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Primary Energy Efficiency through DHC

by

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Who is this woman?

She was chairing the

UN Commission

(1987)

"Our Common Future"

•

"Agenda 21"

"Sustainable development"

•

Said in the OCF- report on

CHP and District Heating:

…" could revolutionize the energy efficiency of buildings world wide."

The main goals
of
Directive on the energy performance of buildings

Reduced primary energy use
Reduced CO_2-emission

EC-Directive on the Energy Performance of Buildings (EPBD)
2002

European Climate Change Programme
2000

Kyoto Protocol
to the
United Nations Framework Convention on Climate Change
1997

EC-Directive to limit carbon dioxide emissions by
improving energy efficiency (SAVE)
1993

Rio Earth Summit
United Nations Framework Convention on Climate Change
1992

Our Common Future
World Commission on Environment and Development
1987

Hypotheses on the future heating of buildings:

In a democratic society the following main factors will decide the future energy demand of buildings and which energy systems and energy sources that will be used:

- Mandatory rules by international and national laws and regulations
- Public support schemes to promote a desired development based on considerations related to social economics
- Private considerations concerning what is user-friendly, private costs and security / flexibility in the energy supply

According to the

Directive on the energy performance of buildings (EPBD)

the buildings in the EU environment from now on

shall have an Energy Certificate

which expresses the

energy performance

according to the European standards

EN 15217:2007 and EN 15603:2007

which is mandated from the EU Commission

If you want to reach a goal
you need some
guiding indicators
that tells you
when you are on the right track!

According to the European standards

EN 15603:2007 and EN 15217:2007

it is recommended to use
the following indicators to express the energy performance and consequently the quality of the energy systems for buildings in the 21 century:

- Primary energy use
- CO_2 production/emission
- An indicator defined by national energy policy

We always have to define the right system borders !

The mandated EN-Standards sets the rational system border when calculating the

Primary energy use

and the

CO_2 emission:

The whole energy chain !

The Kyoto protocol sets the rational geographically system border:

The whole world !

From the EPBD/2002: "The energy performance of a building shall be expressed in a transparent manner and may include a CO_2 emission indicator".

The **"Recast" of EPBD** from The Commission of 2008-11-13 is **demanding** the following expression of the energy performance of the buildings on the Energy Certificate:

"The energy performance of a building shall be expressed in a transparent manner and shall also include a numeric indicator of carbon dioxide emissions and primary energy use.

The methodology of calculation of energy performance of buildings should take into account European standards."

The Primary Energy Concept for assessing Overall Energy Efficiency

Primary Energy Factors (PEF_T / PRF_R) and CO_2 coefficients

Normative according to EN 15603:2007	Primary energy factors		CO_2 production
	Ressource	Total	[kg/MWh]
Fuel oil	1.35	1.35	330
Gas	1.36	1.36	277
Anthracite	1.19	1.19	394
Lignite	1.40	1.40	433
Coke	1.53	1.53	467
Wood shavings	0.06	1.06	4
Log	0.09	1.09	14
Beech log	0.07	1.07	13
Fir log	0.10	1.10	20
Electricity from hydraulic power plant	0.50	1.50	7
Electricity from nuclear power plant	2.80	2.80	16
Electricity from coal power plant	4.05	4.05	1340
Electricity Mix UCPTE	3.14	3.31	617

Source: Oekoinventare für Energiesysteme - ETH Zürich (1996)
These factors include the energy to build the transformation and transportation systems for the transformation of the primary energy to delivered energy.

The development of the PEF calculation ?

Have we forgotten something until lately ?

From drafts from CEN CEN/TC 228
Until June 2004:
Primary Energy Factor
Electricity:
(European average)
$PEF_T = 2.50$
(Default value)
$\eta_T = 0.40$

