Latest achievements promoting heat pumps in Finland: energy carrier factors and ESBO freeware

SITRA

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Suomen itsenäisyyden juhlarahasto Sitra

Energy Programme 2008-2012

Energy use and emissions of communities peak and decline – a systemic change in energy production and use in buildings

Sustainable Built Environment

Energy Efficient Built Environment

- Energy efficiency into town planning
- Energy efficient and sustainable new buildings
- New operation models for building renovation

Empowered citizens

Finns become Energy-concious

- Citizens join the energy bee
- New operation models for energy guidance

Growing well-being and new business through diminishing energy use of individuals and communities

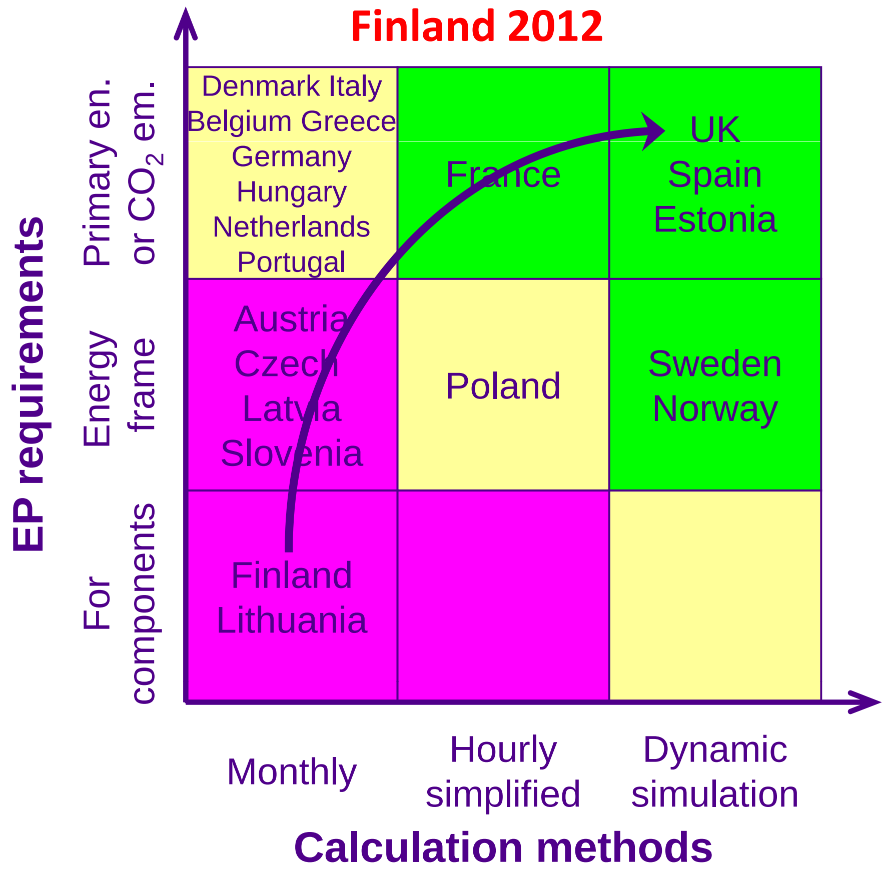
Business and markets

New Business from the Energy Revolution

- AW Energy Ltd
- Kodin Onniset Ltd
- Viola Systems Ltd
- Norrhydro Ltd
- Scancool Ltd

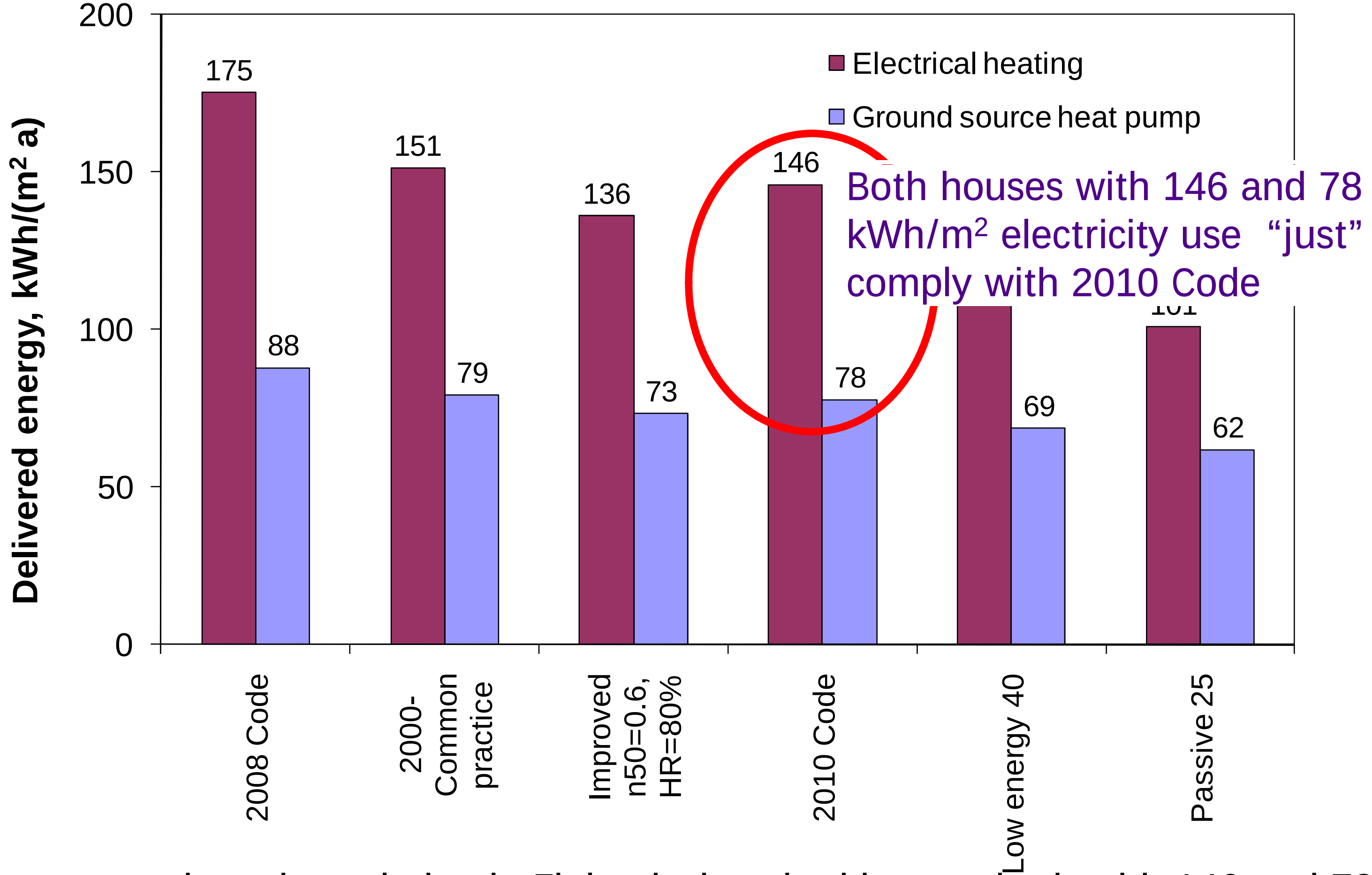
EPBD 2002, EuP 2005, RES 2008, EPBD recast 2010 have resulted regulation revisions in 2-3 years interval

Source: Kurnitski J. Contrasting the principles of EP requirements and calculation methods in EU member states. *REHVA journal, December 2008, 22–28.*



- 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

Example of component based regulation: limited control on energy use and CO_2-emissions



- Component based regulation in Finland: detached houses both with 146 and 78 kWh/(m^2a) electricity use comply with 2010 building code!
- Emission based/primary energy requirements to be launched in 2012

