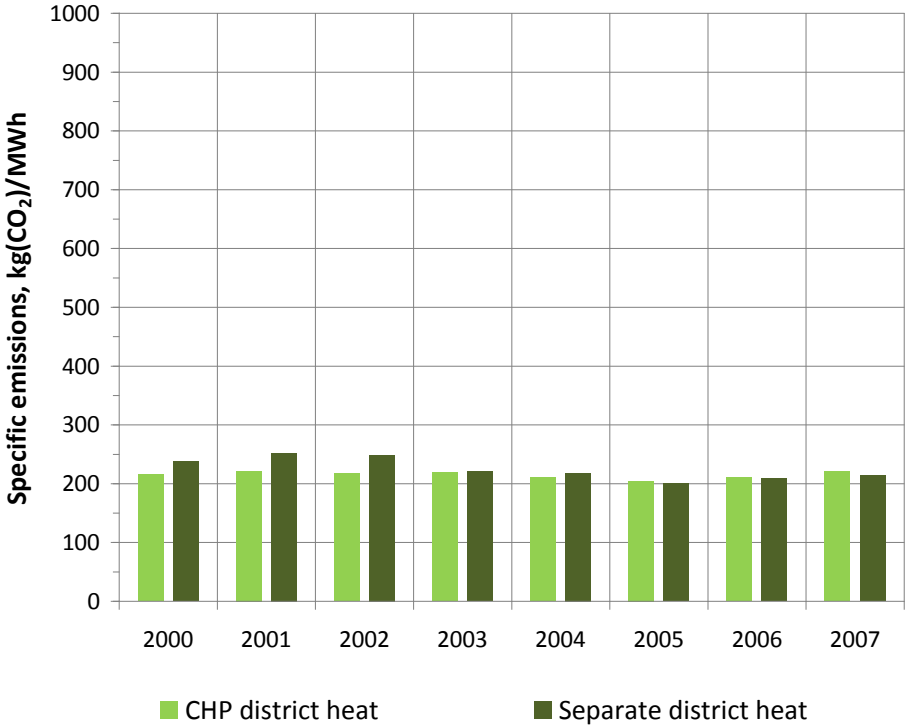
Specific emissions calculated with benefit allocation method (Energy Statistics Finland 2008)

Specific CO_2 emissions 2000–2007



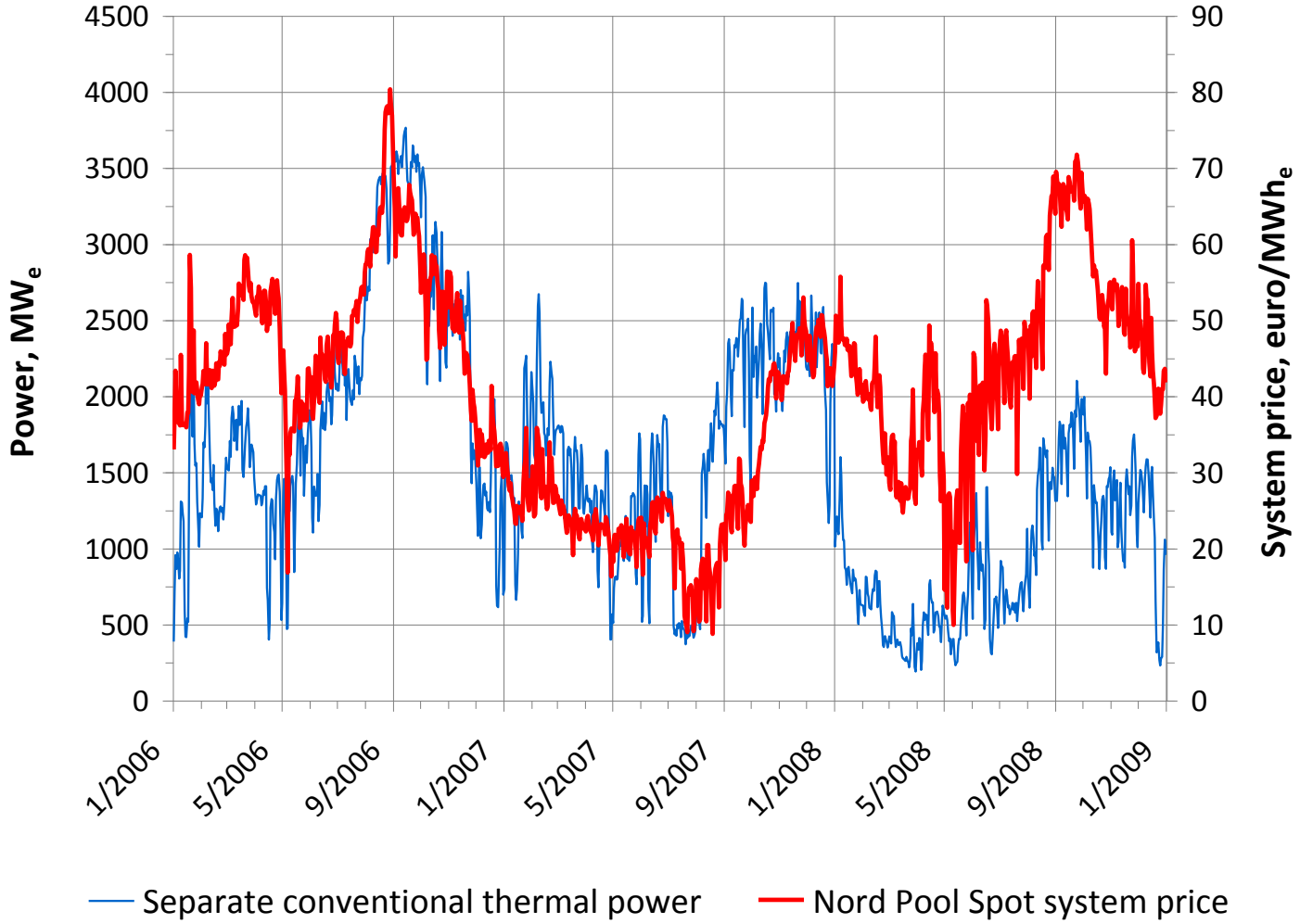


- almost constant specific emissions
- calculated with benefit allocation method (Energy Statistics Finland 2008)

Why not to use average data for the factors?