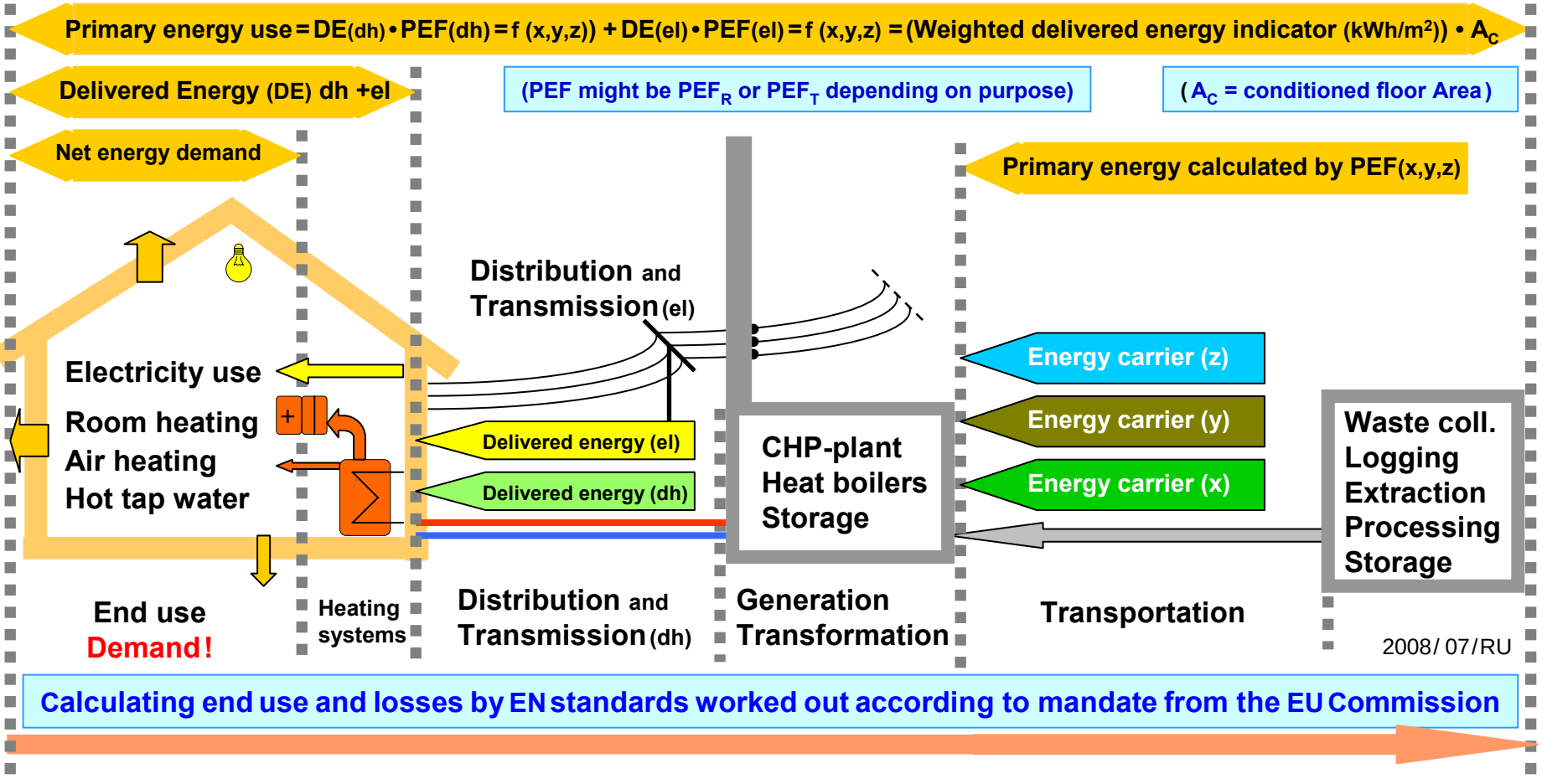
From a draft from TC 228
December 2004:
Primary Energy Factor
Electricity:
(European average)
$PEF_T = 2.80$
$PEF_R = 2.60$
(Informative value)
$\eta_T \sim 0.36$

(prEN 1520) prEN 15603
December 2005:
Primary Energy Factor
Electricity:
(Mix UCPTE)
$PEF_T = 3.06$
$PEF_R = 2.80$
(Informative values)
$\eta_T \sim 0.33$

EN 15603:2007 Primary Energy Factors (PEF)
Electricity (Mix UCPTE):
$PEF_T = 3.31$ ($\eta_T \sim 0.30$) , $PEF_R = 3.14$
Electricity from coal power plants:
$PEF_T = PEF_R = 4.05$ ($\eta_T \sim 0.25$)
(Informative values)

Standardised PEF values will solve the problem
from the energy source to the outside wall
of the house at the end user

The Primary Energy concept according to EPBD and mandated EN-standards



”Delivered energy”

can be

Calculated ”net energy demand” / system efficiency

or

Measured ”Delivered energy”

”Primary energy use”

can be

Calculated ”Delivered energy” • Primary Energy Factor

or

Measured ”Delivered energy” • Primary Energy Factor

Examples on calculation of system efficiency for heating systems in buildings according to the standards EN 15316-x-x:2007

Example 1:

2-pipe hydronic heating system with dimensioning $\Delta\theta$=80-60° (η_{str1}) and radiators on external wall (η_{str2}) and a controller valve - P-controller - 1K (η_{ctr}). Distribution pipes only in heated rooms and heat supply (20 kW) from DH.