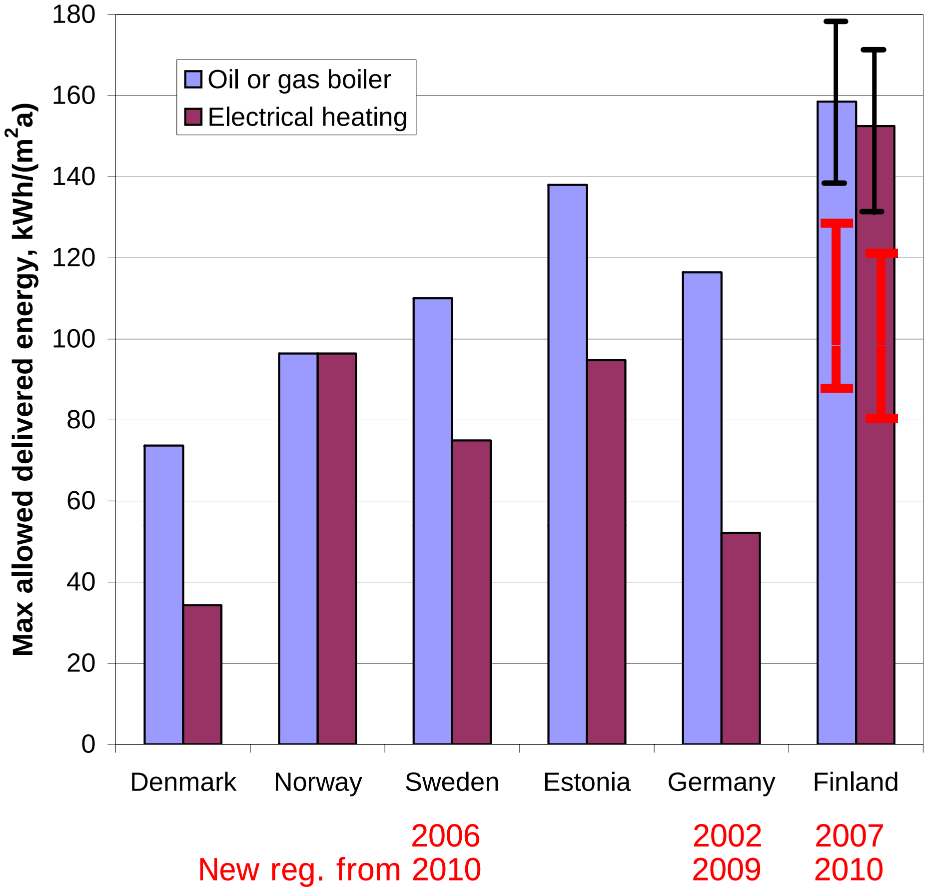
EP-value comparison in 2008

- How much delivered energy may be used in houses?
- Denmark (DK):
  - Primary energy $70+2200/A_{gross}$ kWh/(m^2a)
  - The value does not include the household electricity
  - Primary energy factor 2.5 for the electricity and 1.0 for oil and gas
- Sweden 2006 (S):
  - Delivered energy 110 kWh/(m^2a) (130 kWh/(m^2a) in North region)
  - 75 kWh/(m^2a) (95 in North) in the case of electrical heating (2010: 55 and 75)
  - The values do not include the household electricity
- Norway (N):
  - Delivered energy $125+1600/A_{heated}$ kWh/(m^2a) in detached houses and 120 kWh/(m^2a) in apartment buildings
  - The values include household electricity of 40 kWh/(m^2a)
- Estonia (EST):
  - Primary energy 180 kWh/(m^2a) which includes household electricity; 180-38=142 primary energy without household electricity
  - Primary energy factor 1.5 for the electricity and 1.0 for oil and gas
- Germany (D):
  - Primary energy $130+2600/(100+A_{heated})$ kWh/(m^2a) (without household electricity) (2009 new)
  - Primary energy factor 2.7 for the electricity and 1.1 for oil and gas
- Finland 2007 (FIN):
  - Requirements for components only, so the value depends on the building (2010: -30%, +2012)

EP-value comparison

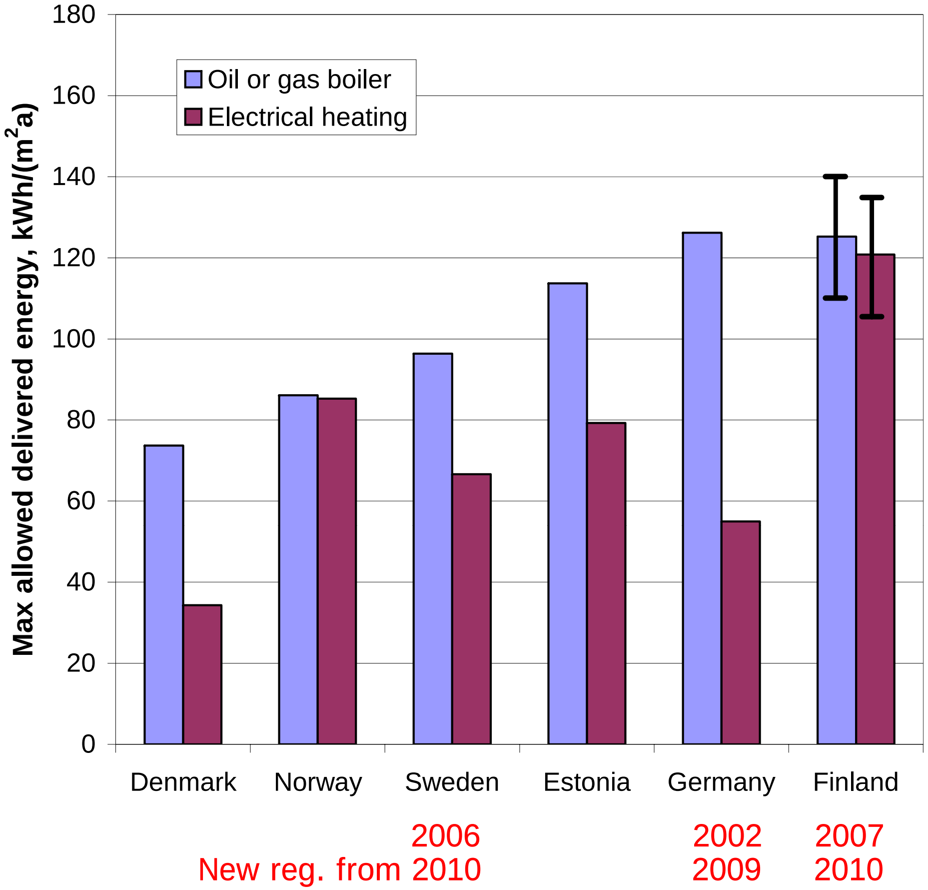
Source: Kurnitski J. Contrasting the principles of EP requirements and calculation methods in EU member states. *REHVA journal, December 2008, 22–28.*

- As requirements are both for primary (DK, EST, D) and delivered (S, N) energy, only the delivered energy can be compared
- DK,S &D do not include household electricity, therefore this is reduced from the values of EST & NOR
- 140 m^2 house is considered as EP-value depends slightly on heated area in DK, N & D
- Electricity use of 3 kWh/(m^2a) for fans of ventilation and 5 kWh/(m^2a) for circulation pumps of water based heating (0 kWh/(m^2a) for electrical heating) is assumed
- The figure shows maximum allowed **delivered energy without household electricity** (i.e. delivered energy to heating, hot water and ventilation systems) in each country for fossil fuel or electrical heating



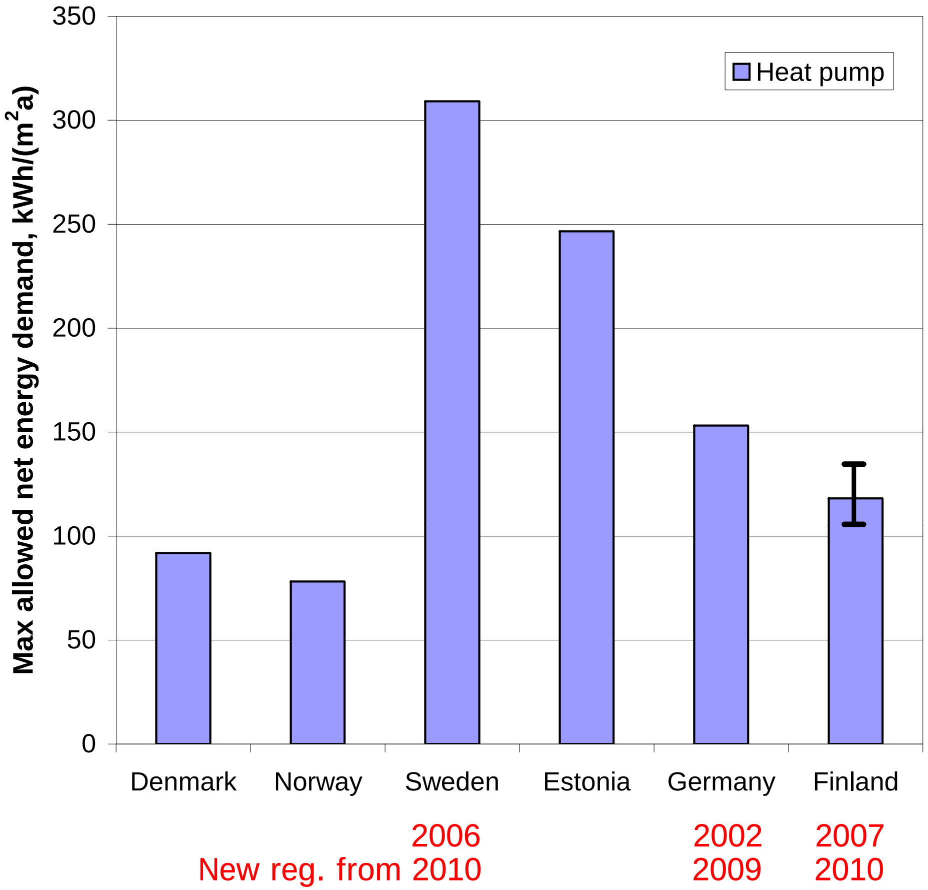
EP-value, degree-day corrected data

- Assumptions for degree-day correction:
- Energy use for hot water heating 25 kWh/(m²a)
- Electricity use of 3 kWh/(m²a) for fans of ventilation and 5 kWh/(m²a) for circulation pumps of water based heating (0 kWh/(m²a) for electrical heating)
- Remaining space heating energy is corrected with degree-days calculated from ASHRAE 2001 data; 17°C degree-days used:
  - 2917 Berlin, 3259 Copenhagen, 3894 Oslo, 3963 Stockholm, 4240 EstoniaTRY, 4422 °Cd Helsinki
  - the values are corrected to Copenhagen



