# The European Approach to Decrease Energy Use in Buildings

## Towards ZEB (Zero Energy Buildings)

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President Elect ASHRAE

# Energy Demand-Energy Efficiency-Renewable Energy Sources

- **Decrease energy demands (building design)**
- **Increase energy efficiency (HVAC systems)**
- **Increase use of renewable energy sources (wind, solar, geothermal, biomass)**
- New energy sources (fuel cell,fracking)

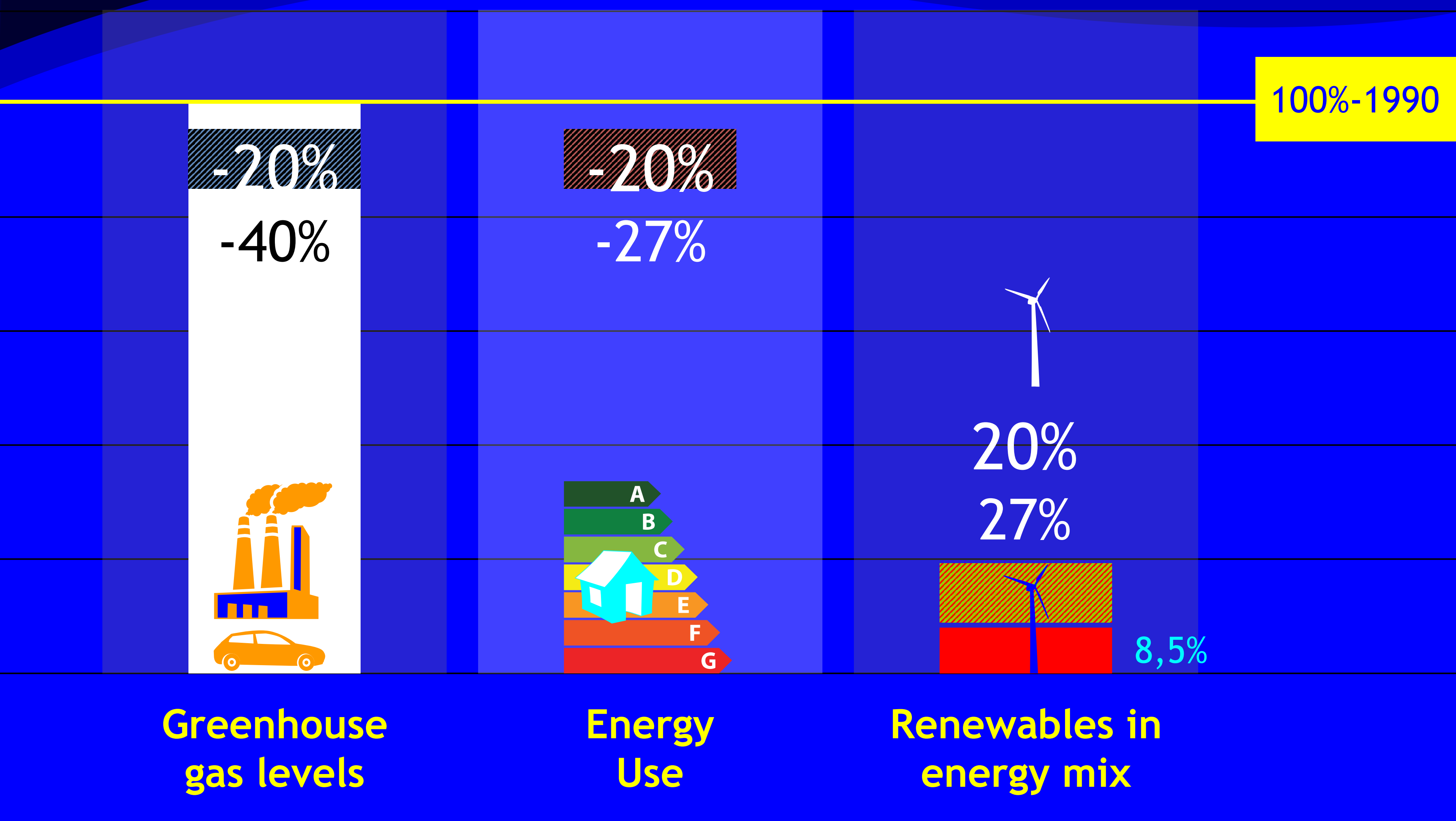
# Role of the Building Sector in Europe

40 % of EU's energy use

- 36 % of EU's $CO_2$ emissions
- Cost-effective energy savings potential: ~30 % by 2020
- 9 % of GDP, 8 % of employment and
- €2 trillion annual turnover

Directorate-General for Energy and Transport

# The 20-20-20 EU policy by 2020
# New policy for 2030 proposed



# Comprehensive set of legislation to enhance energy efficiency

**Services**
- Energy **end-use efficiency and energy services** Directive

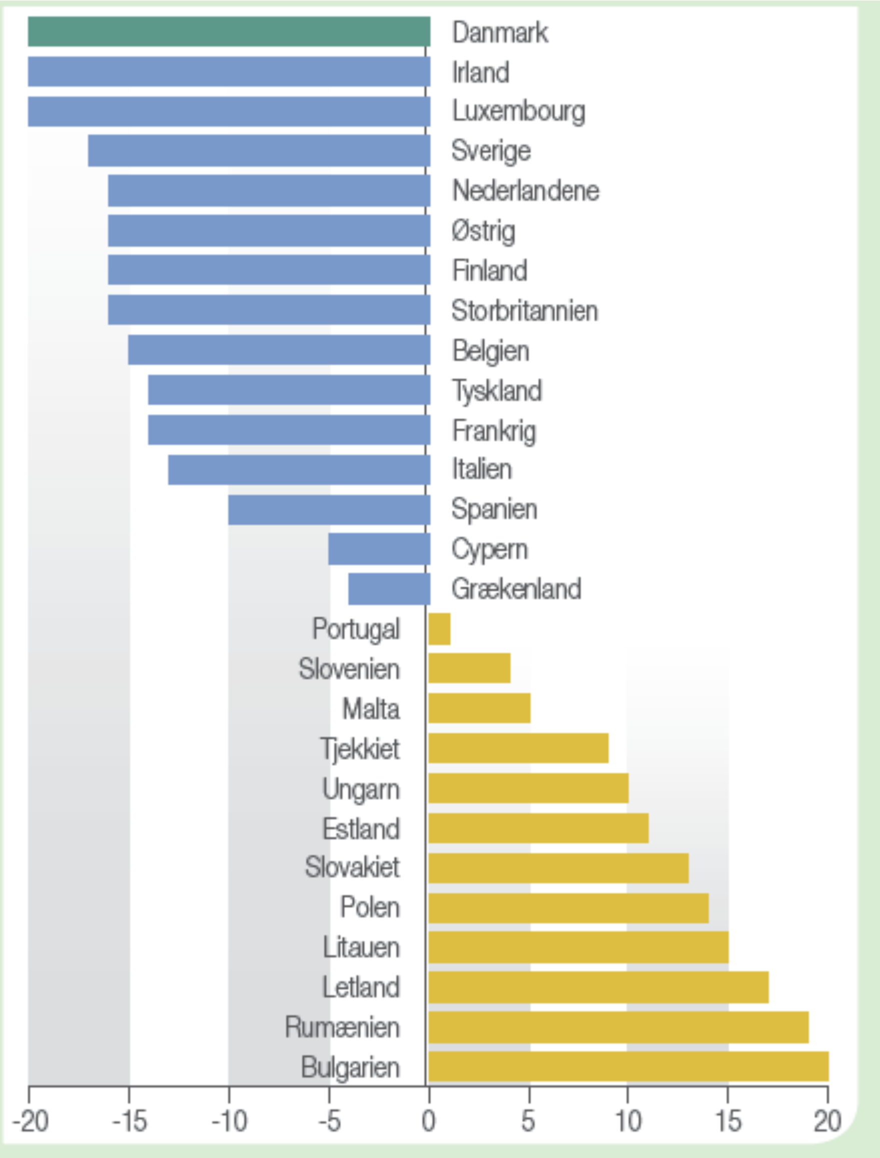
**Buildings**
- Energy performance of **buildings Directive (EPBD)**

**Generation**
- Directive on the promotion of **cogeneration**

**Product Labelling**
- Directives for **labelling of e.g. electric ovens, air-conditioners, refrigerators and other domestic appliances**
- Regulation of Energy Star labelling for office equipment

**Eco-Design**
- Directive establishing a framework for the setting of **eco-design requirements** for energy-using products (implementing directives for **e.g. boilers, refrigerators, freezers and ballasts for fluorescent lighting**