System efficiency:

Controller efficiency for radiators in the room: η_{ctr} = 0.95.

Efficiency due to temperature level: η_{str1} = 0.91 Efficiency due to radiators on normal external wall: η_{str2} = 0.95 $\eta_{str} = (\eta_{str1} + \eta_{str2})/2 = (0.91+0.95)/2 = 0.93$.

Total efficiency in the room: $\eta_{em} = 0.95 \cdot 0.93 = 0.88$

Efficiency for the dwelling substation (S) in an unheated room calculated from the heat loss according to EN 15316-4-5, Annex B ~ 0.97 (S in heated room: η_s=1.0)

Total efficiency for the heating system in the building: $0.88 \cdot 0.97 = 0.85$ (0.88)

Example 2:

Electrical direct heating in the external wall region with P-controller - 1K.

System efficiency: Total η_{em} = 0.91

How will the typical heat load and heat demand of future buildings affect the competitiveness of District Heating?

Directive 2009/28/EC
on the promotion of the use of energy from renewable sources

Article 13

Administrative procedures, regulations and codes

3.

Member States shall recommend to all actors, in particular local and regional administrative bodies to ensure equipment and systems are installed for the use of electricity, heating and cooling from renewable energy sources and for district heating and cooling when planning, designing, building and renovating industrial or residential areas.

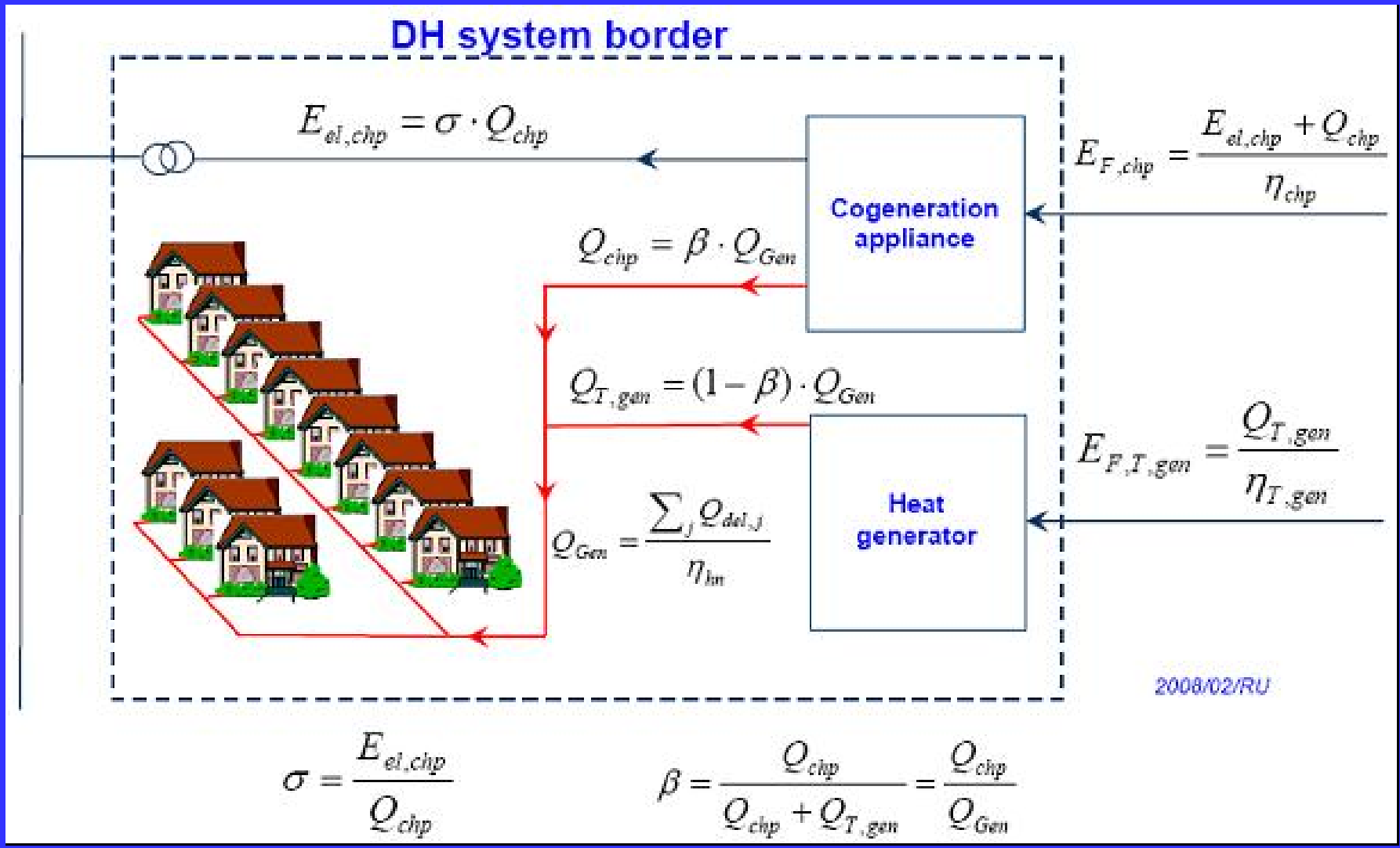
4.