EP-value, heat pumps

- To compare requirements for houses with heat pumps the net energy demand for space heating (ventilation heating included) and hot water heating should be compared
- Maximum allowed net energy demand is calculated for each country
- Seasonal energy efficiency ratio of 3.5 is used for the heat pump
- Results:
  - In N and FIN heat pumps cannot be taken into account
  - In DK, the net energy increase is 3.5/2.5 compared to delivered energy, i.e. quite modest due to 2.5 primary energy factor for electricity
  - S has no primary energy factors, so the increase is by 3.5



EPBD recast 2010

Roadmap to improved energy performance:

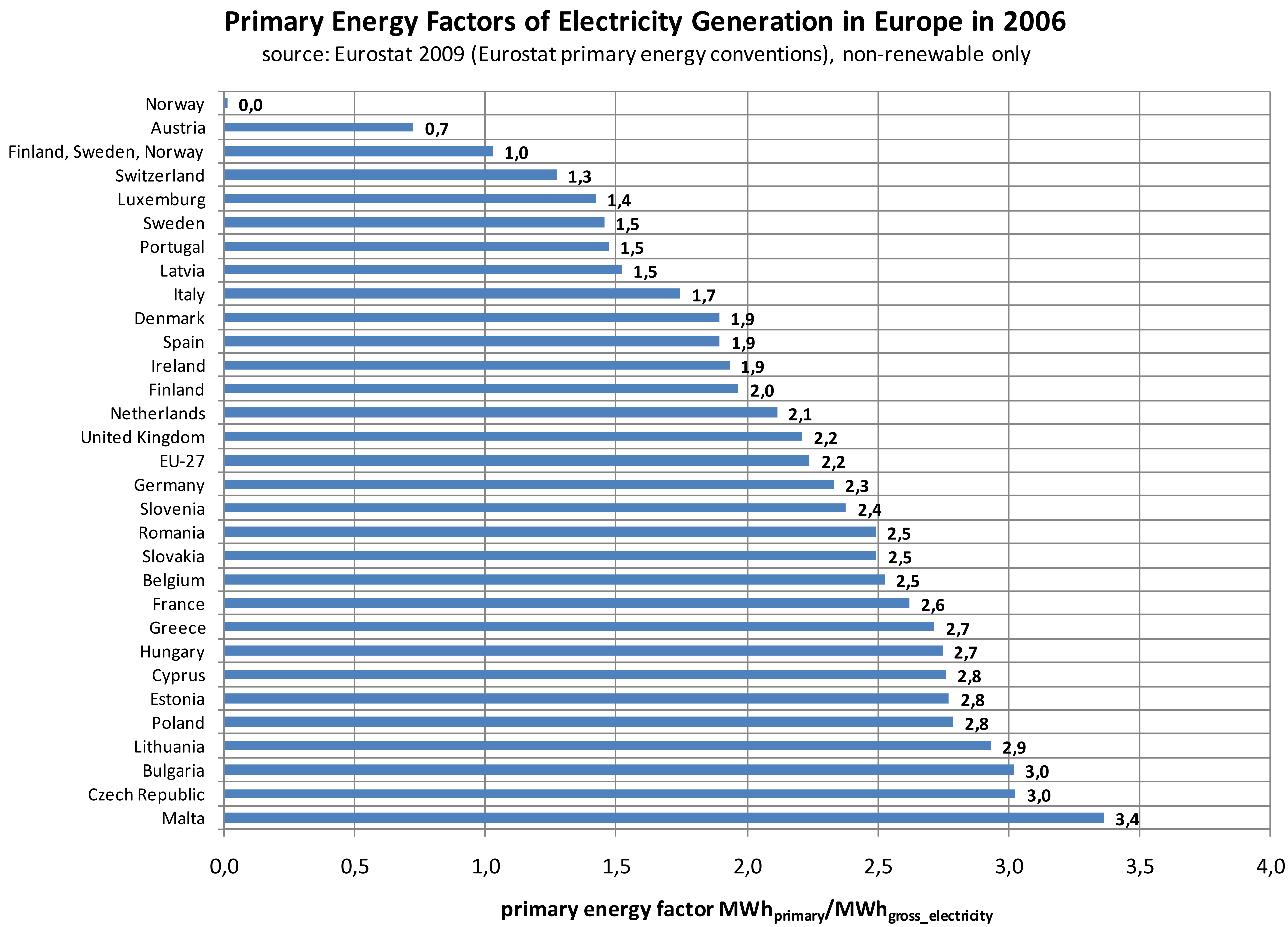
- Setting of minimum energy performance requirements based on calculation of **cost-optimal** levels :
  - The Commission shall establish by 30 June 2011 a comparative methodology framework
  - Member states shall report by 30 June 2012
- After 31 Dec 2018, public authorities that occupy and own a new building shall ensure that the building is a **nearly zero energy** building
- By 31 Dec 2020, all new buildings are **nearly zero energy** buildings

- Setting of minimum energy performance requirements for **major renovation:**
  - The threshold of 1000 m^2 is deleted
  - The definition of 'major renovation‘ is by the investment that should be more than 25% of the whole buildings value, excluding the land, e.g. the actuarial value, or more than 25% of the building envelope undergoes structural renovation

Finnish case study to determine emission based energy carrier factors including demand-capacity coupling effects

- 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 energy system scenario calculations to show how much one energy carrier is causing more emissions than another

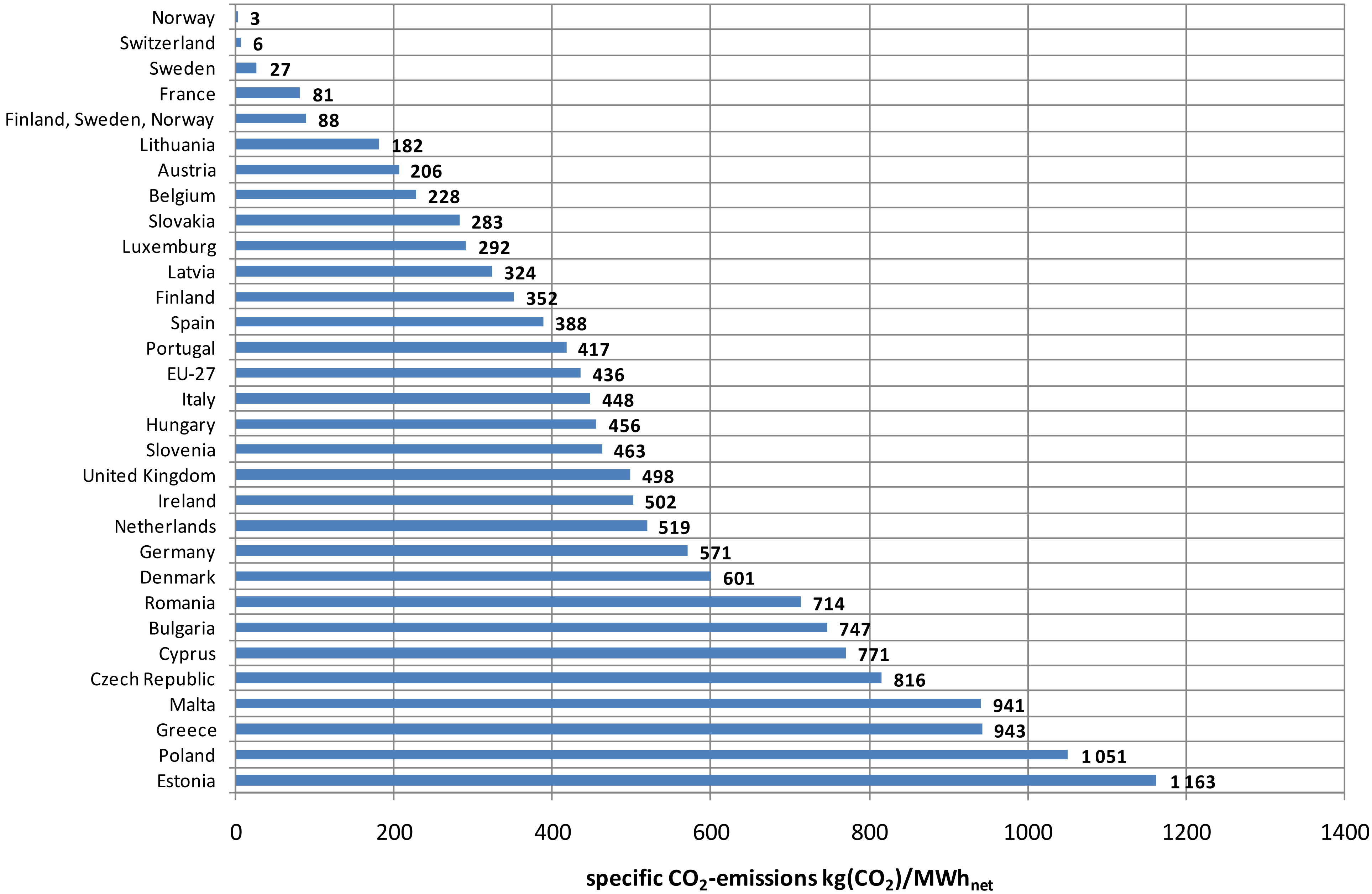
Source: Kurnitski J, Keto M. Accounting CO_2 emissions for electricity and district heat used in buildings – a scientific method to define national energy carrier factors. CLIMA 2010, 10th REHVA WORLD CONGRESS "Sustainable energy use in buildings", 9–12 May 2010, Antalya, Turkey