- Long term data (2000-2007) shows that average electricity generation causes somewhat higher specific CO_2-emissions relative to average district heating production (273 vs. 217 kg(CO_2)/MWh)
- For the accountability, it is important to know which specific emissions are caused by construction of a new building, or how much emissions are decreased due to energy performance improvement measures in an existing building
- For that purpose we need to know a link between a new or non-appearing energy use in a building and energy production source (i.e. which type of plant will generate or is cutting down this energy production)
- This can be shown with the demand change study:
  - For the district heat, the new demand will not change the specific emission, if there exists available capacity in the production and the fuel distribution will be the same
  - The electricity market has a lack of carbon-neutral generation capacity and each production source has different variable cost. The change in the demand is **allocated typically to the production with highest variable cost** (i.e. separate conventional thermal power). This can be justified by the correlation between the Spot price and amount of generated separate conventional thermal power shown in next slide.

Nord Pool Spot system price and the amount of generation of separate conventional thermal power



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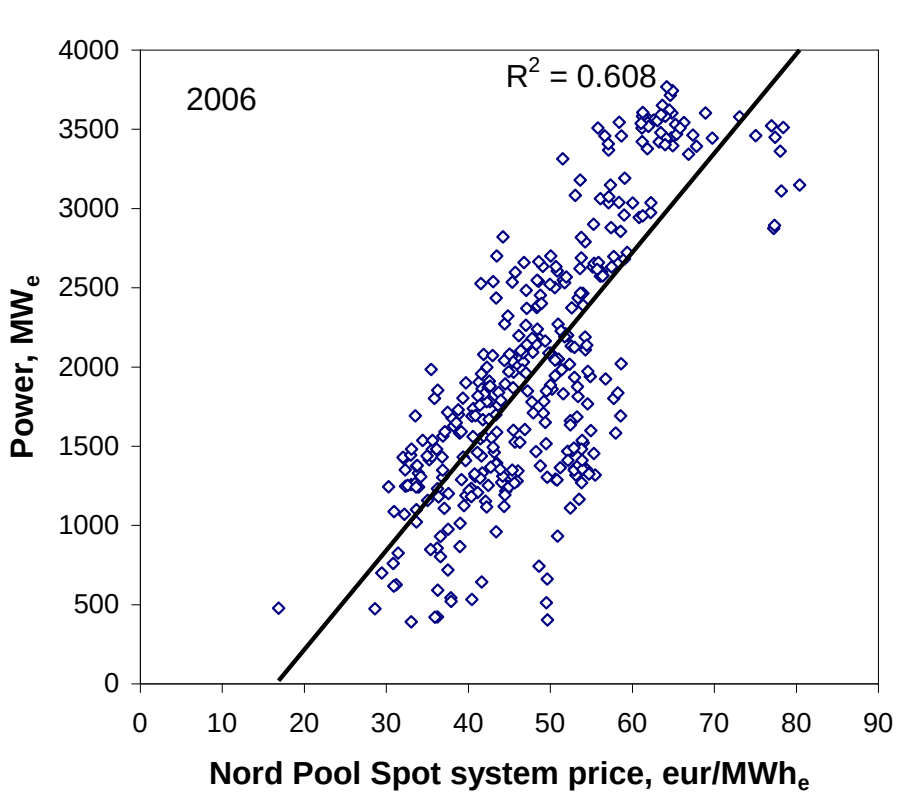
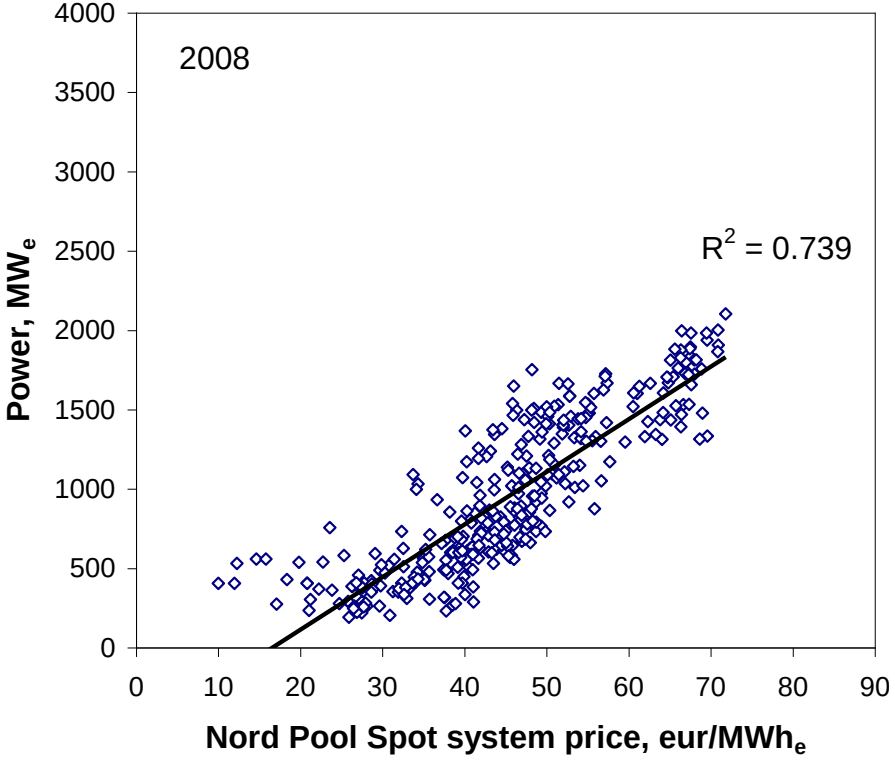
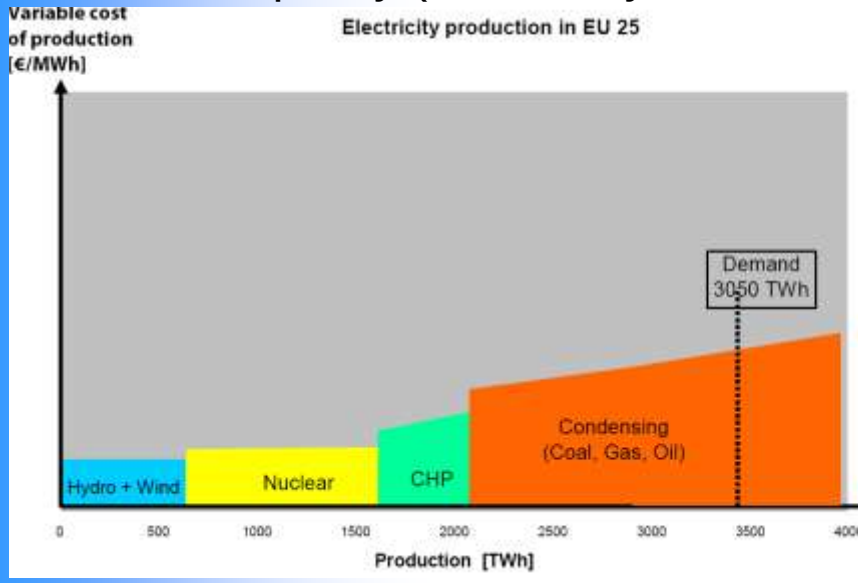
Nord Pool Spot system price and the amount of generation of separate conventional thermal power