Member States shall introduce in their building regulations and codes appropriate measures in order to increase the share of all kinds of energy from renewable sources in the building sector. In establishing such measures or in their regional support schemes, member States may take into account national measures relating to substantial increases in energy efficiency and relating to cogeneration and to passive, low or zero-energy buildings. ?

In the following some calculation examples based on **EN 15316-4-5:2007** are shown that should elucidate some aspects on **the future heating of buildings**

DH-system with CHP and additional heat generating system

(Somewhat like example A.3 in Annex A of EN 15316-4-5:2007)



Elaboration on example A.3 in Annex A of EN 15316- 4-5:2007:

The primary energy balance of the system in example A3:

$$f_{P,DH} \cdot \sum_j Q_{del,j} + f_{P,el} \cdot E_{el,chp} = f_{P,chp} \cdot E_{F,chp} + f_{P,T,gen} \cdot E_{F,T,gen}$$

Solving this equation for $f_{P,DH}$ and replacing all terms by the design data and the product efficiency characteristics, respectively, yields:

$$f_{P,DH} = \frac{(1+\sigma)\cdot\beta}{\eta_{hn}\cdot\eta_{chp}} \cdot f_{P,chp} + \frac{1-\beta}{\eta_{hn}\cdot\eta_{T,gen}} \cdot f_{P,T,gen} - \frac{\sigma\cdot\beta}{\eta_{hn}} \cdot f_{P,el}$$

Actual system data from example A.3 is shown below

A.3 Typical situation of a small heat and power cogeneration system

A small heat and power cogeneration system is planned to supply a new settlement of 100 one-family houses. The design heat load of the settlement is 500 kW and the base load is 50 kW. A gas engine shall be used for heat and power cogeneration. Its heat power is 50 kW, the electrical power is 40 kW and the fuel consumption is 115 kW. The cogeneration module can operate 6 000 hours per year determined from the frequency of the heat loads. The remaining heat is produced by gas fired heating boilers. The total heat energy requirement equals 1 400 hours full load operation per year. All efficiency values are based on net calorific values.

Efficiency of the cogeneration module:	$\eta_{chp} = (40 + 50) / 115 = 0{,}78$
Efficiency of the heating vessels:	$\eta_{T,gen} = 0{,}87$
Efficiency of the heating network:	$\eta_{hn} = 0{,}90$
Power to heat ratio of the cogeneration module:	$\sigma = 40 / 50 = 0{,}80$
Cogeneration heat to total heat ratio:	$\beta = (50 \cdot 6\,000) / (500 \cdot 1\,400) = 0{,}43$

Delivered heat to each house/apartment): $Q_{del,j}$ = 7000 kWh/house/year

Produced heat for each house: $Q_{gen,j}$ = 7000/0,90 = 7777 kWh/house/year

Heat loss from the district heating network: = 777 kWh/house/year

Applying "power bonus method" according to EN 15316-4-5 with primary energy supply by natural gas only: $f_{P,gas} = 1.36$