Primary Energy Factors of Electricity Generation in Europe in 2006
source: Eurostat 2009 (Eurostat primary energy conventions), non-renewable only
Norway 0,0
Austria 0,7
Finland, Sweden, Norway 1,0
Switzerland 1,3
Luxemburg 1,4
Sweden 1,5
Portugal 1,5
Latvia 1,5
Italy 1,7
Denmark 1,9
Spain 1,9
Ireland 1,9
Finland 2,0
Netherlands 2,1
United Kingdom 2,2
EU-27 2,2
Germany 2,3
Slovenia 2,4
Romania 2,5
Slovakia 2,5
Belgium 2,5
France 2,6
Greece 2,7
Hungary 2,7
Cyprus 2,8
Estonia 2,8
Poland 2,8
Lithuania 2,9
Bulgaria 3,0
Czech Republic 3,0
Malta 3,4
0,0 0,5 1,0 1,5 2,0 2,5 3,0 3,5 4,0
primary energy factor $MWh_{primary}/MWh_{gross\_electricity}$

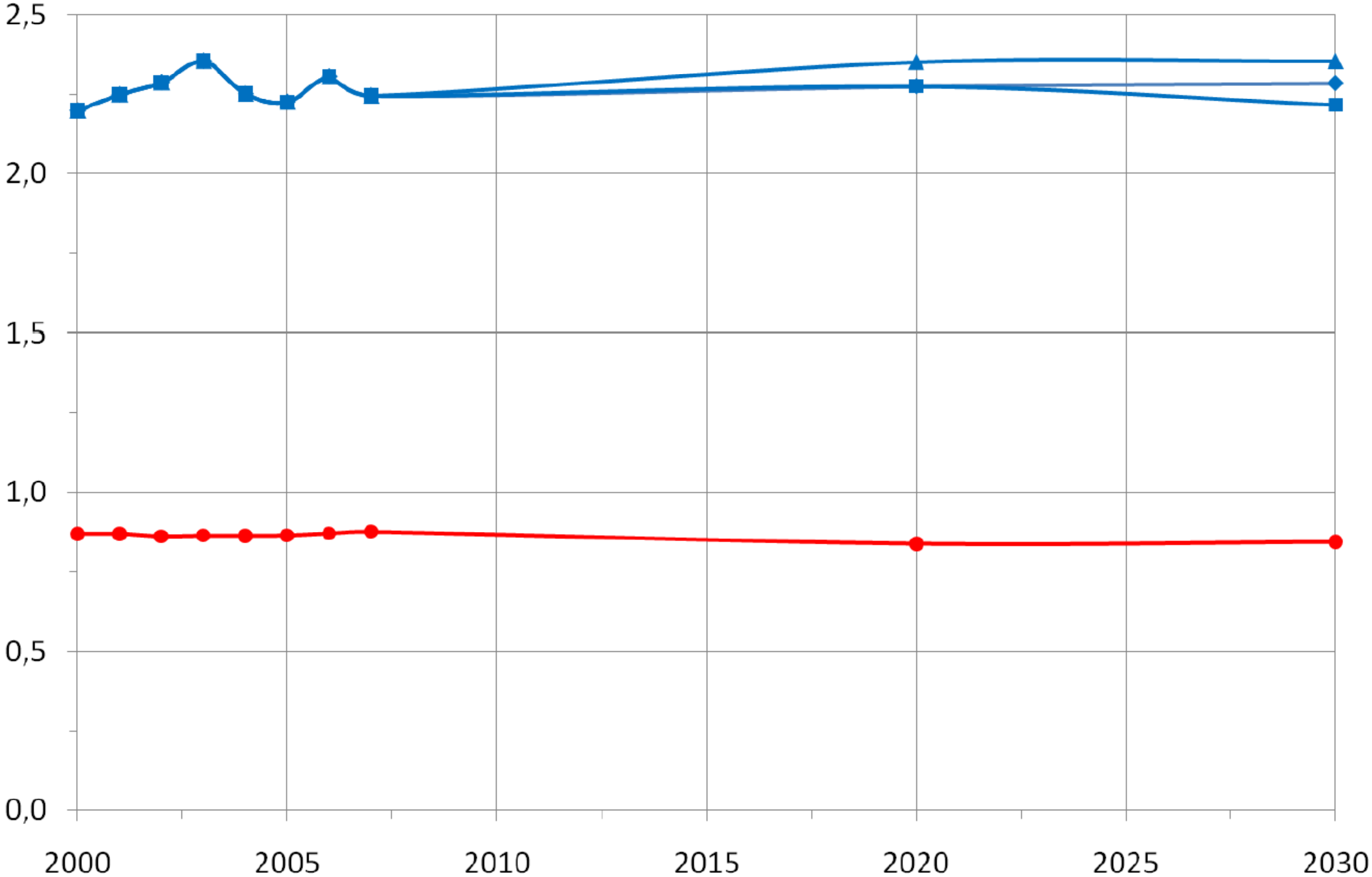
Specific CO_2-emissions of Electricity Generation in Europe in 2006

sources: Eurostat 2009 (IPCC default emission factors)



Non-renewable primary energy factors in Finland

(blue electricity and red district heat)



Why primary energy factors are almost constant in the long run?

- Major changes in Finnish energy production until 2030:
  - Significantly increased share of nuclear energy
  - CHP is used as much as today, almost constant district heat production
  - Increased use of renewables (wind, bio, solar), as much as technically feasible, but still less dominating than nuclear or CHP

- With IEA and Eurostat definition, primary energy equivalent of nuclear and conventional condensing power very similar, so, the compensating of condensing power will even slightly increase primary energy factor (40% vs. 33% efficiency)
- $\Rightarrow$ cutting emissions with nuclear energy has no effect on primary energy factor...

Just use average specific emission factors?