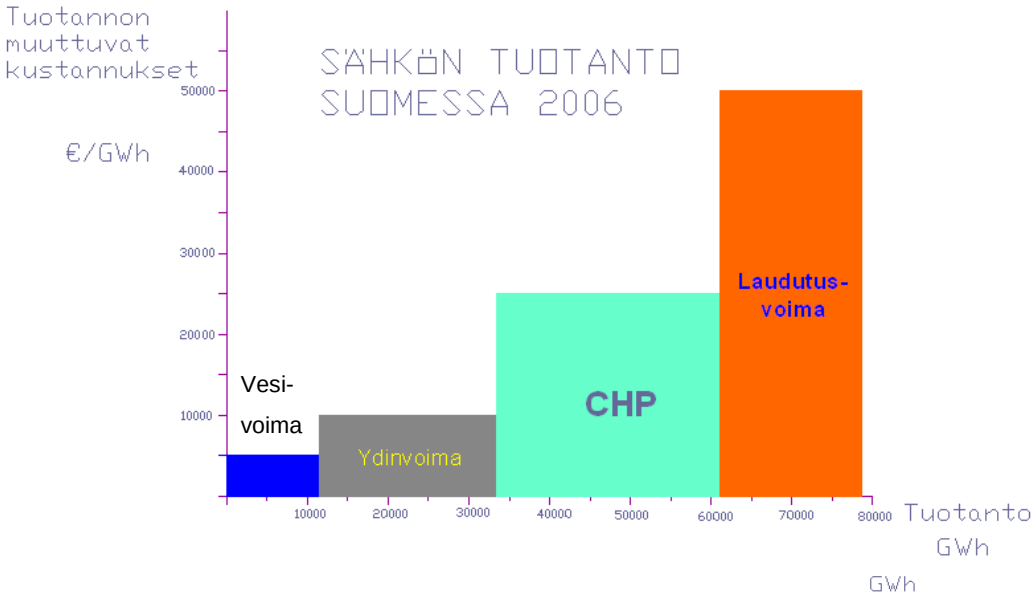




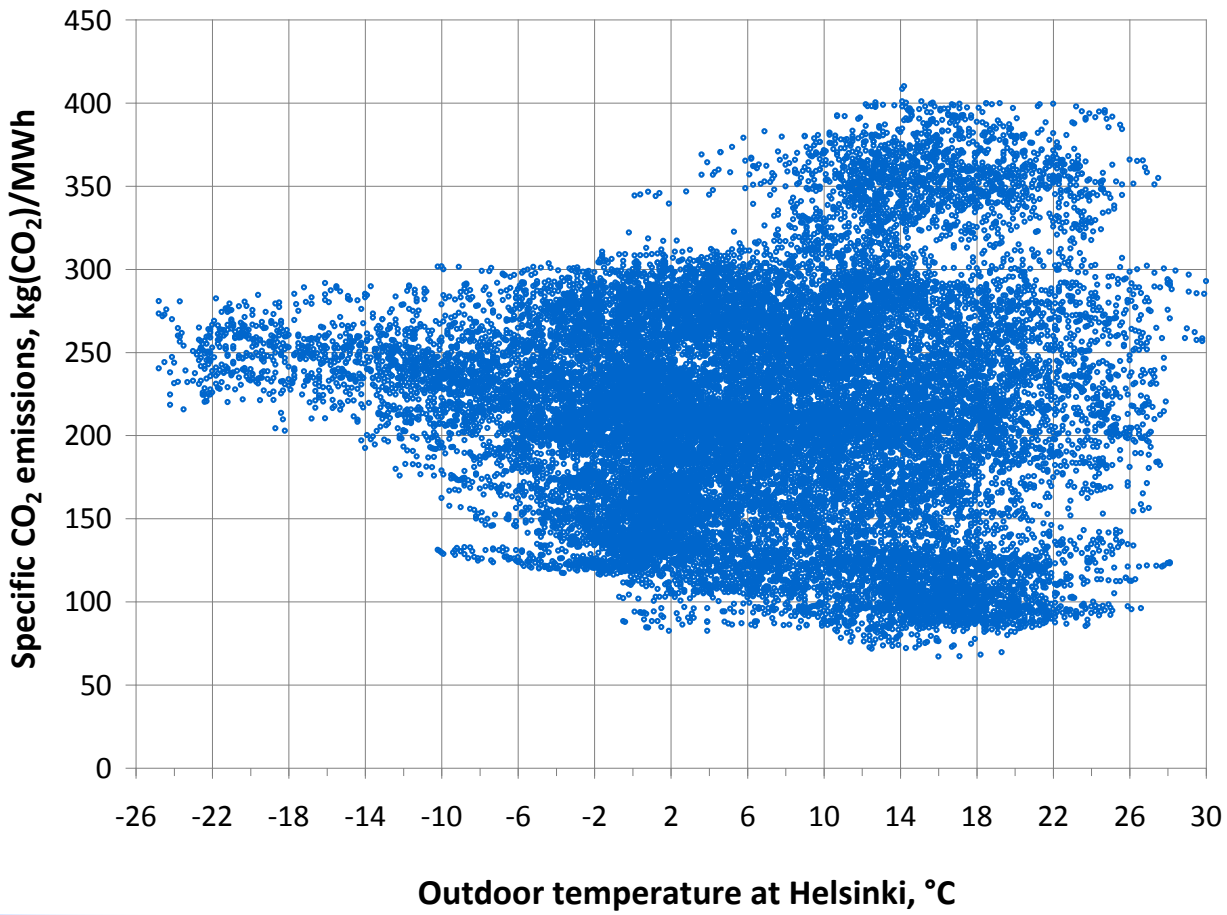
Allocation to the variable cost

- Strong correlation with Spot price and no correlation at all with outdoor temperature ⇒ good justification for the allocation to variable cost
- The same order for whole EU and Finland
- Hourly calculation: if enough generation capacity with lower variable cost is available, then the demand change will be allocated to that capacity (CHP or hydro or nuclear).