**Taxation**
- **Directive for the taxation of energy products and electricity**




Required reductions in energy use in European countries
2020 in relation to 2005

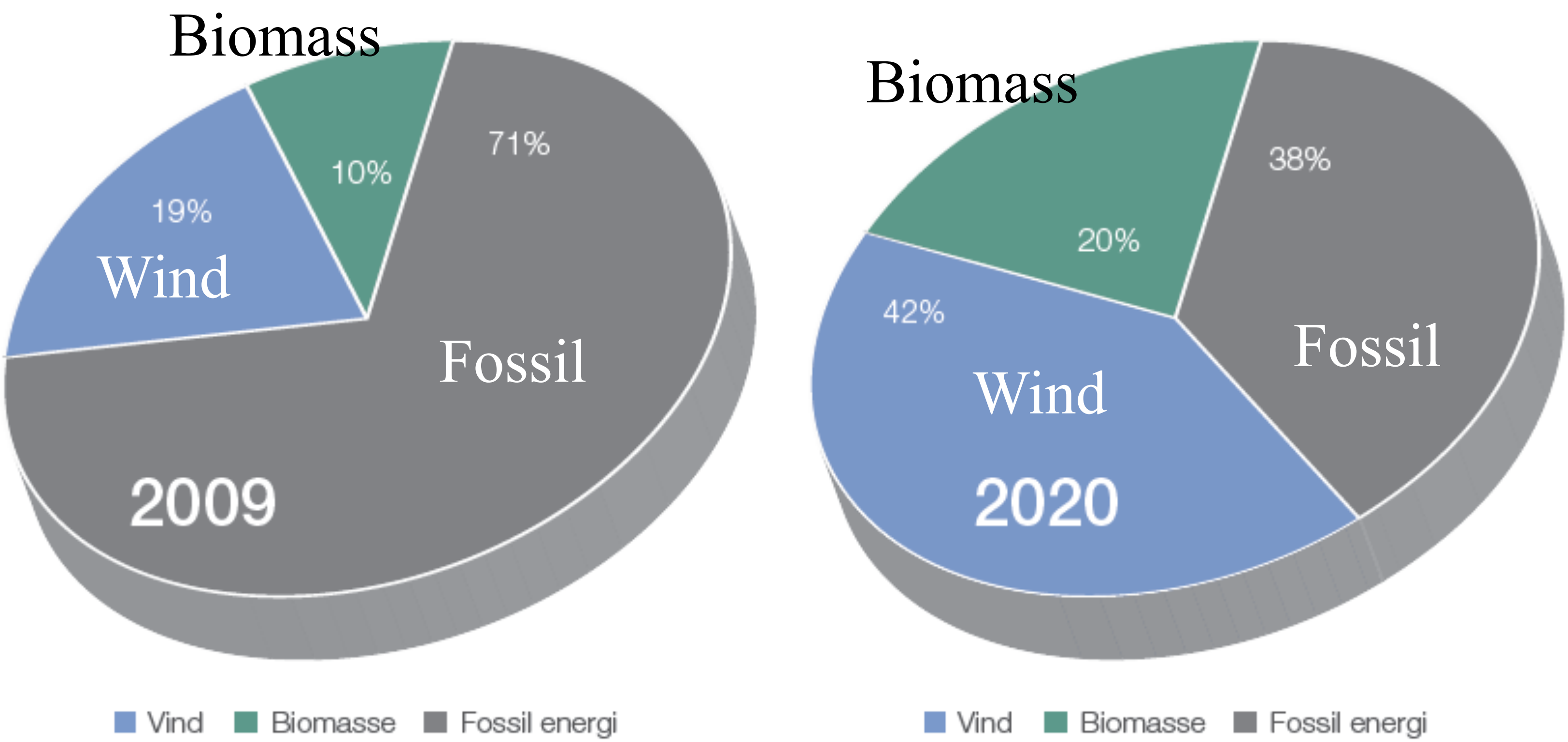
**Directive 2009/28/EC (Renewable Energy Directive 2009) of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources**

# National overall targets for the share of energy from renewable sources in gross final consumption of energy in 2020

| | 2005-2020 | |
|---|---|---|
| Belgium | 2,2 | 13 % |
| Bulgaria | 9,4 | 16 % |
| Czech Republic | 6,1 | 13 % |
| **Denmark** | **17,0** | **30 %** |
| **Germany** | **5,8** | **18 %** |
| **Estonia** | **18,0** | **25 %** |
| Ireland | 3,1 | 16 % |
| Greece | 6,9 | 18 % |
| Spain | 8,7 | 20 % |
| France | 10,3 | 23 % |
| Italy | 5,2 | 17 % |
| Cyprus | 2,9 | 13 % |
| **Latvia** | **32,6** | **40 %** |
| Lithuania | 15,0 | 23 % |
| Luxembourg | 0,9 | 11 % |

| | 2005-2020 | |
|---|---|---|
| Hungary | 4,3 % | 13 % |
| Malta | 0,0 % | 10 % |
| Netherlands | 2,4 % | 14 % |
| **Austria** | **23,3 %** | **34 %** |
| Poland | 7,2 % | 15 % |
| Portugal | 20,5 % | 31 % |
| Romania | 17,8 % | 24 % |
| Slovenia | 16,0 % | 25 % |
| Slovak Republic | 6,7 % | 14 % |
| **Finland** | **28,5 %** | **38 %** |
| **Sweden** | **39,8 %** | **49 %** |
| United Kingdom | 1,3 % | 15 % |

# Part of renewable energy sources (wind and bio-fuel) in power generation in Denmark




*4.2 Andel vedvarende energi i elproduktion 2009 og 2020*

# Comprehensive set of legislation to enhance energy efficiency

| | |
|---|---|
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| Taxation | **Directive for the taxation of energy products and electricity** |

# Research Program

## Innovation opportunities in Europe

- EU RTD and Innovation framework program
  ***HORIZON 2020***


## Energy Efficiency

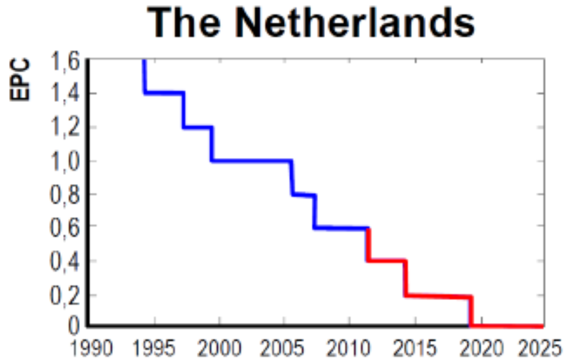
# Energy Performance of Buildings Directive – EPBD (2002/91/EC)

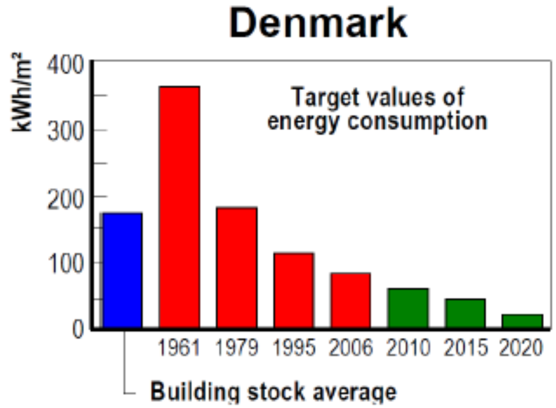
**Requirements - for Member States to specify and implement:**

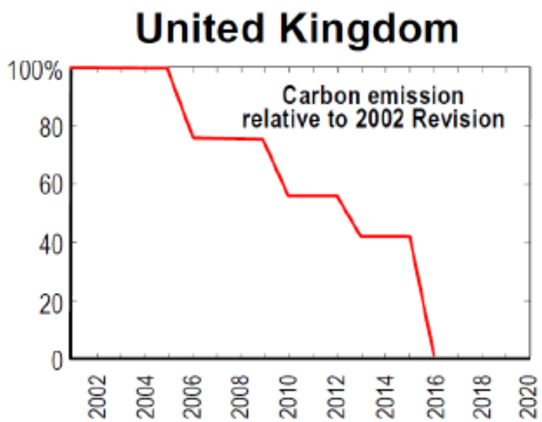
- **An integrated methodology to rate the energy performance of buildings**
- **Minimum energy performance standards for new and for existing buildings that undergo major renovation**
- **Energy performance certificates for buildings**
- **Regular inspections of boilers and air-conditioning systems**

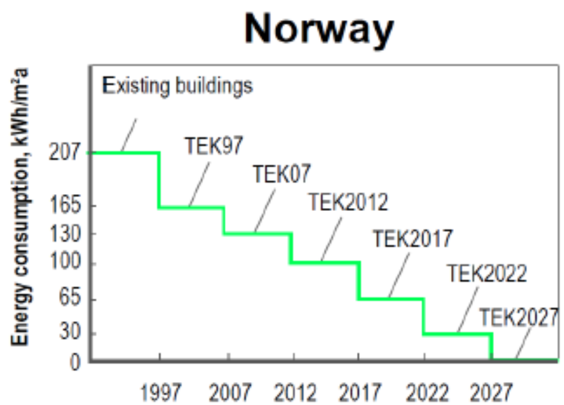
Directorate-General for Energy and Transport