- Average specific CO_2-emissions 2000-2007:
  - 273 kg(CO_2)/MWh) for electricity
  - 217 kg(CO_2)/MWh) for district heat

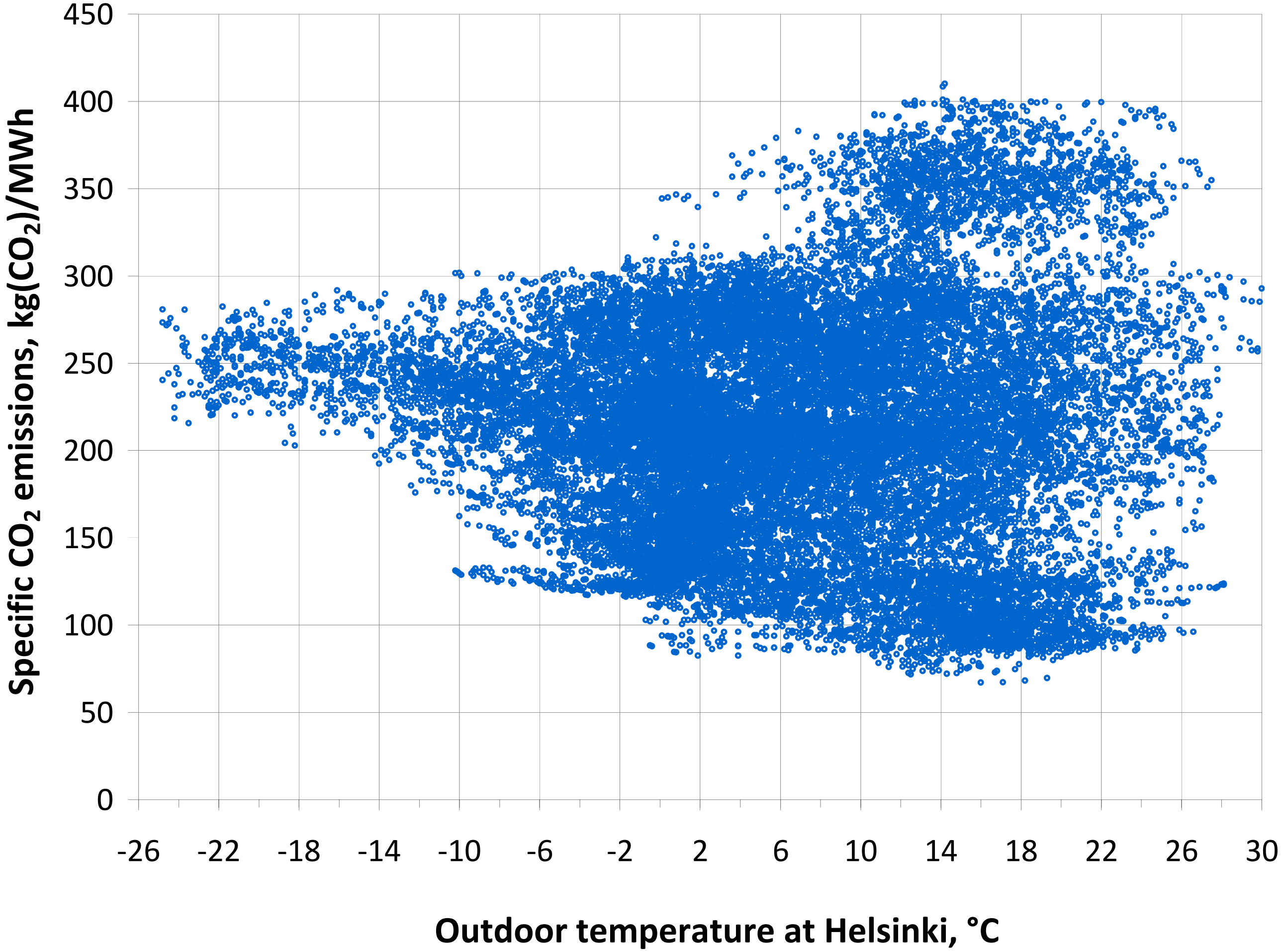
- Or average relative energy carrier factors (previous ones divided by reference specific emission of oil 267 kg(CO_2)/MWh)):
  - 1.0 for electricity
  - 0.8 for district heat
  - (reference: 1.0 for oil)

- These average factors would probably lead to increased use of electricity in buildings (electrical heating etc.) as **1.0** is very low compared to common primary energy factor of **2.5** for electricity
- What was not taken into account?

Higher factor for electricity in winter?

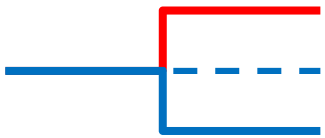
- Hypotheses: peak loads cause higher specific emissions in the production
- Can be easily tested with hourly data

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

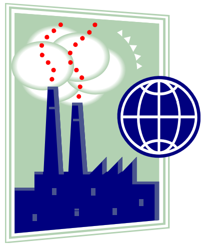


- Generation of separate conventional thermal power in Finland can be high in summer period due to shortage of hydro power and lack of CHP which is generated against heat load of district heating + service breaks of nuclear power plants

Demand change analyses (emissions response to a step change in the demand)



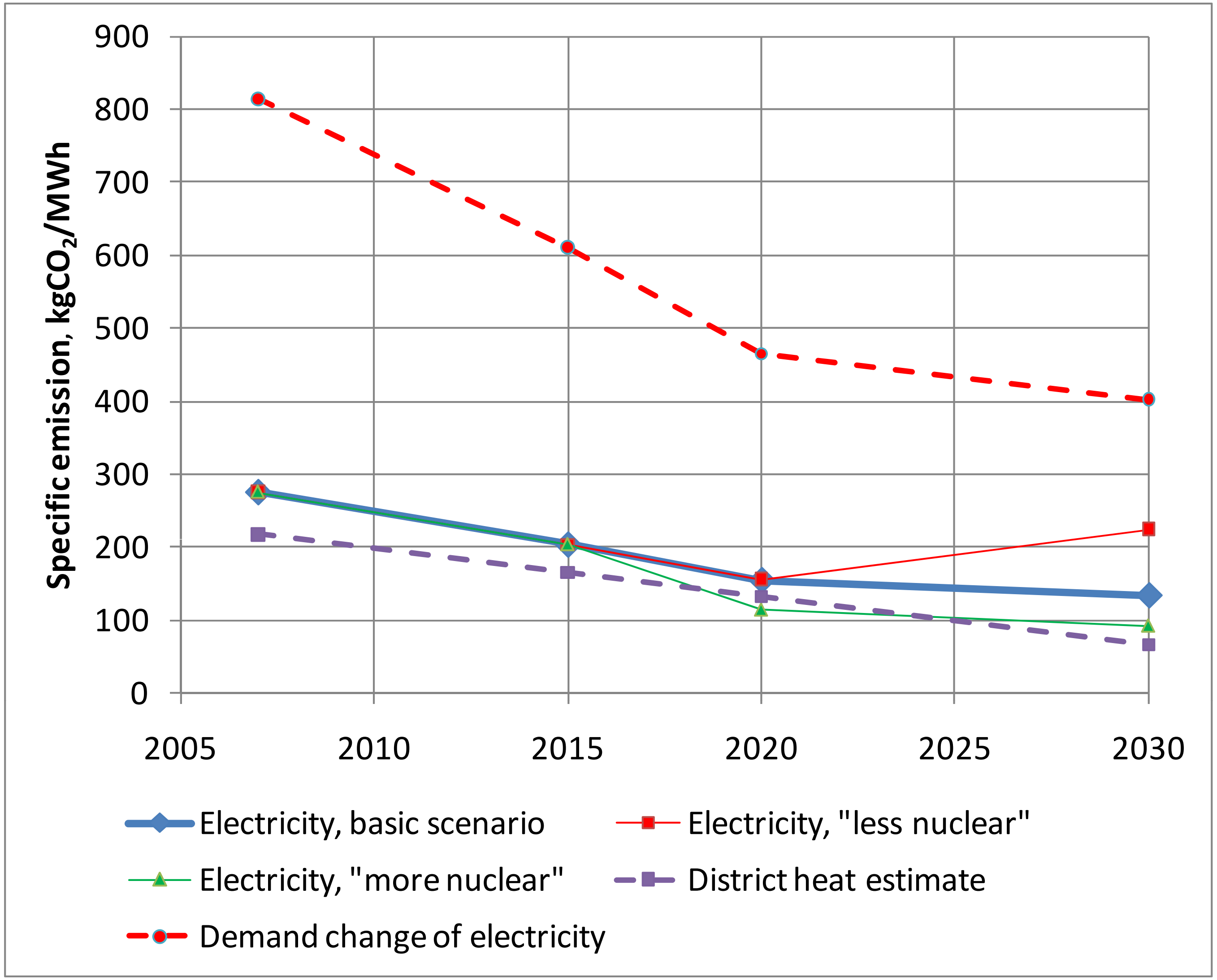
+ or – step change in electricity or district heat



Change in emissions ?