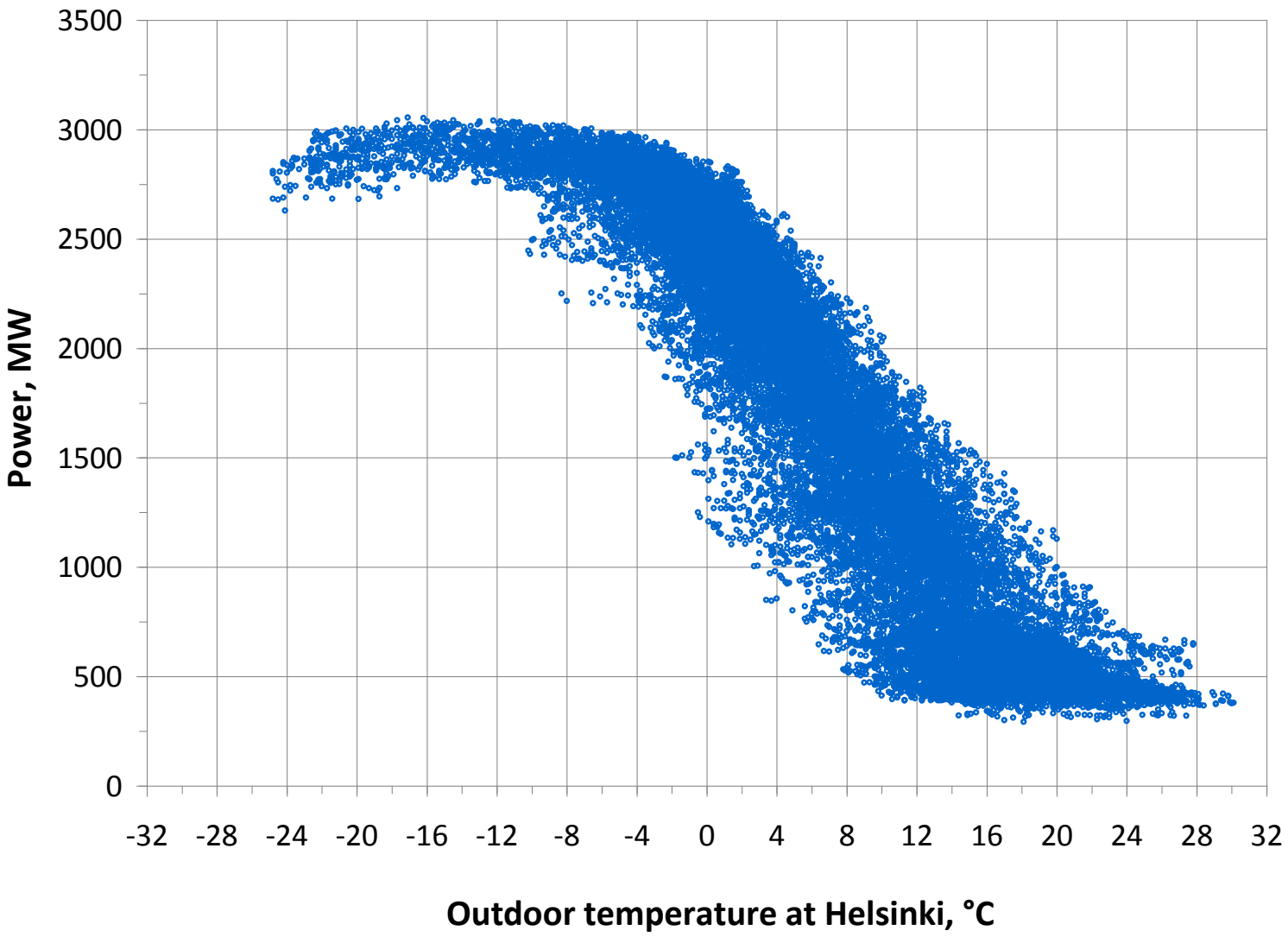


Specific CO_2 emissions of total electricity generation as a function of outdoor temperature 2006–2008



- Generation of separate conventional thermal power in Finland can be high in summer period due to shortage of hydro power and lack of CHP which is generated against heat load of district heating

CHP electricity in district heat production as a function of outdoor temperature 2006–2008



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Results for current situation (2007)

- We have calculated the demand change allocation an hour by hour for the current situation (2007) according to the order of variable cost of generation types

Specific CO_2 emissions by new or non-appearing electricity use (demand change) for current situation

Current situation (year 2007)	Total electricity generation	Separate conventional thermal power	CHP electricity generation	Industrial CHP	Weighted average specific emission
Specific emission kg(CO_2)/MWh	**279**	893	439	190	**814**
Share of the demand change		90 %	2 %	0 %	

- Results show that during 90% of the time of the year the demand change will be allocated to the separate conventional thermal power, 2% to CHP and the rest for carbon-neutral production (not shown in the Table). This means that an hourly weighted specific emissions by new or non-appearing electricity use is as high as 814 kg(CO_2)/MWh that is average emission of total generation by factor 3.

Scenario of 1600 MW new nuclear energy

- We calculated a simple scenario, where new 1600 MW of nuclear energy will **replace only separate conventional thermal power with no changes in energy demand structure**. If hourly amount of the thermal power is less than 1600 MW, additional nuclear power is pushed in the market and this surplus is not taken into account in this simple scenario (there are not very many such hours available).

Specific CO_2-emissions of the demand change for the scenario where 1600 MW new nuclear energy replaces only separate conventional thermal power

1600 MW new nuclear power replaces only separate conventional thermal power	Total electricity generation	Separate conventional thermal power	CHP electricity generation	Industrial CHP	Weighted average specific emission
Specific emission kg(CO_2)/MWh	**137**	893	439	190	**466**
Share of the demand change		24 %	57 %	0 %	

- 1600 MW new nuclear power will decrease in this scenario an average specific emission by almost of factor 2, and only during 24% of the time the demand change will be allocated to the thermal power and 57% to CHP, resulting as specific emission of 466 kg(CO_2)/MWh of the demand change.

Demand change allocation based energy carrier factors relative to specific CO_2-emission of oil