Equivalent primary energy factor ($PEF_T = PEF_R$) for the district heating system when produced electricity is replacing electricity from coal condensing plant:

$$f_{P,DH} = \frac{(1+0.80)\cdot 0.43}{0.90\cdot 0.78}\cdot \underline{1.36} + \frac{1-0.43}{0.90\cdot 0.87}\cdot \underline{1.36} - \frac{0.80\cdot 0.43}{0.90}\cdot \underline{4.05} \approx \underline{0.95}$$

Primary energy saving by CHP and DH:

(compared to local, individual gas heating)

$[(1.36 - 0.95)/(1.36)] \cdot 100 \sim \underline{30\ \%}$

Total CO_2 saving:

(compared to a coal condensing el plant and local, individual gas heating)

$\sim \underline{46\ \%}$

Quite favourable !

Question concerning district heating and "low energy houses:

What would be the lowest value of η_{hn} giving equal consumption of primary resource energy and CO_2 emission with PEF_{el} = 4.05 (el from coal condensing plant) **for the replaced electricity when assuming no change in the actual heat loss from the district heating system?**

$$f_{P,DH} = \frac{(1+0.80)\cdot 0.43}{\eta_{hn}\cdot 0.78}\cdot 1.36 + \frac{1-0.43}{\eta_{hn}\cdot 0.87}\cdot 1{,}36 - \frac{0.80\cdot 0.43}{\eta_{hn}}\cdot 4.05 = 1.36$$

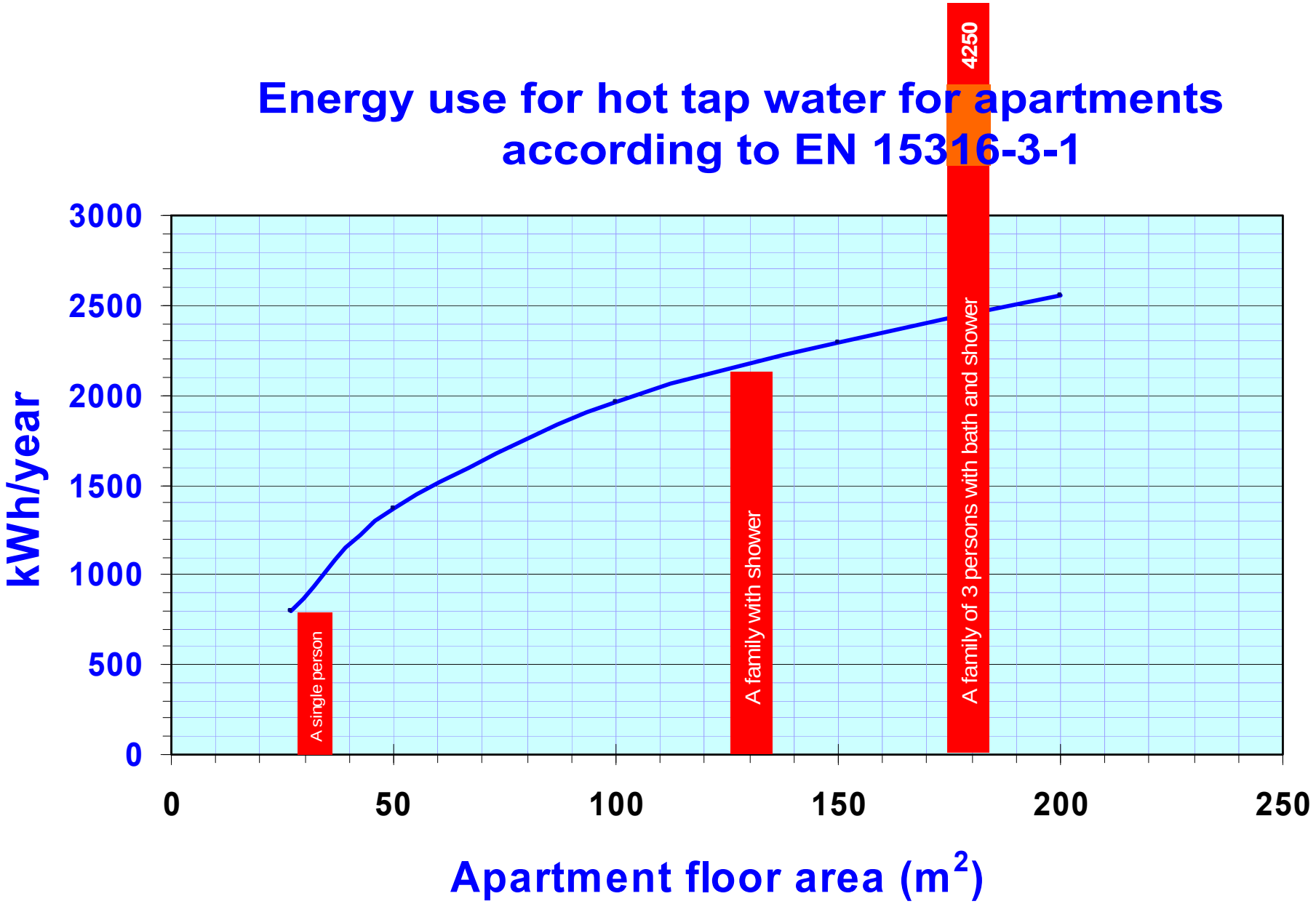
$0.92 \cdot \eta_{hn} = 0.92 + 0.60 - 0.95$ $\quad\quad$ $\eta_{hn} = 0.57 / 0.92 \sim \underline{0.76}$