- In the electricity production especially carbon-neutral capacity is limited
- District heat CHP is produced against heat load without similar lack of capacity (demand change has no effect on the specific emission)
- Construction of new buildings or renovation of existing ones means changes in the demand responded by electricity market
- To account emissions of the step change 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)
- These analyses resulted with **electricity factor for demand change 3 times higher than the average electricity factor**

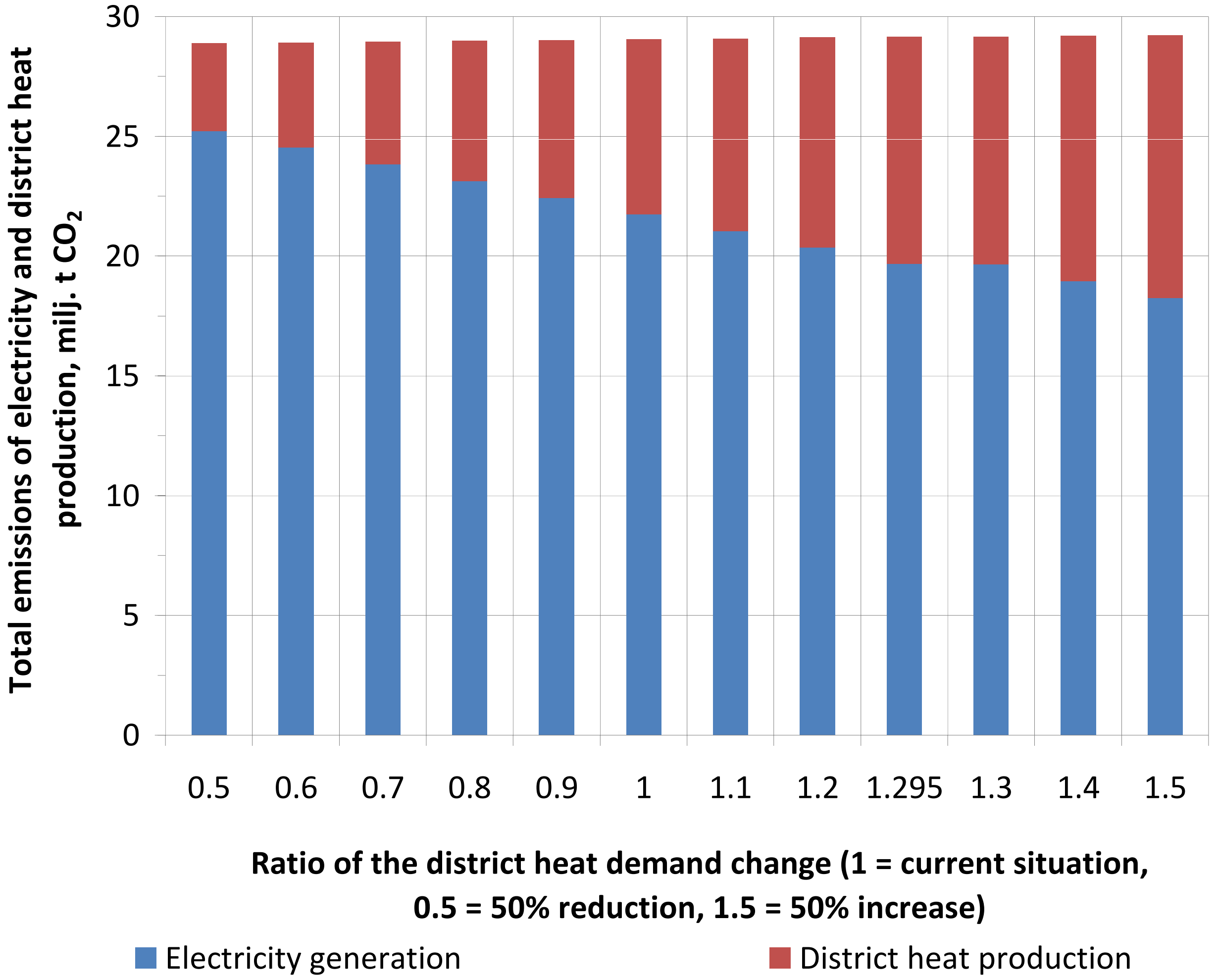
Energy carrier factors for selected scenarios



How to quantify the factors between average and demand change values?

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 (e.g. additional insulation of existing multi-storey buildings) or increased
- ⇒ Due to CHP, the total emissions do not depend on the amount of district heat used



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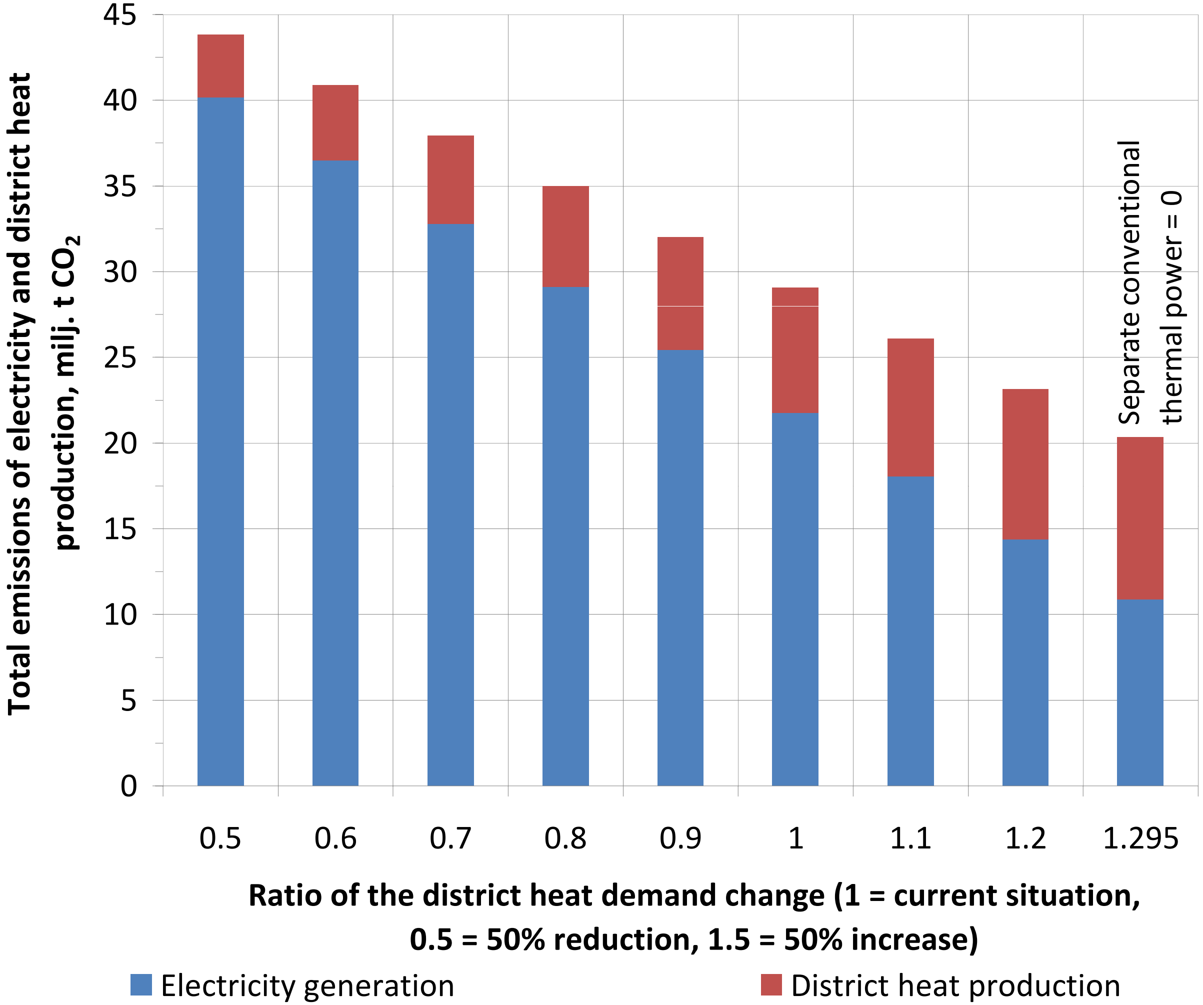
District heat replacing electricity use or vice versa

- 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
- ⇒ Replacing district heat by electrical heating drastically increases total emissions



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Demand change analyses with flexible capacity

- Main principle: **energy system model allowing both changes in the demand and production capacities**, annual balance calculation

1. Select reference electricity and district heat production (e.g. 90 TWh el. and 33 TWh DH, repeat the calculation for other relevant values)
2. Define rules for production sources/capacities allowing to introduce new capacity to cover increased demand:
   - production sources with fixed capacity, hydro and nuclear (fixed capacity can be selected as input parameter)
   - production sources with flexible capacity, in this case condensing power and CHP
   - limits for district heat produced by CHP, 70...80% in this case
   - wind power and solar electricity fixed in this case, but can be treated with similar rules if considered flexible
3. Introduce a step change of heat and electricity demand (+3 TWh in this case) and solve energy production balance by minimizing emissions or production cost
4. Results: emissions and cost caused by +3 TWh electricity or heat production ≡ specific emission factors of the studied scenario