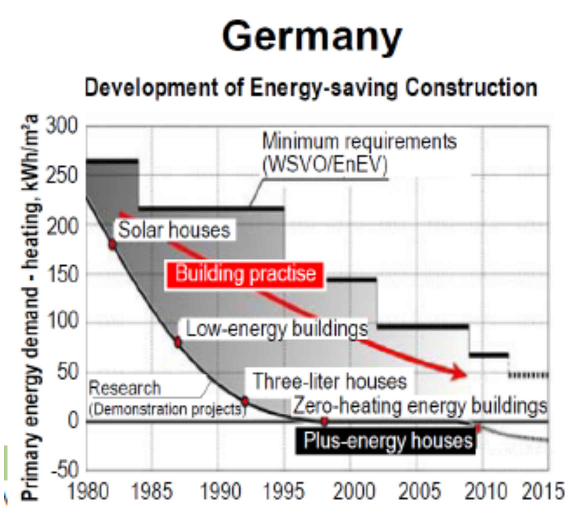
# The effect of building regulations

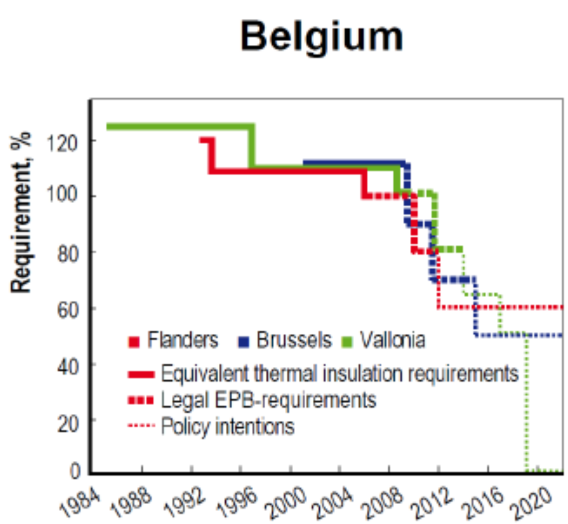


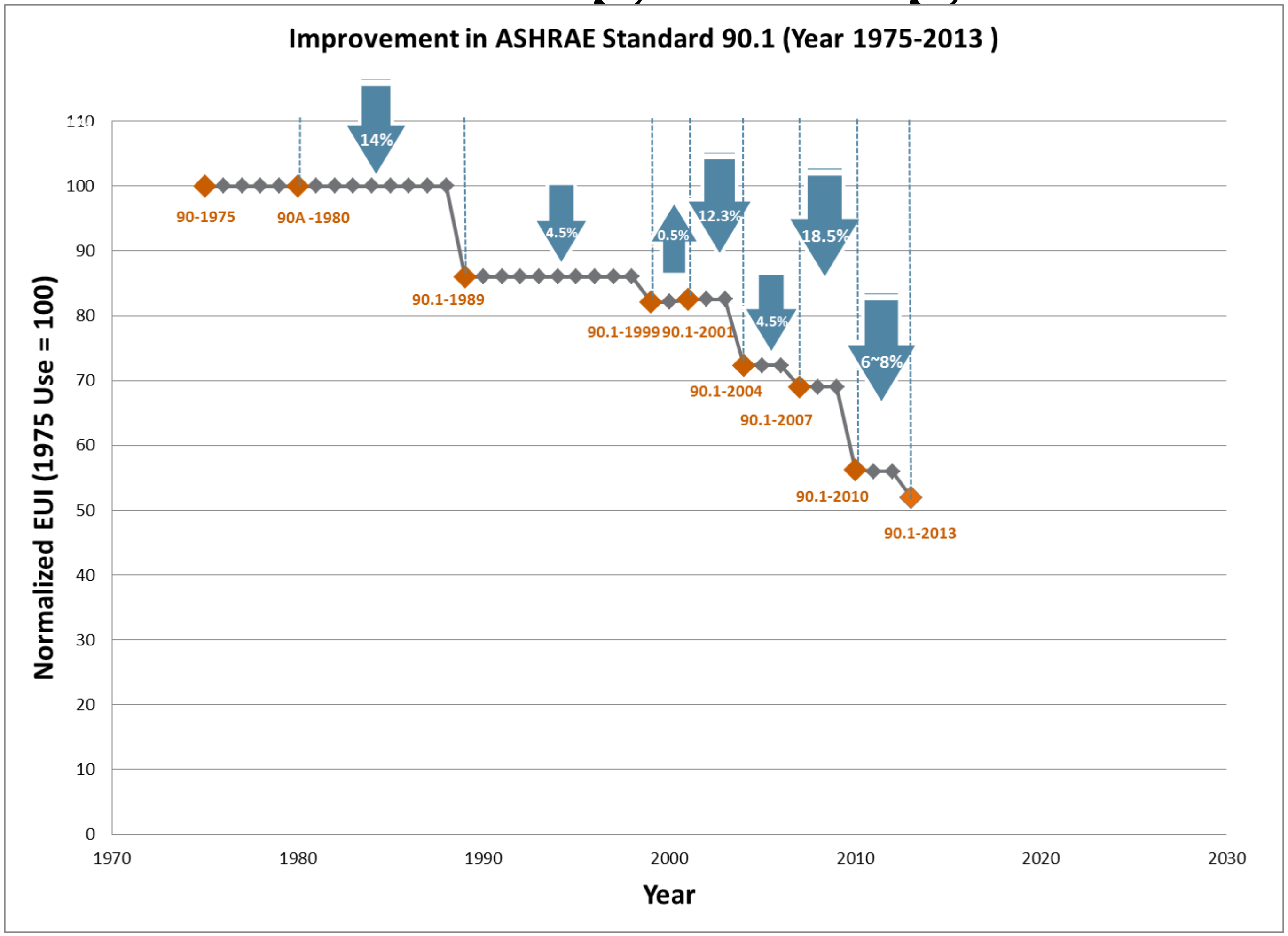



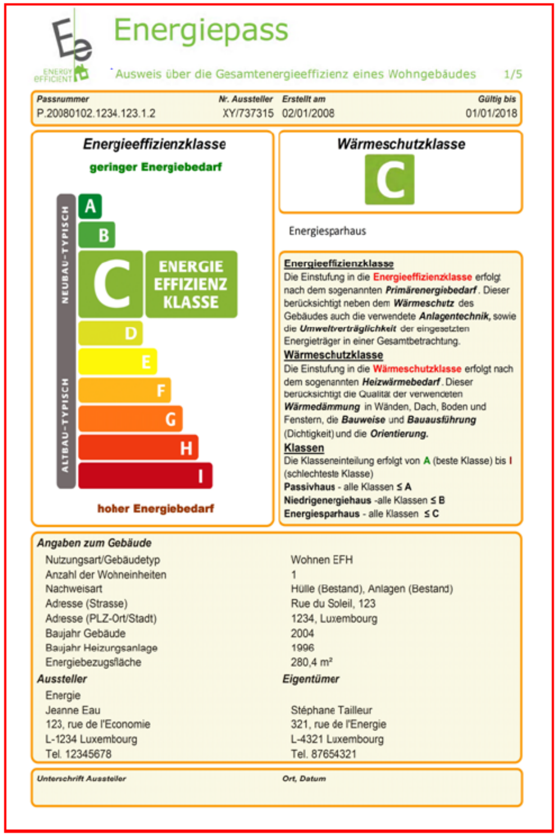



# Driving Change



# New in the recast EPBD

- Introduction of "nearly zero-energy buildings" by 2021/2019
- "Cost-optimal methodology"
- Extension of minimum requirements to ALL buildings but no obligation to renovate
- Strengthening of Energy Performance Certificates and Inspections
- Requirements for technical building systems in existing buildings, optional for new



European Commission

# “Nearly zero-energy buildings”

*Article 9: Member States shall ensure, that*

- **After 31 December 2018, new** buildings **occupied and owned by public authorities** are nearly zero-energy buildings, and;
- **After 31 December 2020 all new** buildings are nearly zero-energy buildings
- **MS shall develop national plans** for increasing the number of nearly zero-energy buildings including a detailed application of the definition in practice
- **MS shall develop policies and take measures** to stimulate refurbishments into nearly zero-energy buildings

**Commission launched a study** end of 2011

# EPBD recast – Nearly zero energy buildings nZEB

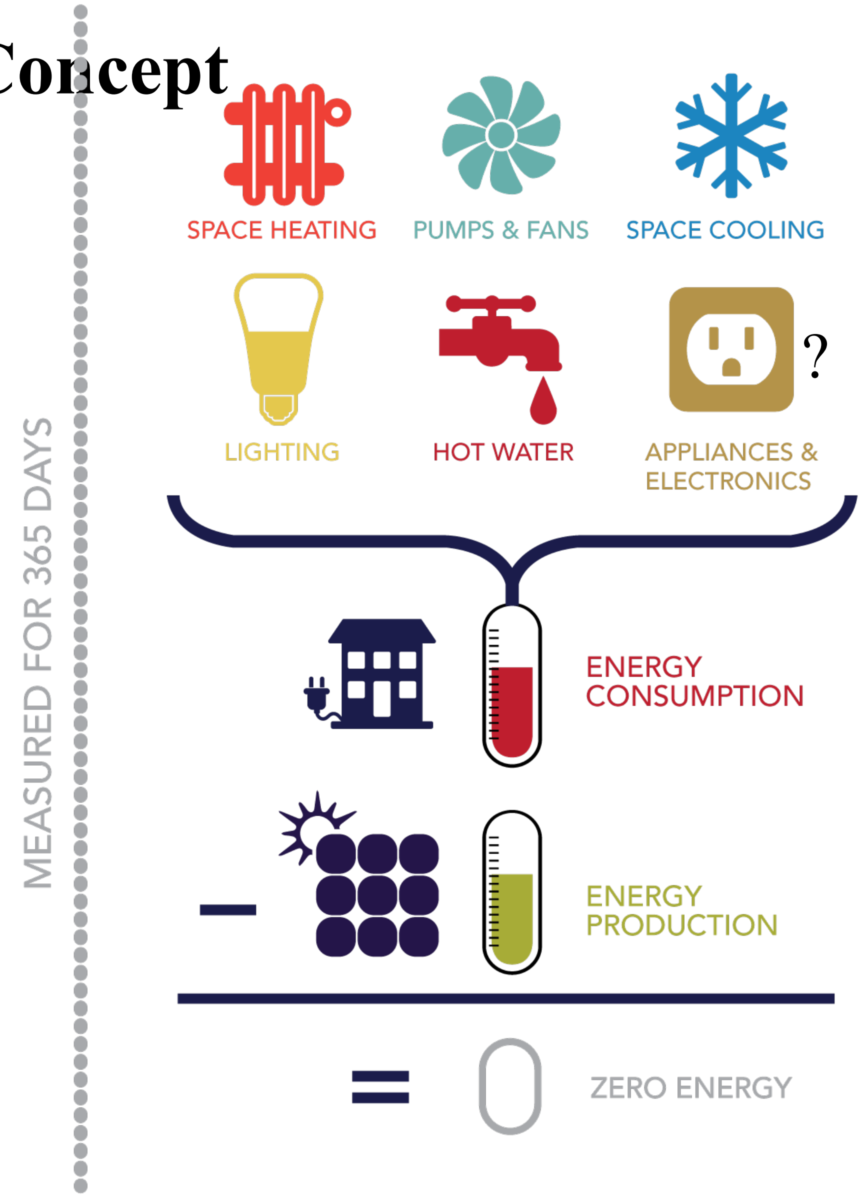
- In the directive 'nearly zero-energy building' means a building that has a very high energy performance. The nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby.

⇒ **nZEB = very high energy performance + on-site renewables**

- Definition of "a very high energy performance" and "significant extent of renewables" let for Member States

# ZEB Concept

Over the course of a year, if the (on-site or source) renewable energy produced ≥ the energy used within the boundary, it is considered a ZEB



# EPBD definition for energy performance

EPBD definitions (article 2):

- ‘energy performance of a building’ means the calculated or measured amount of energy needed to meet the energy demand associated with a typical use of the building, which includes, **inter alia**, energy used for **heating, cooling, ventilation, hot water and lighting**