The lowest amount of $Q_{del,j}$ (kWh/house/year) giving equal consumption of primary resource energy and CO_2 emission as by individual gas heating:

$Q_{gen,J} = (Q_{del,j} + 777) \bullet \eta_{hn}$ $\quad\quad$ $Q_{del,j} = (Q_{del,j} + 777) \bullet 0.76 \sim \underline{2460}$

Using the PEF value for Mix UCPTE: $\quad\quad$ $Q_{del,J} \sim \underline{3540}$

Energy use for hot tap water for apartments according to EN 15316-3-1



Applying "power bonus method" according to EN 15316-4-5 with primary energy from gas (CHP) and biomass for heat generation:

$f_{PR,bio} = 0.10$

Delivered heat from CHP: $Q_{del,j,gas}$ = 2730 kWh/house/year (39%)

Delivered heat from bio: $Q_{del,j,bio}$ = 4370 kWh/house/year (61%)

Equivalent primary energy factor (PEF_R) for the district heating system when the produced electricity is replacing el from coal condensing plant:

$$f_{PR,DH} = \frac{(1+0.80)\cdot 0.43}{0.90\cdot 0.78}\cdot 1.36 + \frac{1-0.43}{0.90\cdot 0.87}\cdot 1.36\cdot 0.39 + \frac{1-0.43}{0.90\cdot 0.85}\cdot 0.10\cdot 0.61 - \frac{0.80\cdot 0.43}{0.90}\cdot 4.05 \approx 0.39$$

Total CO_2 saving:

(compared to a coal condensing plant and local, individual gas heating)