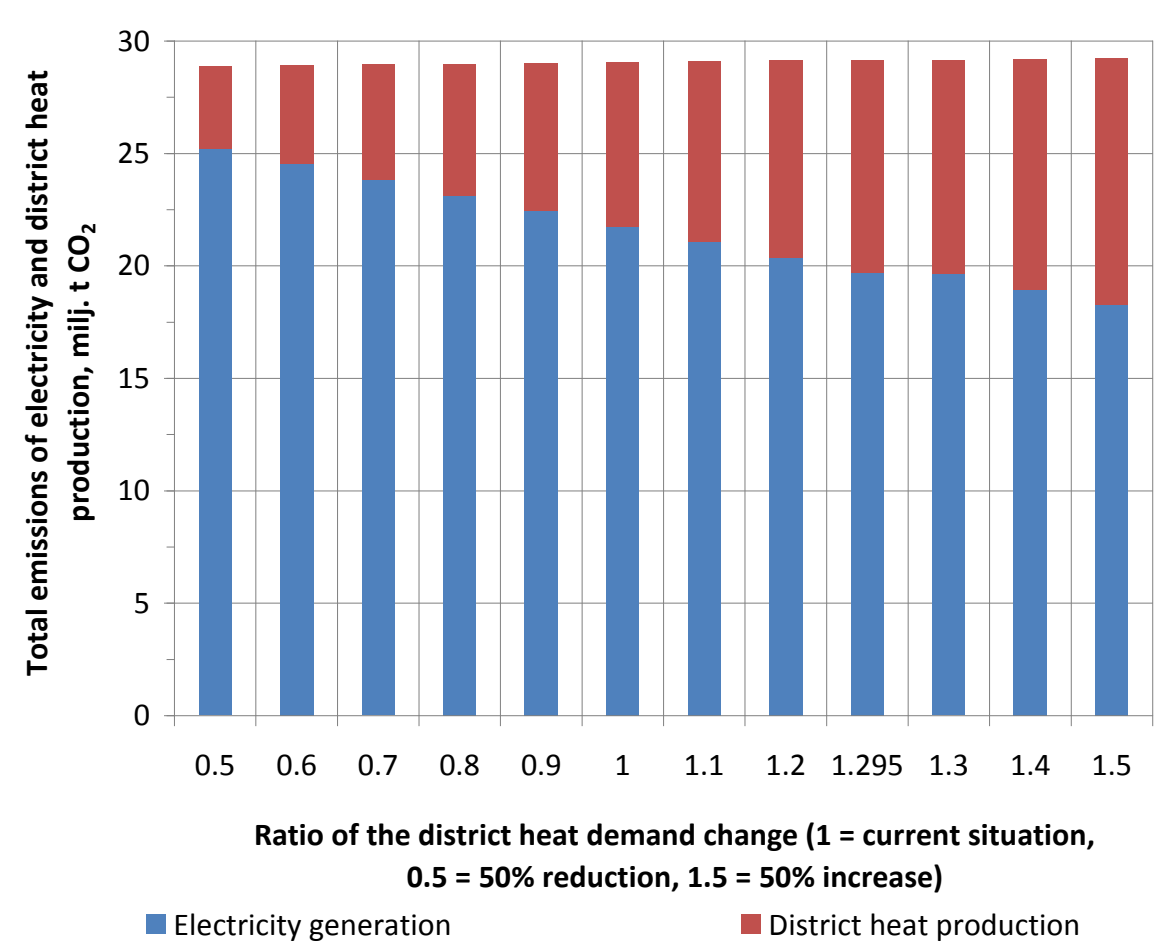
Specific CO_2-emissions of district heating and electricity (weighted average) relative to light fuel oil (heating fuel oil) CO_2-emission factor

		Light fuel oil (heating fuel oil)	Electricity (weighted average specific emission)	District heating
Current situation (year 2007)	Specific emission kg(CO_2)/MWh	267	814	219
	Energy carrier factor	**1**	**3.0**	**0.8**