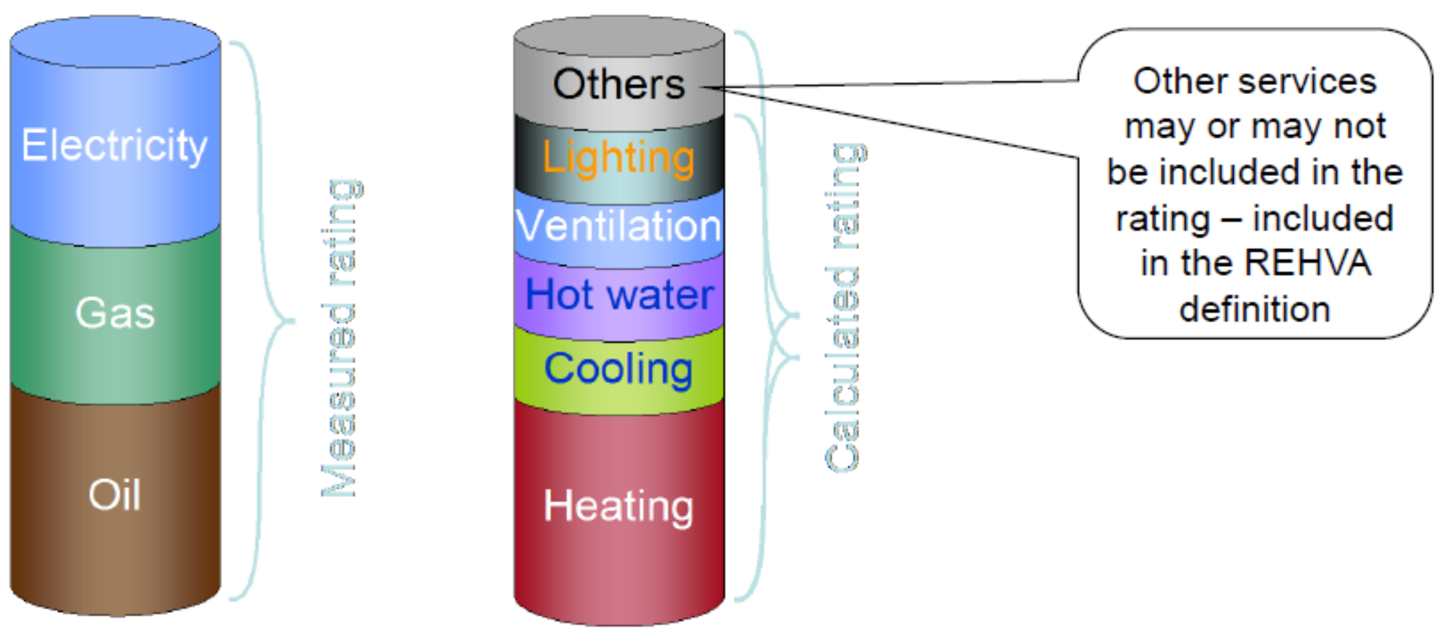


***Table I**. Primary energy frames for new buildings in Denmark 2006, 2010, 2015 and 2020.*

| Building Code | Energy frame kWh/(m² a) BR06 | Energy frame kWh/(m² a) BR10 | Energy frame kWh/(m² a) BR10 - Class 2015 | Energy frame kWh/(m² a) BR10 - Class 2020 |
|---|---|---|---|---|
| Residential | 70 + 2200/A | 52.5 + 1650/A | 30 + 1000/A | 20 |
| Non-residential | 95 + 2200/A | 71.3 + 1650/A | 41 + 1000/A | 25 |

***Table II**. Estonian primary energy requirements (VV No 68: 2012), which came into force since 9.1.2013. The requirements and corresponding energy certificate classes are shown in terms of primary energy for three building types out of nine.*

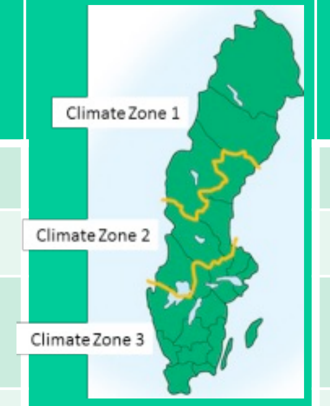
| | nZEB A kWh/(m² a) | Low energy B kWh/(m² a) | Min.req. new C (cost opt.) kWh/(m² a) | Min.req. maj.ren. D (cost opt.) kWh/(m² a) |
|---|---|---|---|---|
| Detached houses | 50 | 120 | 160 | 210 |
| Apartment buildings | 100 | 120 | 150 | 180 |
| Office buildings | 100 | 130 | 160 | 210 |

# Future net energy frames for new buildings in Norway

| | | Energy frame [kWh/m$^2$y] | | | | |
|---|---|---|---|---|---|---|
| Building Code | TEK07 | TEK10 | TEK15 - Passive house | TEK20 | TEK25 | TEK30 |
| Residential (detached house) | 135 | 130 | 80 (Heating: 15, Cooling: 0, DHW: 30) | nearly ZEB | Intermediate | Net ZEB |
| Residential (apartment block) | 120 | 115 | | | | |
| Non-residential (office) | 165 | 150 | 75* (Heating: 20, Cooling: 10, DHW: 5) | | | |

# SWEDEN

| | Annual energy use for heating, comfort cooling, domestic hot water provision and other shared services in the building ($kWh/m^2$) | | |
|---|---|---|---|
| | Climate zone | | |
| | 1 (north Sweden) | 2 (middle Sweden) | 3 (south Sweden) |
| Residential buildings with heating systems other than electric heating | 130 | 110 | 90 |
| Residential buildings with electric heating | 95 | 75 | 55 |
| Commercial and similar premises with heating systems other than electric heating | 120 + 110 x (q – 0,35) | 110 + 90 x (q – 0,35) | 80 + 70 x (q – 0,35) |
| Commercial and similar premises with electric heating | 95 + 65 x (q – 0,35) | 75 + 55 x (q – 0,35) | 55 + 45 x (q – 0,35) |




q is the average specific outdoor air ventilation flow rate during the heating season (l/(s,m2) and is an addition that must be included when the outdoor air flow exceeds 0,35 l/(s,m2) in order to maintain required hygienic air quality in temperature-controlled areas. Its maximum permissible value is 1,00 $l/(s, m^2)$.

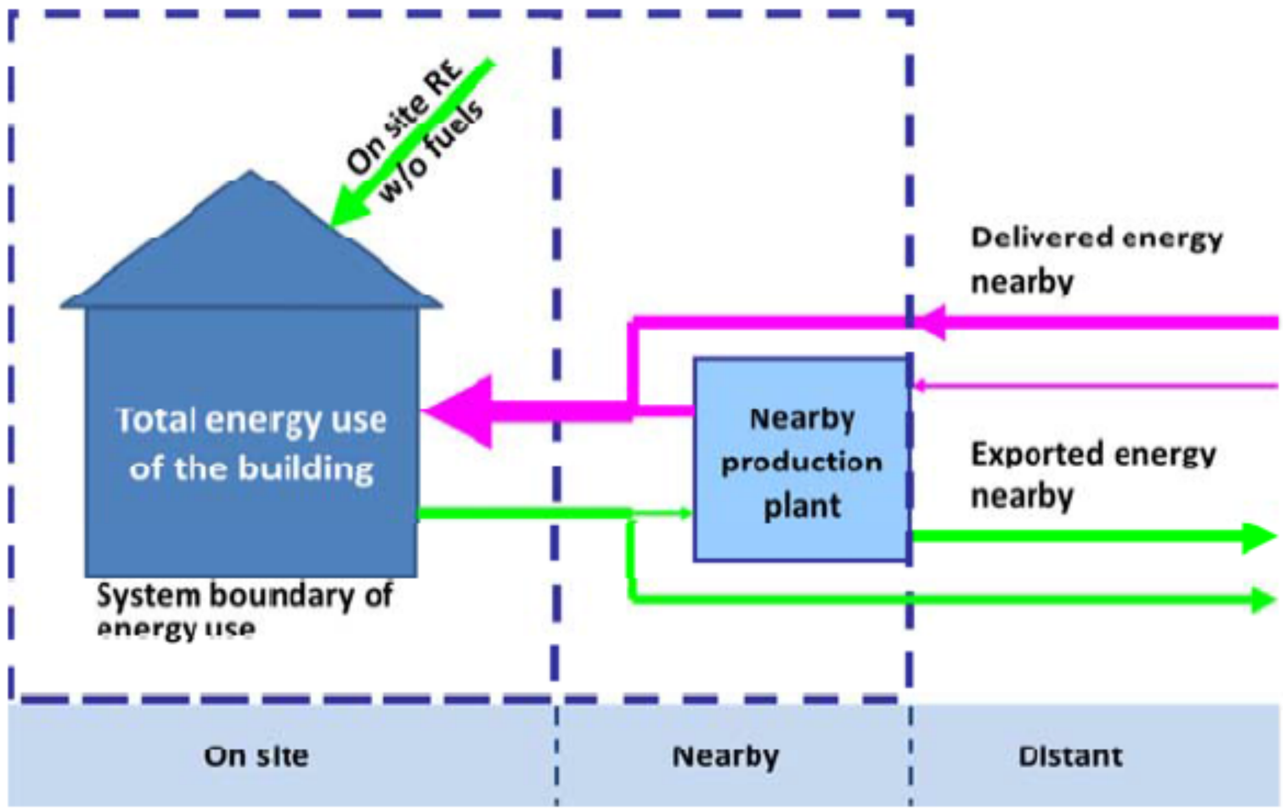



**Figure 3**. *Nearby assessment boundary to be used in the case of nearby energy production linked contractually to the building. Compared to on-site assessment boundary, delivered and exported energy flows on-site are replaced by delivered and exported energy flows nearby.*