~ 77 %

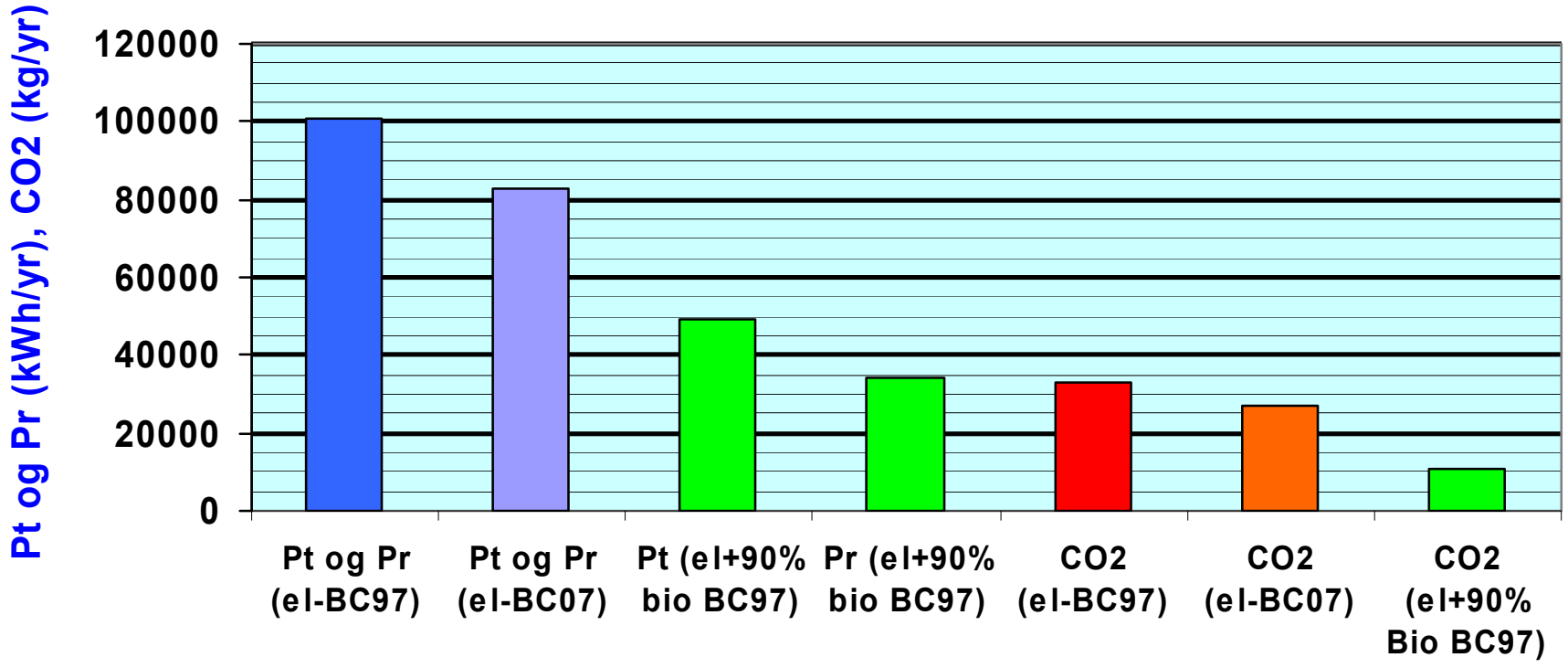
Equivalent primary energy factor (PEF_R) for the district heating system when the produced electricity is replacing el according to Mix UCPTE:

$$f_{PR,DH} = \frac{(1+0.80)\cdot 0.43}{0.90\cdot 0.78}\cdot 1.36 + \frac{1-0.43}{0.90\cdot 0.87}\cdot 1.36\cdot 0.39 + \frac{1-0.43}{0.90\cdot 0.85}\cdot 0.10\cdot 0.61 - \frac{0.80\cdot 0.43}{0.90}\cdot 3.31 \approx 0.67$$

What can we achieve by different attempts to reduce Primary energy use and CO_2 emission ?

Primary energy (Pt), Primary resource energy (Pr) and CO2-emission for a NEW one family house (2008) in Norway. Energy supply of 25 MWh/yr "Delivered energy". Ref: el heating and Building Code(BC97)

(Calculated from EN 15603:2007, NTNU, 081024/RU)



One of the research projects in IEA-DHC under Annex IX: "The potential for increased primary energy efficiency and reduced CO_2 emissions by DHC"

Suggestions of case studies in the project			
Case	**Energy source**	**Type of production**	**Sensitivity analysis included**
Ref	Oil	Heat only	
1	Biomass	CHP	yes
2	Biomass	Heat only	yes
3	Biomass	Power only	yes
4	Refuse	CHP	yes
5	Refuse	CHP with local absorption chillers	yes
6	Refuse	Heat only	yes
7	Refuse	Power only	yes
8	Natural gas	CHP	yes
9	Natural gas	Heat only	yes
10	Natural gas	Power only	yes

My conclusions:

(1) The use of Primary energy and CO_2 emission as the main indicators for the energy performance of buildings will be ”standard” throughout the world - because it make sense

(2) Bio fuel will be the great “winner” in the heating of buildings in the future

(3) District Heating – mostly in combination with CHP – will be built where this gives acceptable cost considered from a social economic point of view

(4) We will have a general increase in the prices of primary energy in the whole world that will increase the competitiveness of CHP in combination with District Heating

(5) A development as in (2) and (3) will be encouraged by legal framework and public support schemes on the background of the performance quality criteria in (1)

2008/10/RU

Some statements:

(1) CHP with District Heating is solving real problems in the real world!

(2) If you **really want to know** what happens when you replace the actual electricity consumption with electricity from a new CHP production plant you should use a marginal consideration!