1600 MW new nuclear power replaces only separate conventional thermal power	Specific emission kg(CO_2)/MWh	267	466	219
	Energy carrier factor	**1**	**1.7**	**0.8**

- When calculated with 2006 data, the emissions are slightly higher for electricity, leading to factor of 2.1 instead of 1.7 (and 3.2 instead of 3.0)

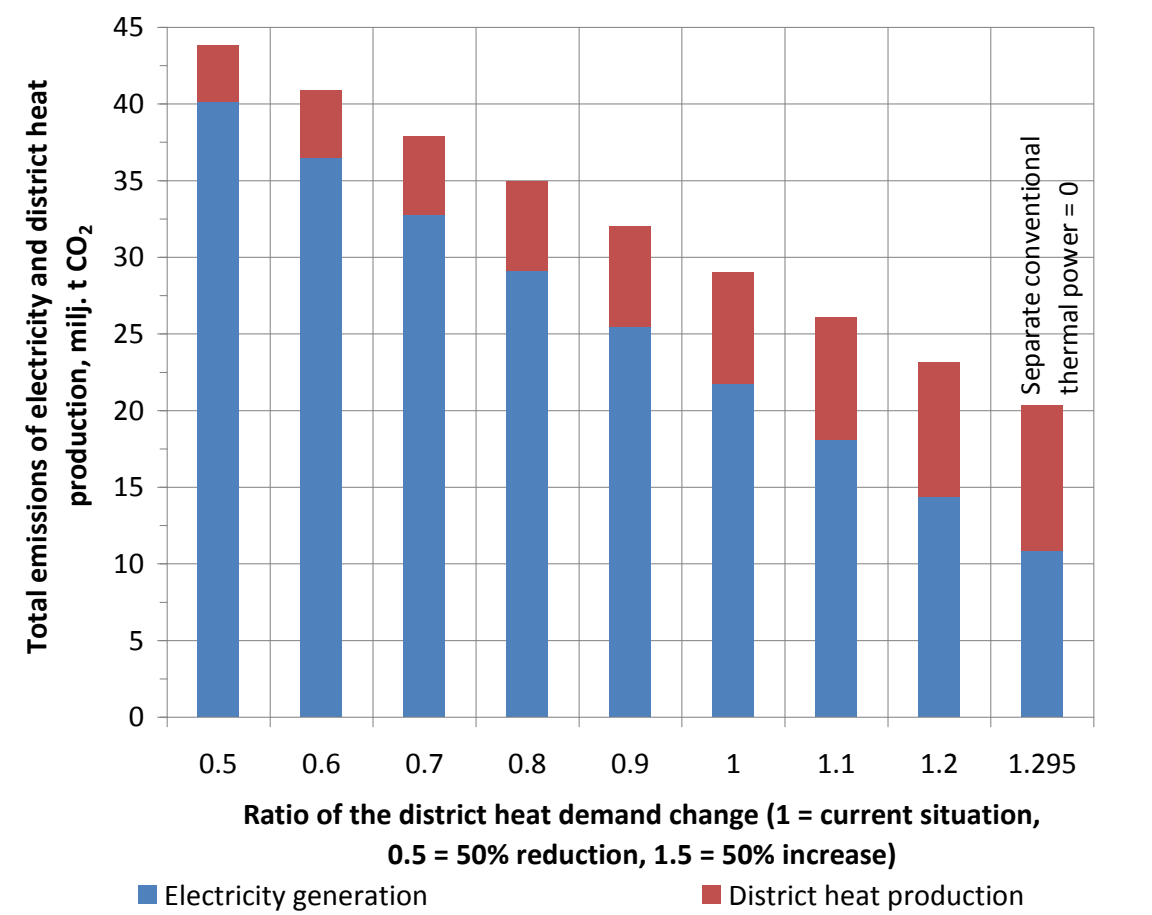
Demand change in district heating energy use