# The CEN proposal for nZEB: a hurdle race

CSTB
le futur en construction

**Start**

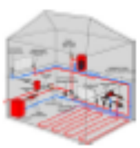
**Arrival**

Hurdle 1:
**Building needs**

Conditioned space

Hurdle 2:
**Building use**
**Total primary energy**

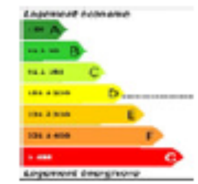
Technical building systems



Hurdle 3:
**Building use**
**Non-renewable prim. energy**

Energy carriers

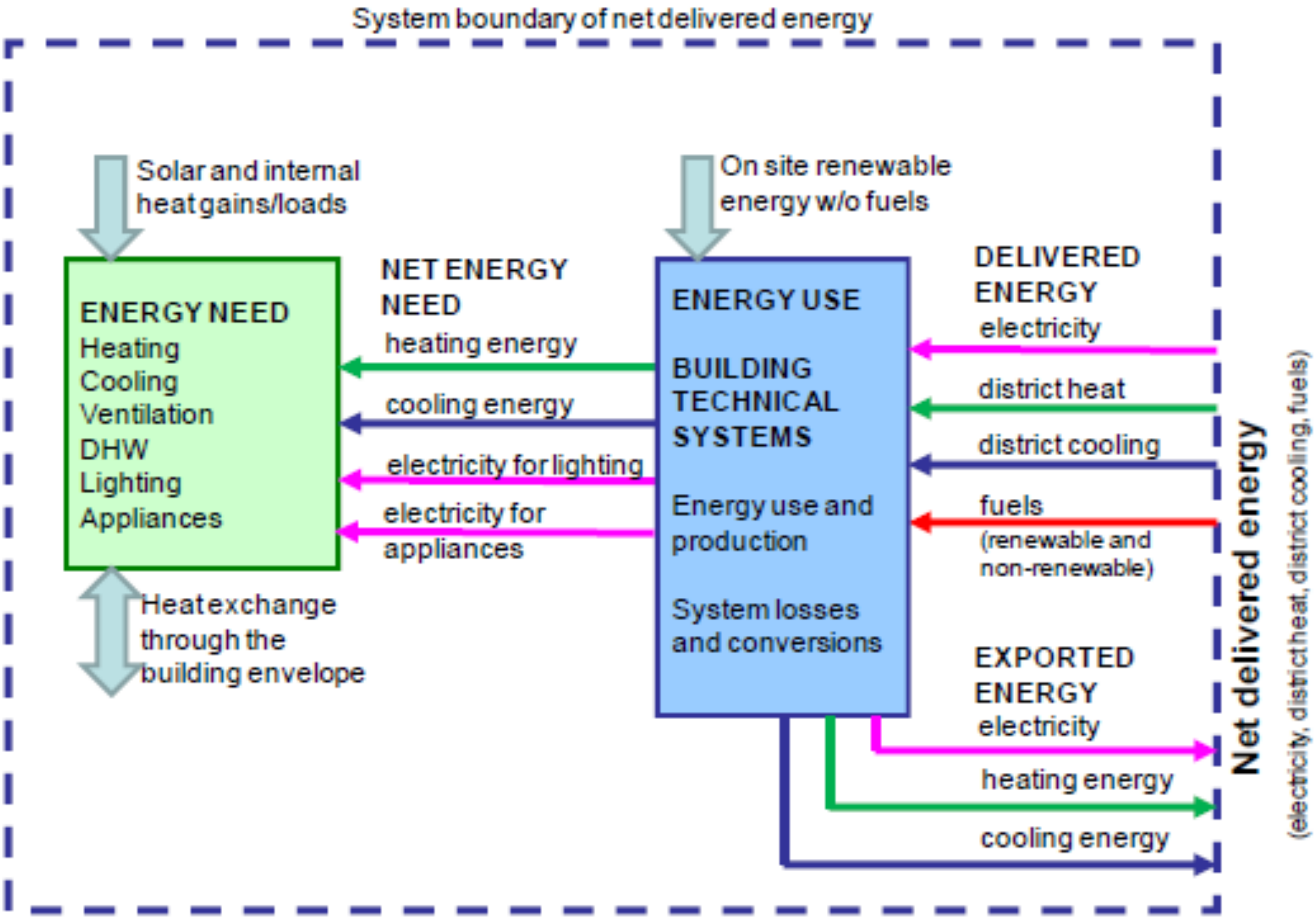
**nZEB rating**
**Primary energy balance**



Delivered - Exported

**Evolution of assessment boundaries**

# nZEB – detailed system boundary




Energy boundary of net delivered energy. The box of "Energy need" refers to rooms in a building and both system boundary lines may be interpreted as the building site boundary.

# Continuity from the product to the system energy performance assessment

**JWG ISO TC 163/ISO TC 205**

Holistic approach

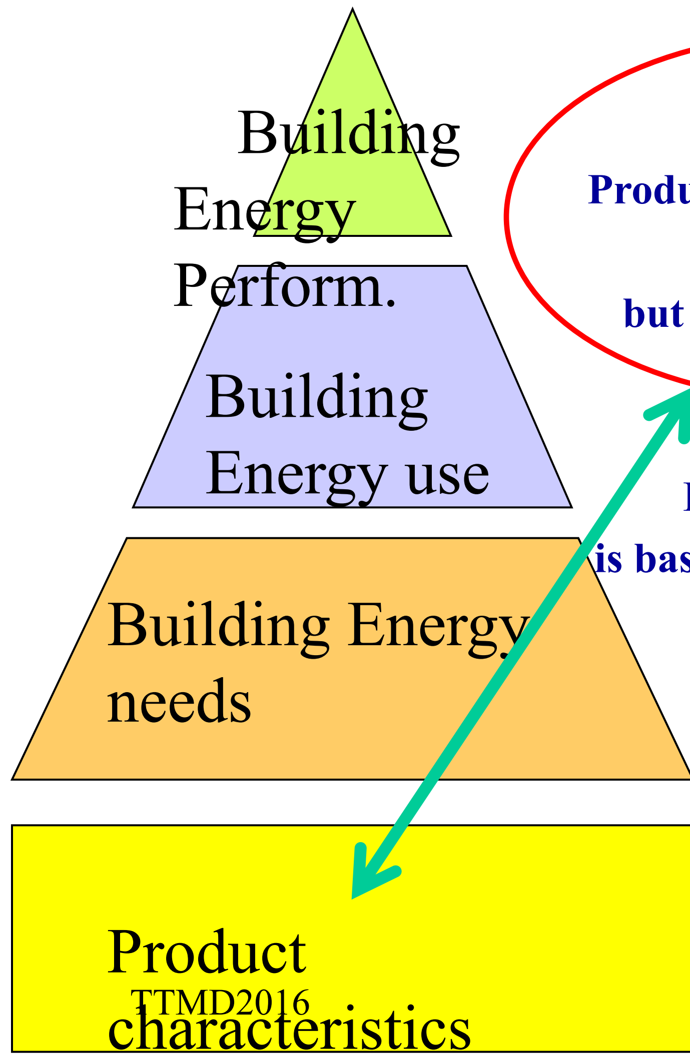
**ISO TC 205 (System TC)**

Technical Building Systems,
bldng environment design
(System loss calculation)

**ISO TC 163 (Building TC)**

Bldng energy use, envelope
characteristics, climatic data
(Building energy use calculation)

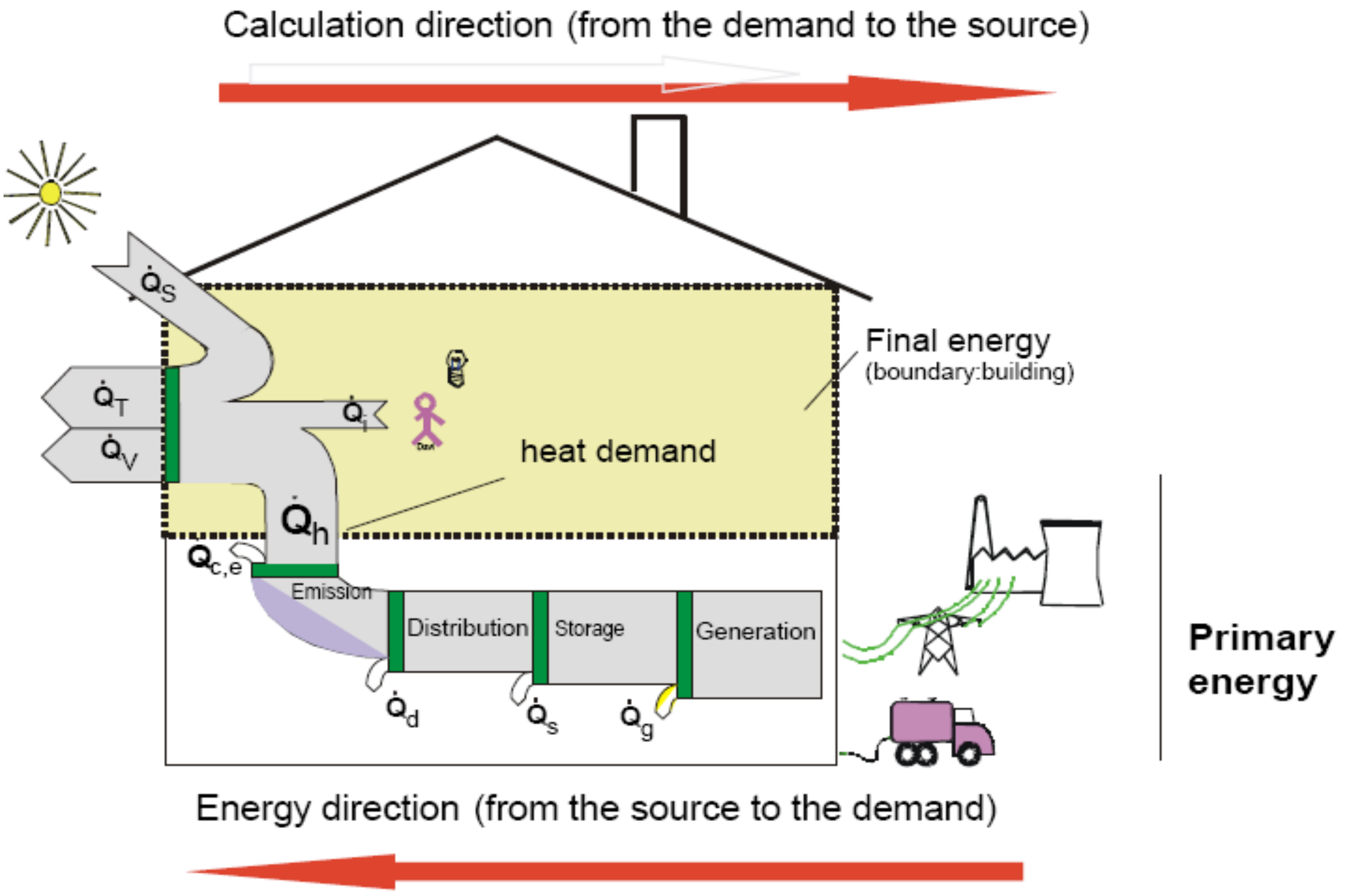
**Product TC's like ISO/TC 86;115;117; 118; etc... (Evaluation of product characteristics)**