(3) If you **do not really want to know** or can not really figure out what happens when you replace the actual electricity consumption with electricity from a new CHP production plant you should use an electricity mix consideration!

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Some statements:

(4) It seems to exist a lot of escapism in the whole world concerning important energy matters!

(5) The reality of the energy/climate situation in the world is - so far - only slowly creping into the minds of energy politicians!

The key question in the energy field:

What about the political will/possibilities to make the right decisions in due time?

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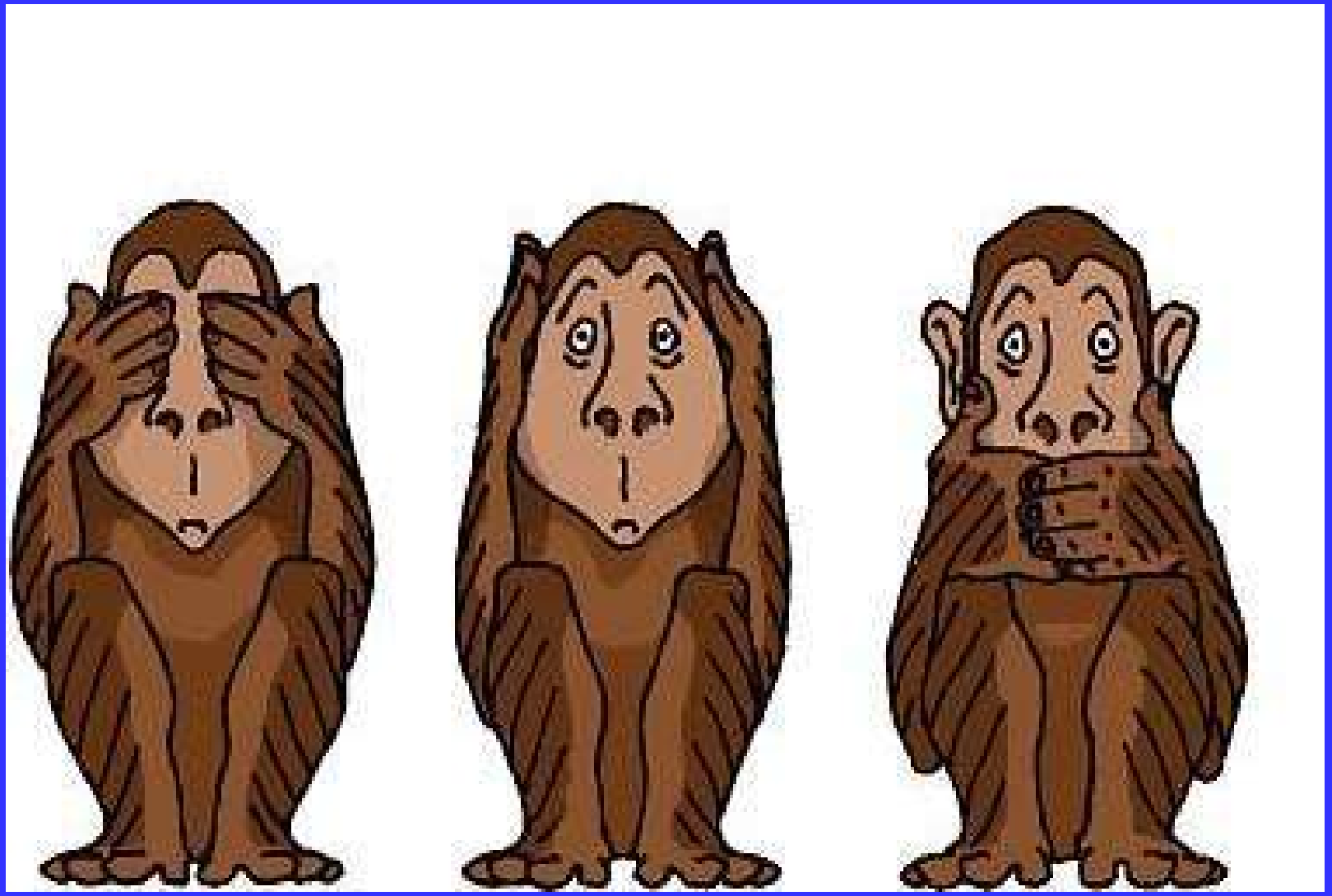

Thank You
for your attention !