- The total CO_2 emissions of Finnish electricity generation and district heating production **if electricity use is kept constant**, but district heating is reduced (i.e. additional insulation of existing multi-storey buildings and other energy saving measures) or increased



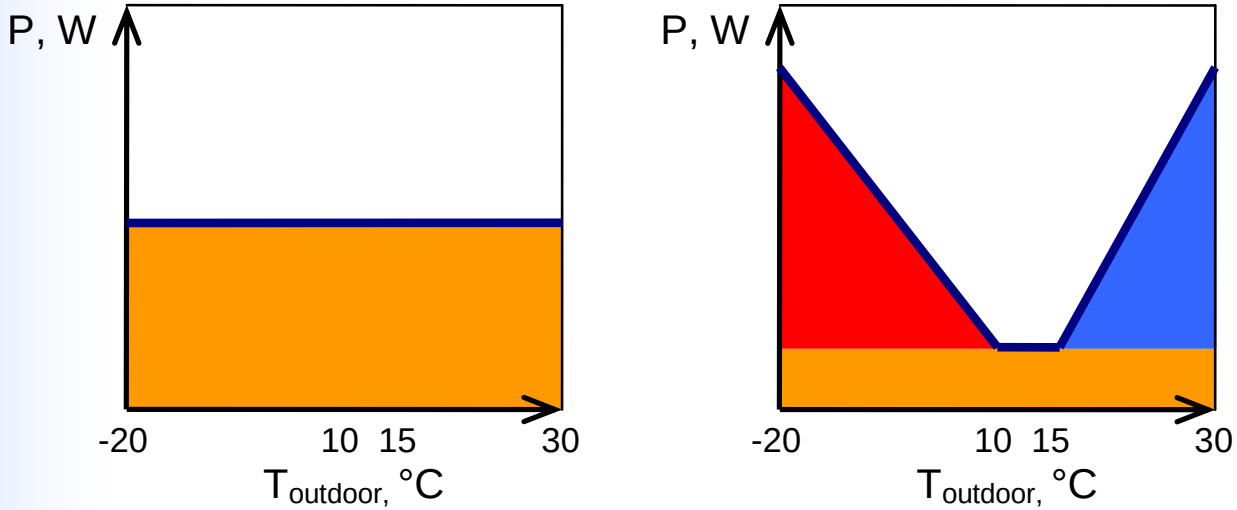
District heat replacing electricity use or vice versa

- The **total use of electricity and district heat is kept constant**
- The ratio of 1 corresponds to the current situation, the ratio 0.5 means that half of current district heating energy used is replaced by electricity use and 2 that the current district heating use is doubled and electricity use reduced correspondingly



Limitations of the methodology

- The use of constant demand change instead of the building profile (to be taken into account in further analyses):



- Limited to Finnish energy production instead of the whole Nordic market:
  - Import is not taken into account (rather constant in Finnish case)
  - Well justified/controlled by Nord Pool Spot price dependency, as the objective was to show the relation between the use in building and the production
- May be proposed for general methodology for energy systems with great variety of production sources

Conclusions 1/2

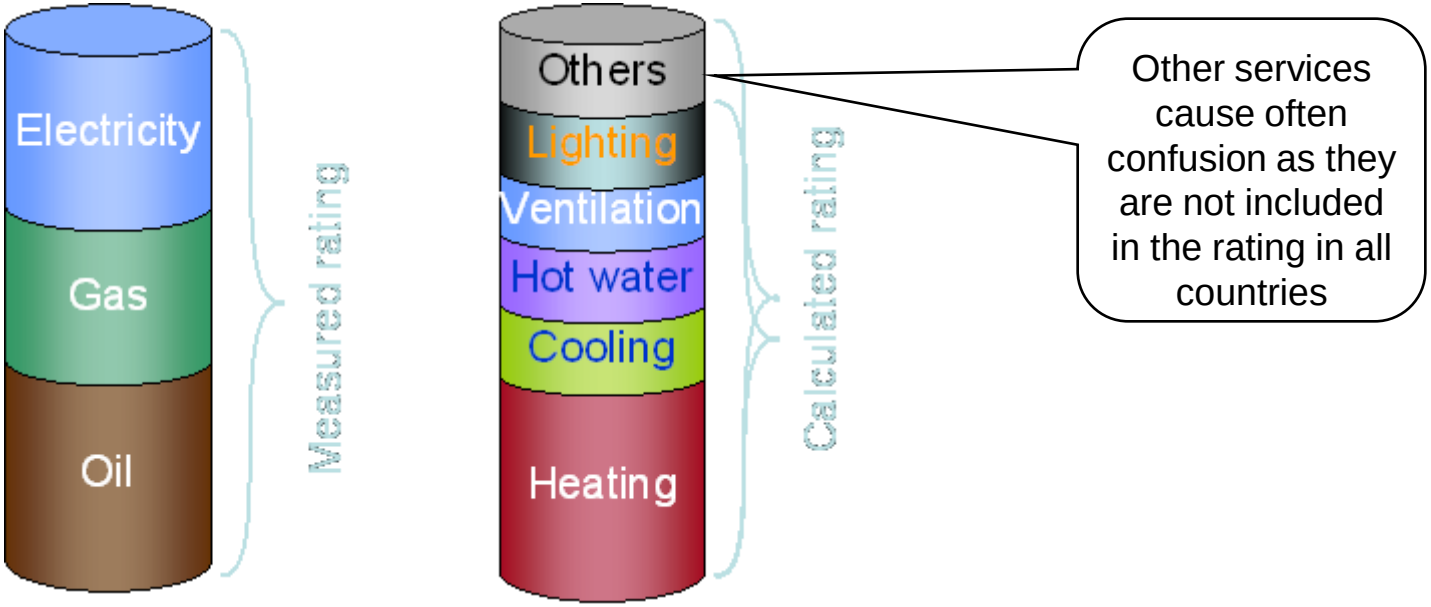
- Ongoing decade data (2000-2007) shows almost constant specific emissions of electricity generation and district heat production, 273 vs. 217 kg(CO_2)/MWh respectively
- The use of relevant energy carrier (emission) factors is likely the only way for comparison of building energy performance commensurate with emissions caused by energy use in the building
- **Replacing district heat by electrical heating will drastically increase total emissions of Finland and vice versa**
- Energy carrier factors cannot be based on average values of specific emissions as the electricity market runs with continuous lack of carbon-neutral generation capacity
- For accountability of the building regulation, one needs to know the link between a new or non-appearing energy use in a building and energy production source