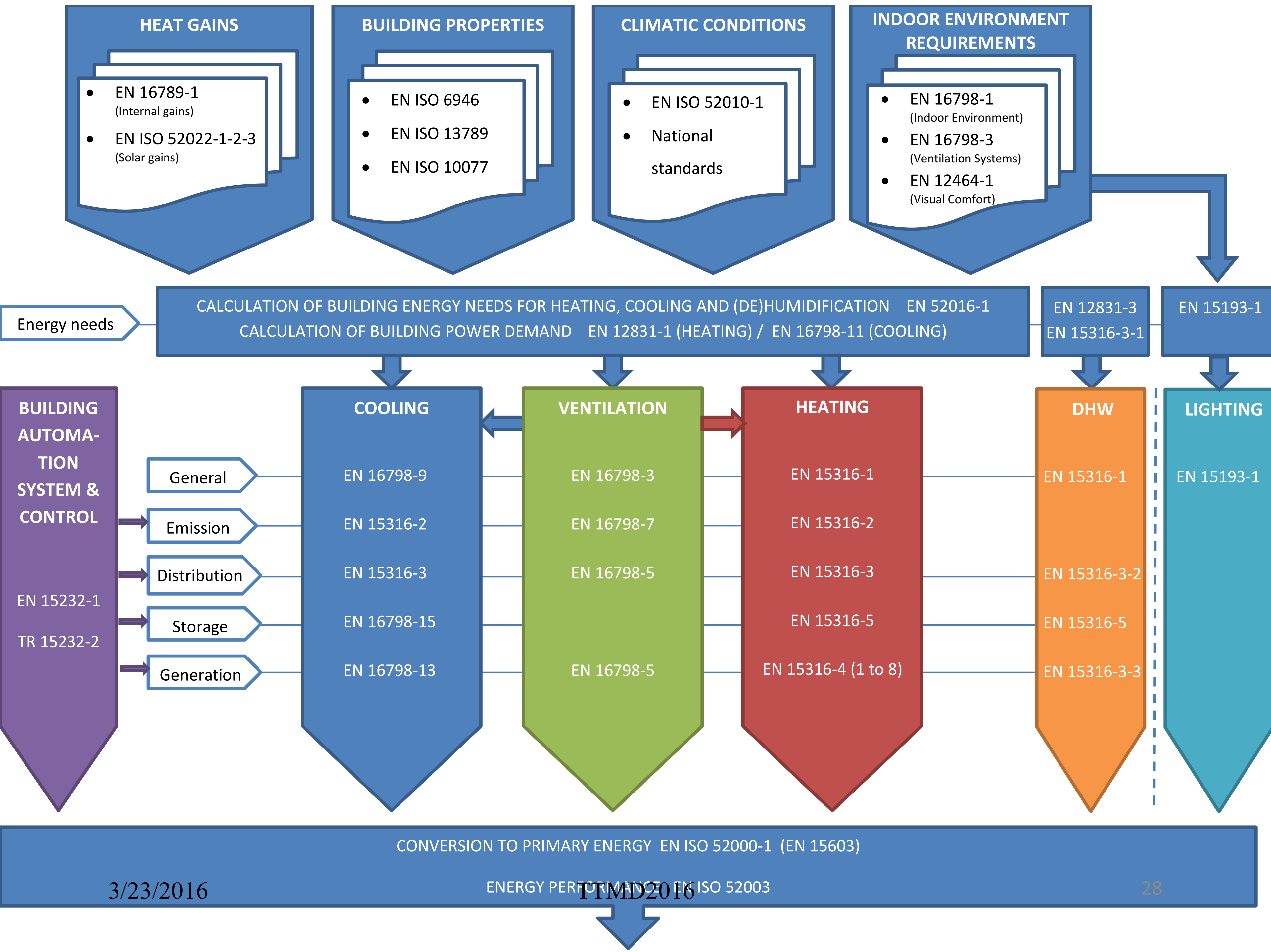



**Product no longer evaluated as a product but as a part of a system**

**IMPORTANT: Holistic approach is based on (tested) product characteristics**

Various **CEN** product TC's like: 48; 57; 62;


Calculation direction (from the demand to the source)
$\dot{Q}_S$
$\dot{Q}_T$
$\dot{Q}_V$
$\dot{Q}_i$
heat demand
Final energy
(boundary:building)
$\dot{Q}_h$
$Q_{c,e}$
Emission
Distribution
Storage
Generation
$\dot{Q}_d$
$\dot{Q}_s$
$\dot{Q}_g$
Primary energy
Energy direction (from the source to the demand)


HEAT GAINS
EN 16789-1
(Internal gains)
EN ISO 52022-1-2-3
(Solar gains)
BUILDING PROPERTIES
EN ISO 6946
EN ISO 13789
EN ISO 10077
CLIMATIC CONDITIONS
EN ISO 52010-1
National standards
INDOOR ENVIRONMENT REQUIREMENTS
EN 16798-1
(Indoor Environment)
EN 16798-3
(Ventilation Systems)
EN 12464-1
(Visual Comfort)
Energy needs
CALCULATION OF BUILDING ENERGY NEEDS FOR HEATING, COOLING AND (DE)HUMIDIFICATION EN 52016-1
CALCULATION OF BUILDING POWER DEMAND EN 12831-1 (HEATING) / EN 16798-11 (COOLING)
EN 12831-3
EN 15316-3-1
EN 15193-1
BUILDING AUTOMA-TION SYSTEM & CONTROL
EN 15232-1
TR 15232-2
General
Emission
Distribution
Storage
Generation
COOLING
EN 16798-9
EN 15316-2
EN 15316-3
EN 16798-15
EN 16798-13
VENTILATION
EN 16798-3
EN 16798-7
EN 16798-5
EN 16798-5
HEATING
EN 15316-1
EN 15316-2
EN 15316-3
EN 15316-5
EN 15316-4 (1 to 8)
DHW
EN 15316-1
EN 15316-3-2
EN 15316-5
EN 15316-3-3
LIGHTING
EN 15193-1
CONVERSION TO PRIMARY ENERGY EN ISO 52000-1 (EN 15603)
ENERGY PERFORMANCE EN ISO 52003

# Primary energy factors

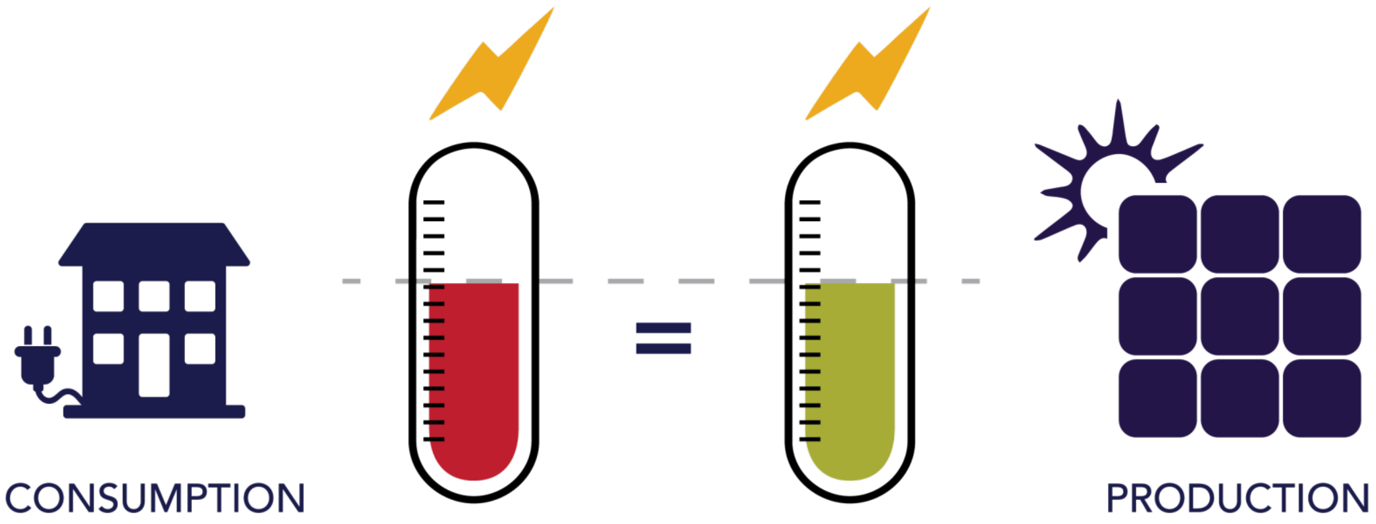
| | Energy carrier | | $f_{Pnren}$ | | | $K_{CO2e}$ (g/kW h) |
|---|---|---|---|---|---|---|
| | Delivered from distant | | | | | |
| 1 | Fossil fuels | Solid | 1,1 | | | 360 |
| 2 | | Liquid | 1,1 | | | 290 |
| 3 | | Gaseous | 1,1 | | | 220 |
| 4 | Bio fuels | Solid | 0,2 | | | 40 |
| 5 | | Liquid | 0,5 | | | 70 |
| 6 | | Gaseous | 0,4 | | | 100 |
| 7 | Electricity | | 2,3 | | | 420 |
| | Delivered from nearby | | | | | |
| 8 | District heating [a)] | | 1,3 | | | 260 |
| 9 | District cooling | | 1,3 | | | 260 |
| | Delivered from on-site | | | | | |
| 10 | Solar | PV electricity | 0 | | | 0 |
| 11 | | Thermal | 0 | | | 0 |
| 12 | Wind | | 0 | | | 0 |
| 13 | Environment | Geo-, aero-, hydrothermal | 0 | | | 0 |
| | Exported | | | | | |
| 14 | Electricity [b)] | Never redelivered | 2,3 | | | 420 |
| 15 | | Temporary exported and redelivered later | 2,3 | | | 420 |
| 16 | | To non EPB uses | 2,3 | | | 420 |

# ENERGY RETROFIT OF BUILDINGS

- Only 3% new buildings per year
- Requirements
- Incentives
  - Tax cuts
  - Financial support

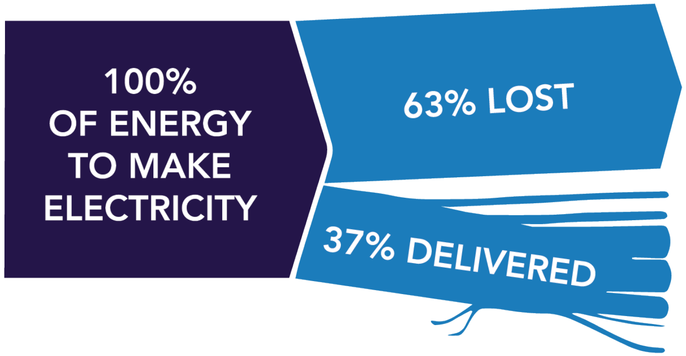
# Site Energy (n)ZEB

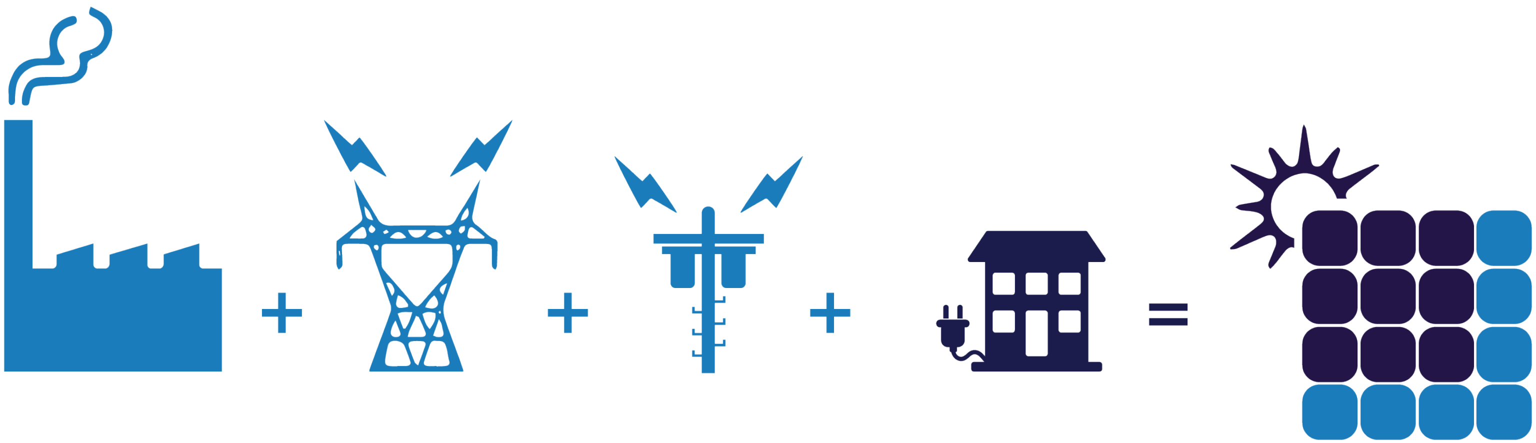
A building where the actual annual delivered energy ≤ on-site renewable exported energy as measured at the site.