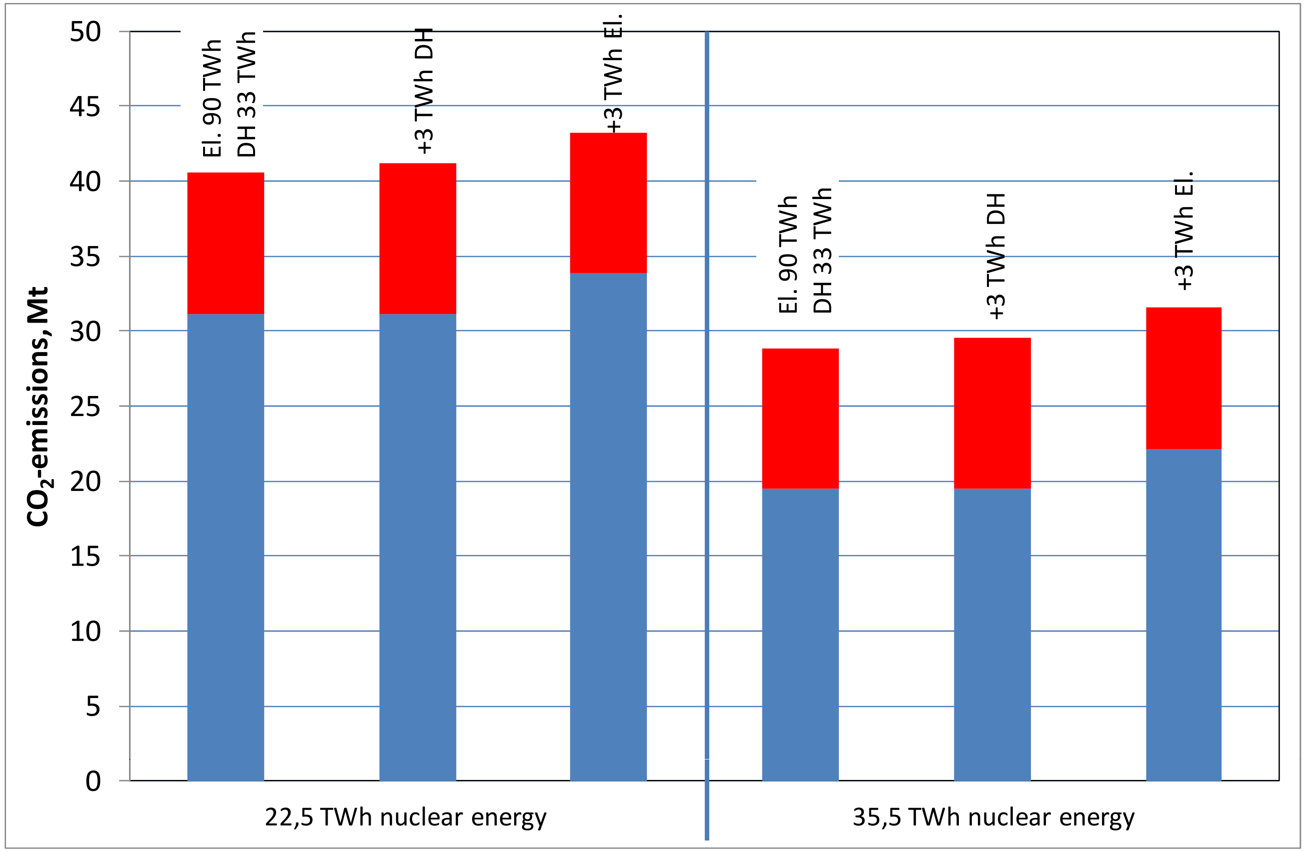
Finnish case study

- +3 TWh step change of heat or electricity demand
- 80 and 90 TWh reference electricity production and 33 TWh district heat production
- Flexible capacity of separate condensing power and CHP
- Nuclear energy capacity fixed, several capacity values calculated
- Hydropower and wind power fixed
- Limits for district heat produced by CHP, to be between 70 and 80%

Specific emission (energy method) and cost data used:

Production source	Fuel cost milj. EUR/TWh	Specific emission $kgCO_2/MWh$
Nuclear energy	5	0
Separate condensing power	25	900
CHP electricity	15	300
CHP district heat	18	300
Separate district heat	22	225

Emissions by + 3 TWh with flexible capacity



- + 3 TWh electricity increased emissions by factor of 4,0 relative to + 3 TWH district heat (0.68 Mt vs. 2.7 Mt)
- This factor of 4 would change to 3, if separate district heat production is not used
- Results confirm that relevant selection of energy carrier factor for electricity should be **close to the demand change values**, not average values of specific emissions

Energy carrier factors: conclusions

- Specific CO_2-emissions factors are scientifically sound (independent on definitions), but average factors cannot be used for regulative purposes, because they may guide to increased electricity use, which will consequently increase emissions as shown in the Finnish case study
- Finnish average specific emission based factors (2000-2007):
  - **electricity 1.0, district heat 0.8 and** oil 1.0 (reference)
- Average factors for electricity and district heat are very close, but **replacing district heat by electrical heating drastically increased total emissions in the Finnish case study and vice versa**
- Hourly demand change allocation increased electricity factor from **1.0 to 3.0** and analyses both with fixed and flexible capacity showed that the factor caused by demand change is 3 to 4 times higher than the average one
- Proposed factors for Finland

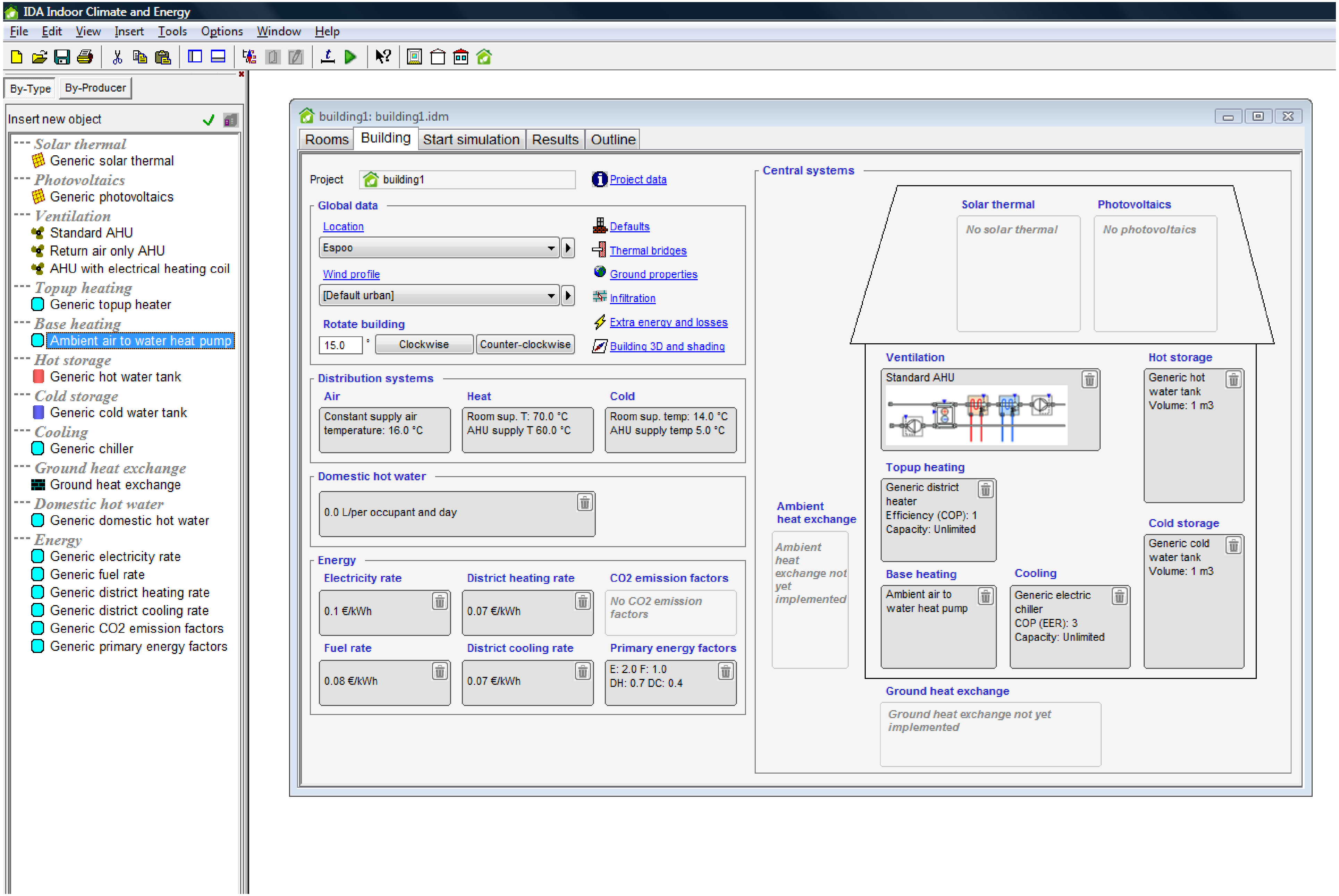
Electricity	2.0
District heat	0.7
District cooling	0.4
Fossil fuels	1.0
Renewable fuels	0.5