Conclusions 2/2

- Energy carrier factors are not constant, but change in the time according to the demand and capacity developments
- Demand change allocation based energy carrier factors relative to specific CO_2-emission of oil for current situation (2007) in Finland:
  - **oil 1**
  - **electricity 3.0**
  - **district heat 0.8**
- and for simple scenario of 1600 MW new nuclear power replacing thermal energy and no change in the demand (calculated with benefit allocation method):
  - **oil 1**
  - **electricity 1.7…2.1**
  - **district heat 0.8**
- New nuclear energy capacity will decrease the factor of electricity, but not as much as shown above due to open Nordic market and continuously increasing electricity use
- Higher energy carrier factor for electricity means in the energy performance design that electricity is more valuable energy than district heat. Such building regulation will generally promote for more effective electricity use in buildings and limit wasteful use of electricity.

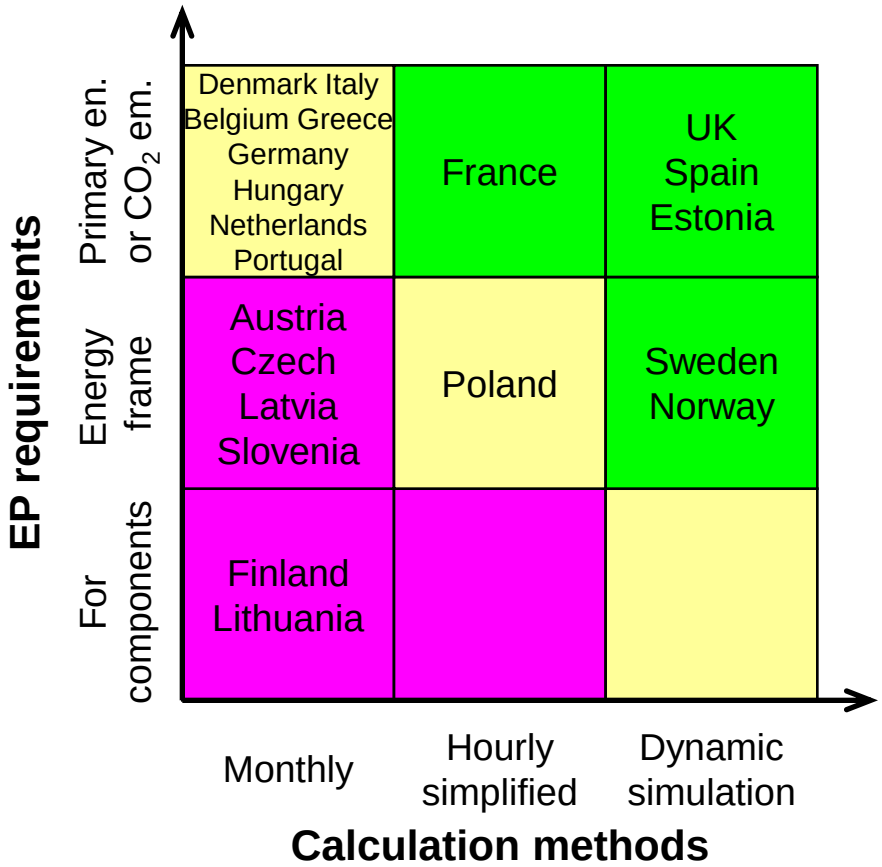
General framework for the assessment of energy use

- EN 15603:2008 specifies general framework for the assessment of overall energy use of a building, and
- the calculation of energy ratings in terms of primary energy, CO_2 emissions or parameters defined by national energy policy



- Energy ratings can be based on measured or calculated energy use

EP-ratings in the member states



- Situation in the member states after EPBD implementation in June 2008 regarding EP requirements for new buildings and calculation methods
- In the figure, the most developed available calculation method is shown; in many countries simplified methods may used in parallel or for some building type as shown in previous comparison table

(Kurnitski 2008)