# Source Energy (n)ZEB

A building where the actual annual delivered energy ≤ on-site renewable exported energy as measured at the building site and converted to source energy.



# Zero Energy Cost Building

A building where the actual annual energy costs are zero.

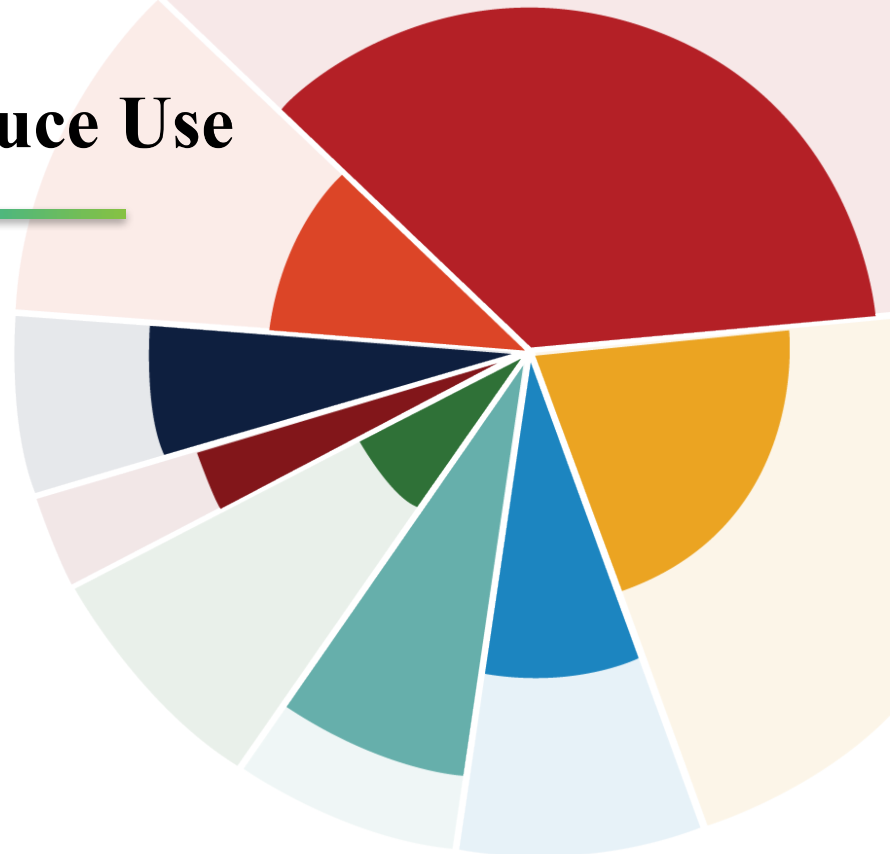
# Can all buildings balance energy use with only on-site renewable energy?

ASHRAE

# ISO EN 52000-1

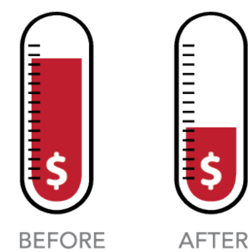
**Energy performance of buildings —
Overarching EPB assessment –
Part 1: General framework and procedures**

# Goal 1: Reduce Use



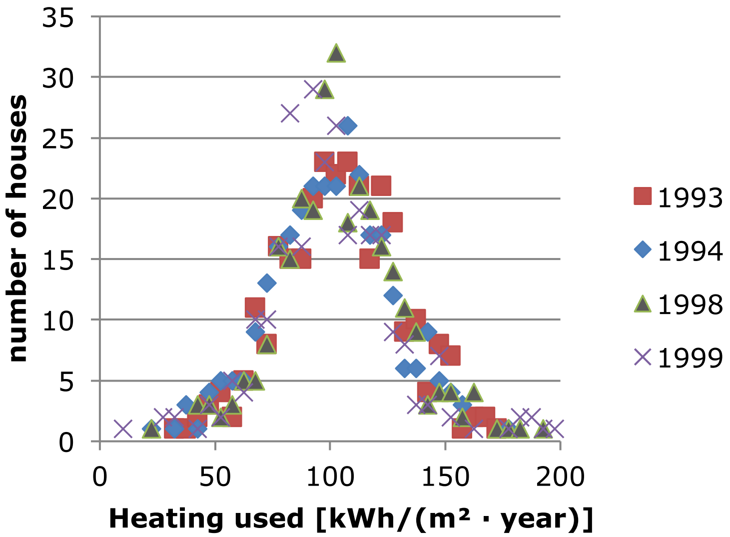
Energy use can be reduced through:

- Efficient building construction
- Passive strategies
- Efficient systems & appliances
- User behavior



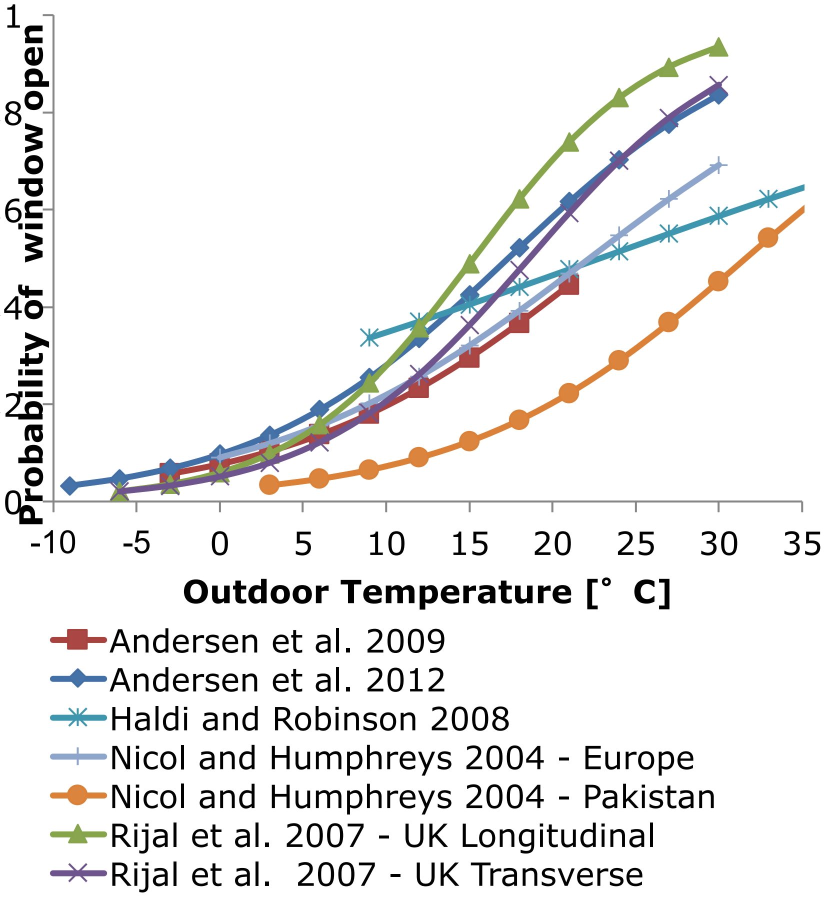
# Investigation of heating used in 290 identical houses*

- Correction for differences in outer wall area
  - End houses vs. Middle houses
- Highest used up to 20 times higher than lowest
- Stable use distribution over time
- No measurements of indoor environment



# Models of occupants' window opening behaviour

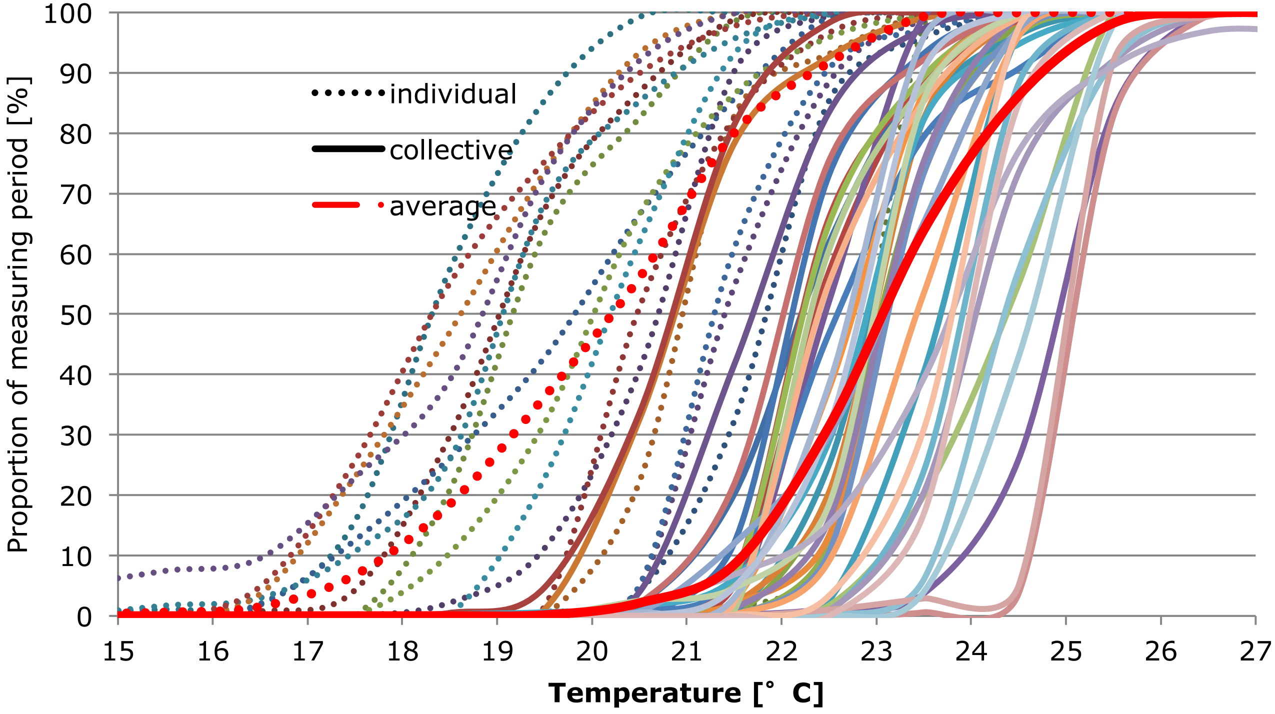
- Many models
- Most, only rely on thermal environment
  - Is that enough?
  - Which one should I use?
- Lack of validation
- Lack of validation methods