ESBO – Early Stage Building Optimization

- Promoting indoor climate and energy simulation
- **Freeware, stand-alone tool**
- Fixed geometries for many building types
- Full access to modify building envelope properties (windows, walls, solar shading etc.)
- Highly developed technical building systems:
  - HVAC (all common systems)
  - Heat pumps (all types)
  - Solar thermal and solar electrical
- Easy to use, just drag and drop of components and systems
- Coming soon! Beta already available

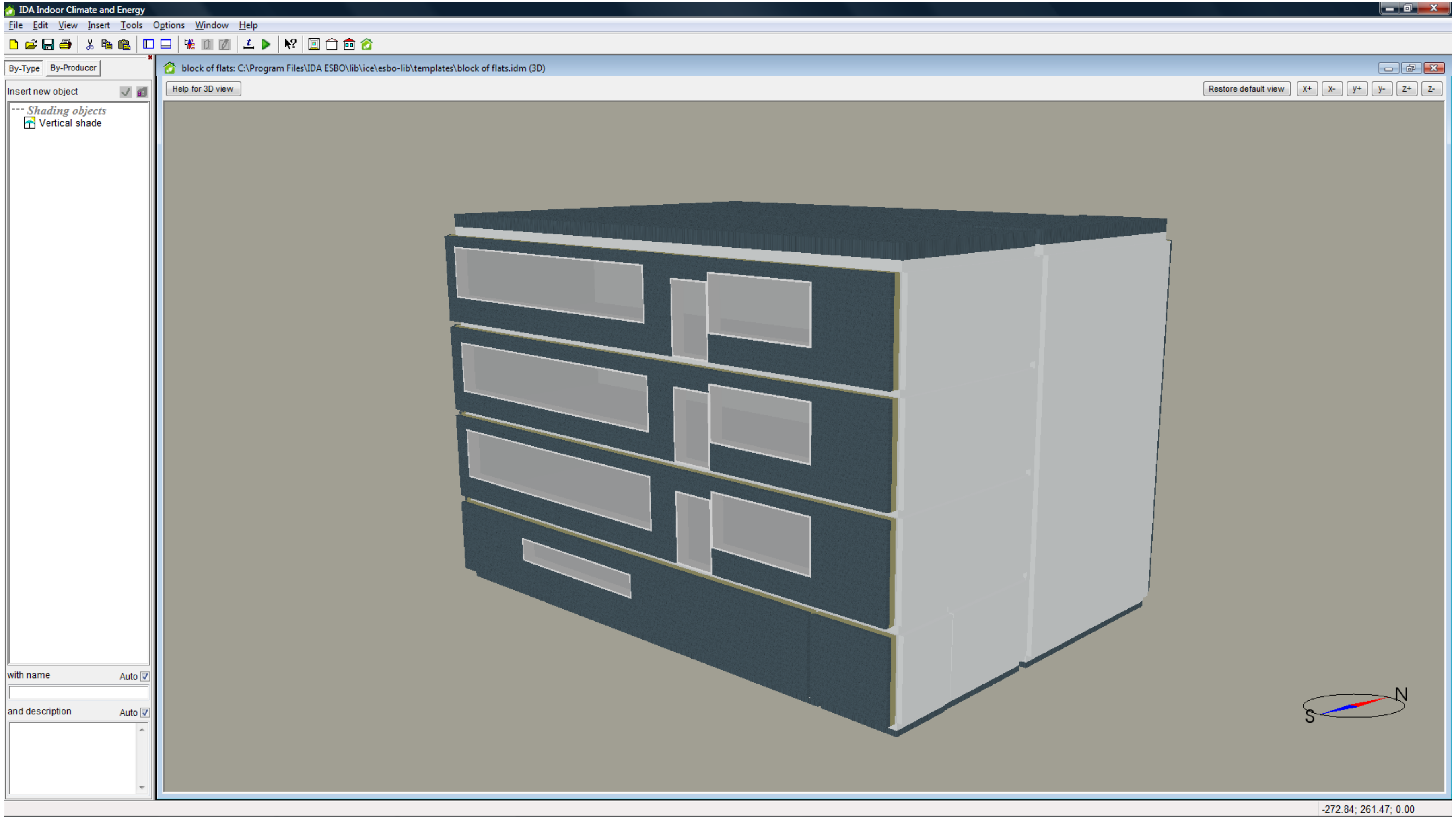
http://www.equaonline.com/esbo/

Selection of systems: drag and drop + double click to modify parameters

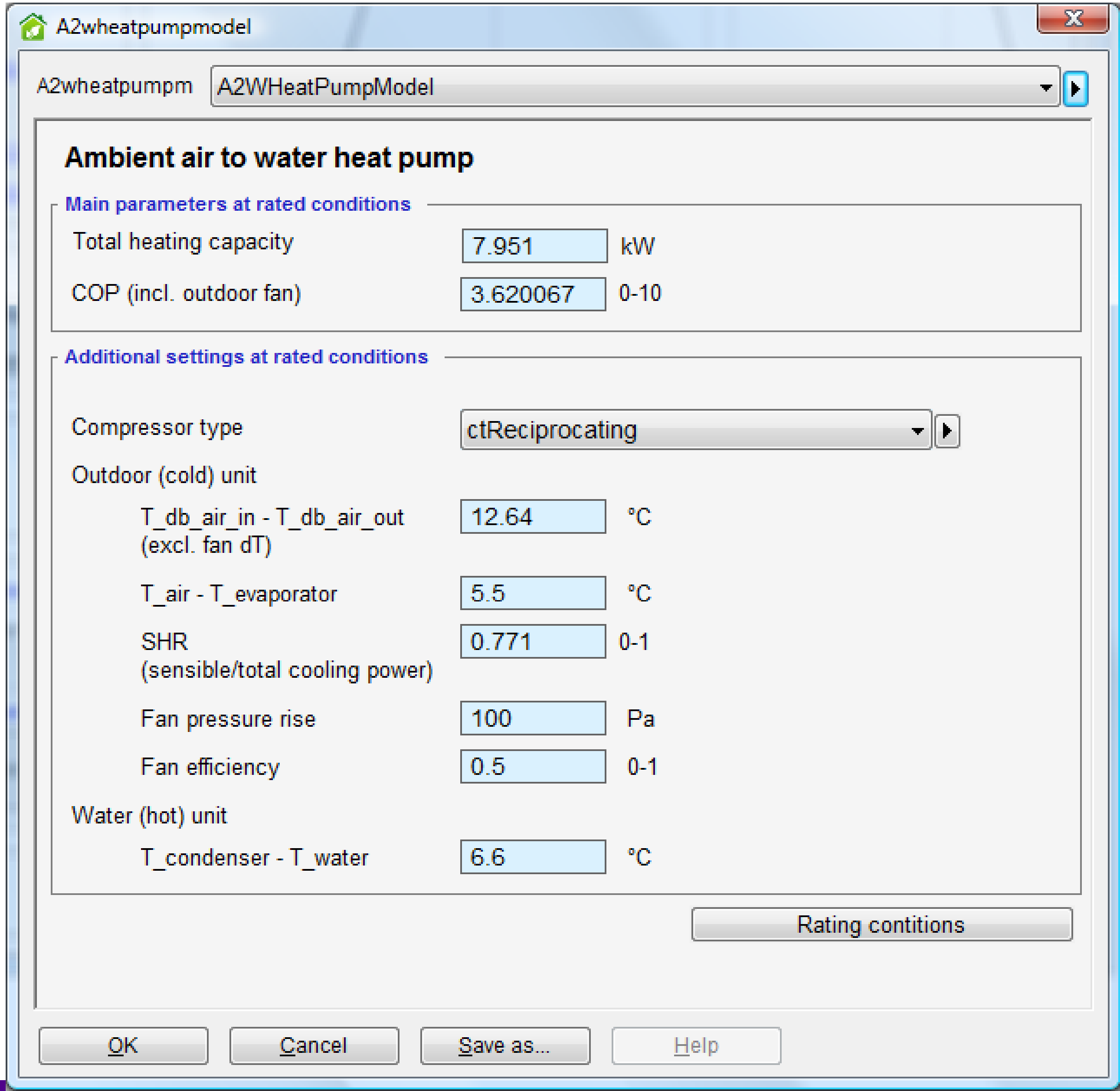


Example of model buildings

(detached houses, apartment buildings, office, school, sport and industrial hall available)



- Example of heat pump model:
  - select the model from the list or fill in performance data at rating conditions



Export to IDA-ICE (commercial) for advanced users

Plant with tanks

Plant model with (by default) very large capacity. Supply hot water setpoint is a function of outside air temp. Chilled water temperatures to zones and AHU are constant.