# Shared or individual heating cost

Interviews of 10 residents

- Possible to heat all apartments to comfortable condition
- Individual billing
  - focus on heat savings
  - Accepted uncomfortable conditions to save money
- Collective billing
  - Focus on health, comfort and avoiding moisture problems



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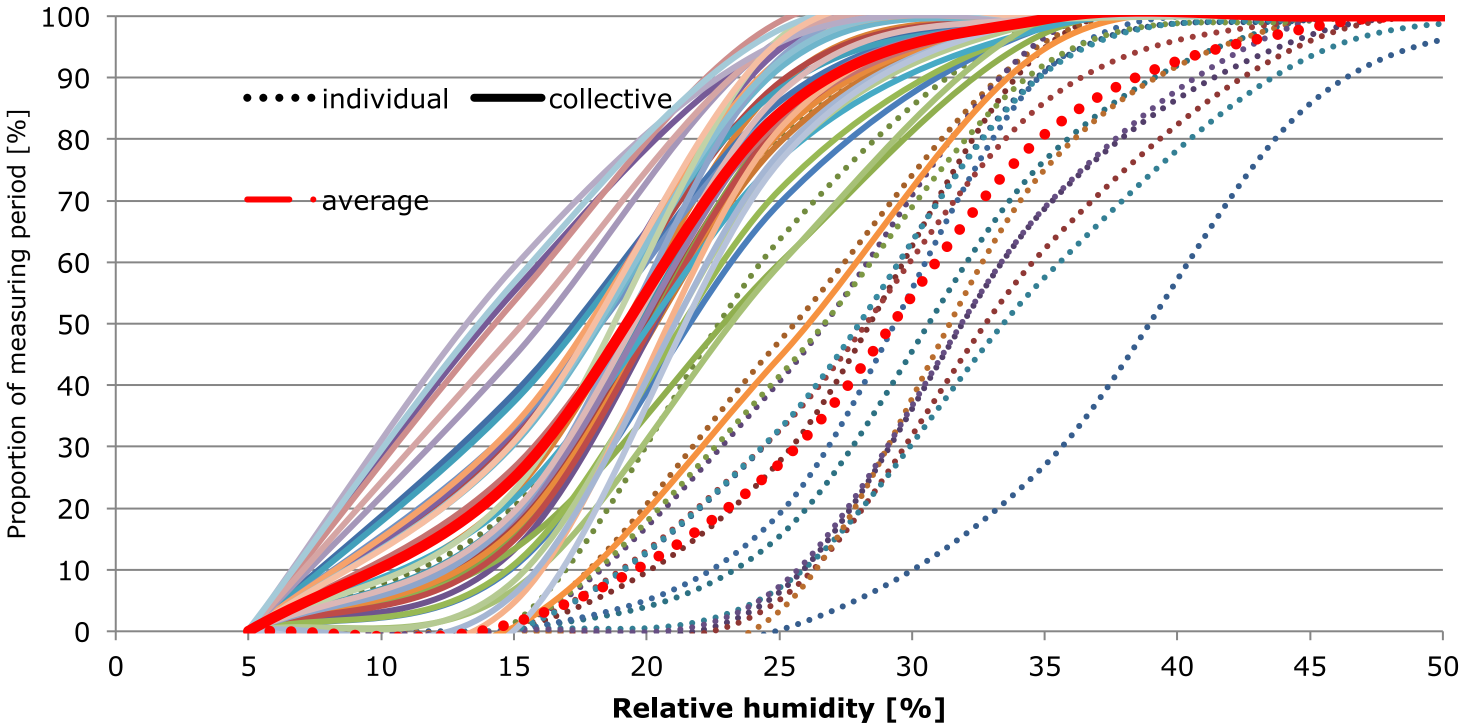

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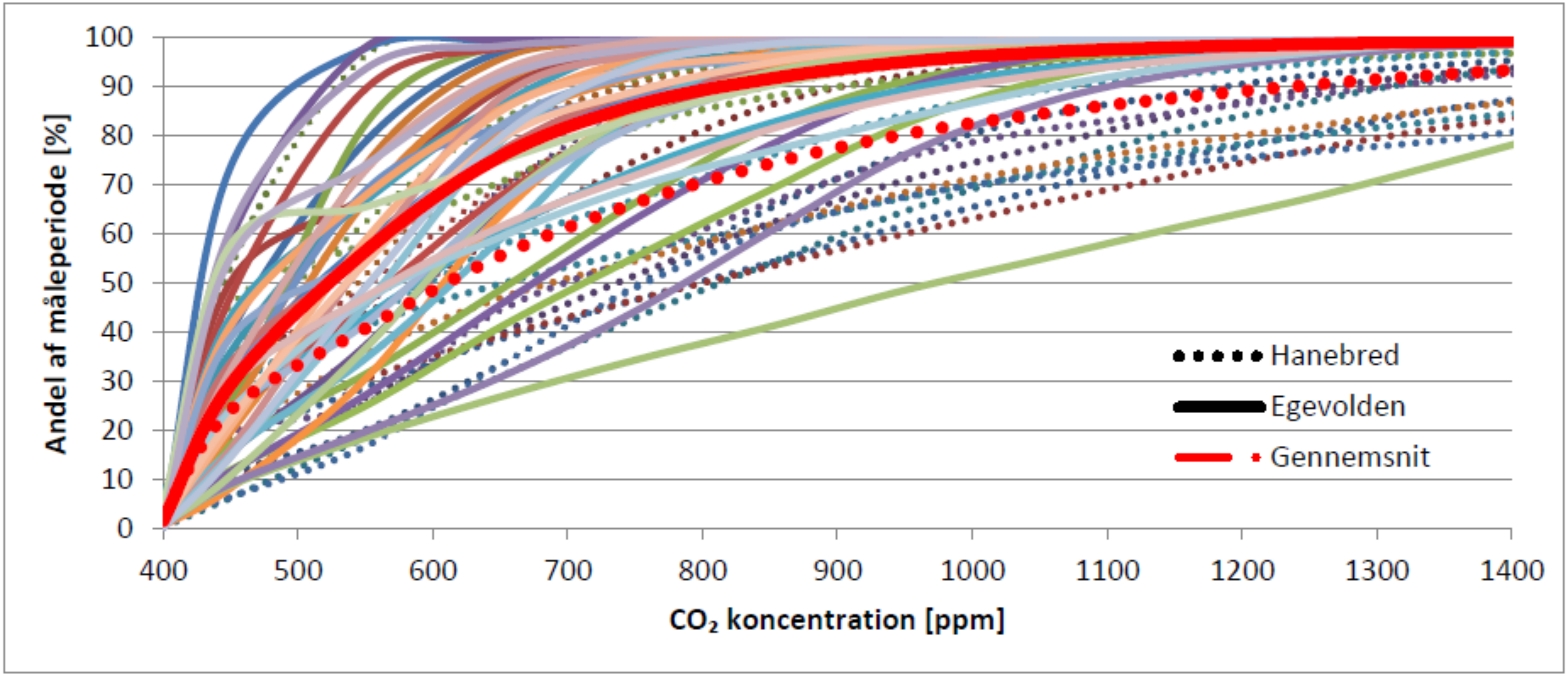
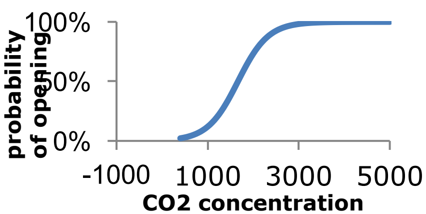


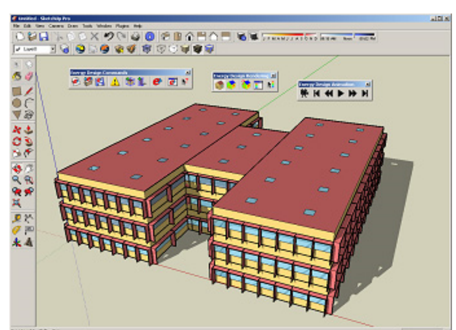
# From deterministic to stochastic modelling

**Stochastic models**

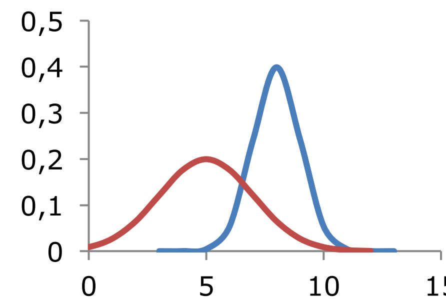
- Window opening
- Heating set-points
- Cooling set-points
- lighting
- …




↔ **Deterministic model of physical aspects**



→ **Probability distribution of performance indicators**



# Energy Efficient Technologies

- Indoor air quality
  - Reduce loads (pollution sources)
  - Heat recovery
  - Increase system efficiency
  - Natural ventilation-Hybrid ventilation
  - Air distribution (contaminant removal) effectiveness
    - Personal ventilation
  - Air cleaning

- Thermal comfort
  - Reduce loads (building shell, solar screen, internal loads)
  - Increase system efficiency
  - Low Temperatur Heating- and High Temperature Cooling Systems
  - Use of building mass to reduce peaks (Thermo-Active-Building-Systems (TABS))
  - Drifting indoor temperatures

# Energy Demand-Energy Efficiency-Renewable Energy Sources

- **Decrease energy demands (building design)**
- **Increase energy efficiency (HVAC systems)**
- **Increase use of renewable energy sources (wind, solar, geothermal, biomass)**
- New energy sources (fuel cell,fracking)

# COMFORT-PRODUCTIVITY
# Building costs

| | |
|---|---|
| People | 100 |
| Maintenance | 10 |
| Financing | 10 |
| **Energy** | **1** |

**This clearly show that buildings are for**

**people**

**not for saving energy**