SMART AND ZERO EMISSION BUILDINGS

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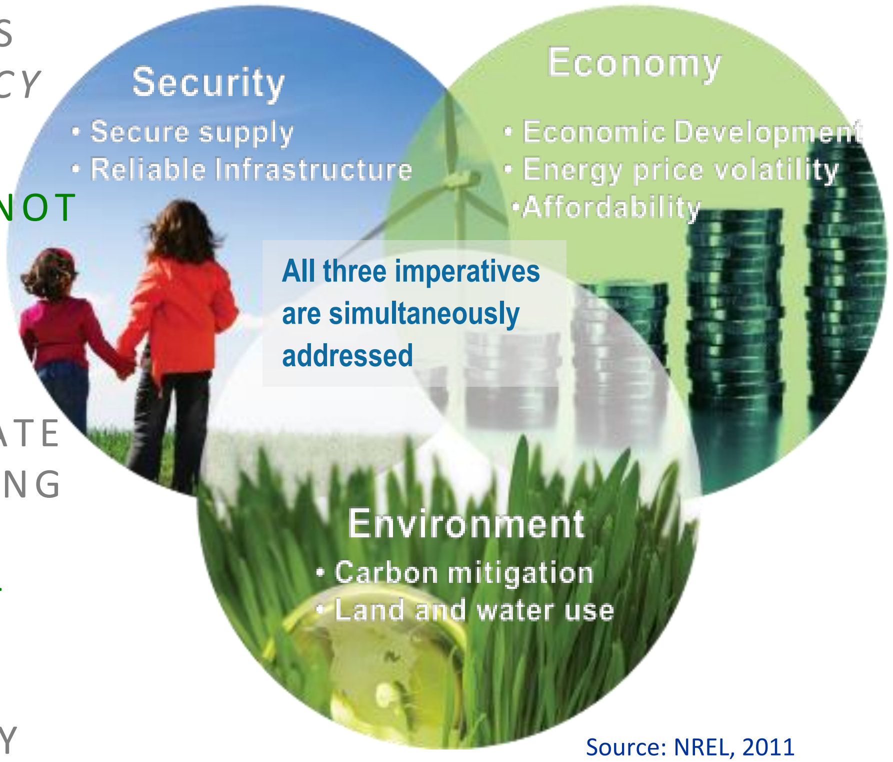
ACHIEVING A SUSTAINABLE ENERGY FUTURE IN BUILDINGS

ENERGY USE IN BUILDINGS WORLDWIDE ACCOUNTS FOR OVER 40% OF PRIMARY ENERGY USE AND 24% OF GREENHOUSE GAS EMISSIONS *(PROMOTING ENERGY EFFICIENCY INVESTMENTS, IEA, PARIS. 2008)*

SIMPLY **INCREASING ENERGY SUPPLY WILL NOT SOLVE** THE CURRENT ENERGY SUPPLY AND SECURITY SITUATION AND ASSOCIATED ENVIRONMENTAL PROBLEMS.

GIVEN THE CHALLENGES RELATED TO CLIMATE CHANGE AND RESOURCE SHORTAGES, MAKING RESIDENTIAL AND NON-RESIDENTIAL BUILDINGS **MORE ENERGY- AND RESOURCE-EFFICIENT WHILE MAINTAINING THERMAL COMFORT AND COST-EFFECTIVENESS** REPRESENTS AND ENORMOUS OPPORTUNITY TO SAVE MONEY AND REDUCE POLLUTION

RADICAL IMPROVEMENTS IN THE ENERGY PERFORMANCE AND USE OF RENEWABLES IN BUILDINGS ARE REQUIRED



Source: NREL, 2011

CONCLUSIONS RELATED TO BUILDINGS

NECESSARY TO REDUCE BUILDING ENERGY USE

- Heating by 50-60% in average for all buildings
- Heating by more than 75% in new buildings
- Electricity in households by 50% through development of more efficient products

FLEXIBLE DEMAND OF ELECTRICITY AND HEAT

- Intelligent electricity system
- Intelligent control of heat pumps in combination with heat storage

NEW BUILDINGS

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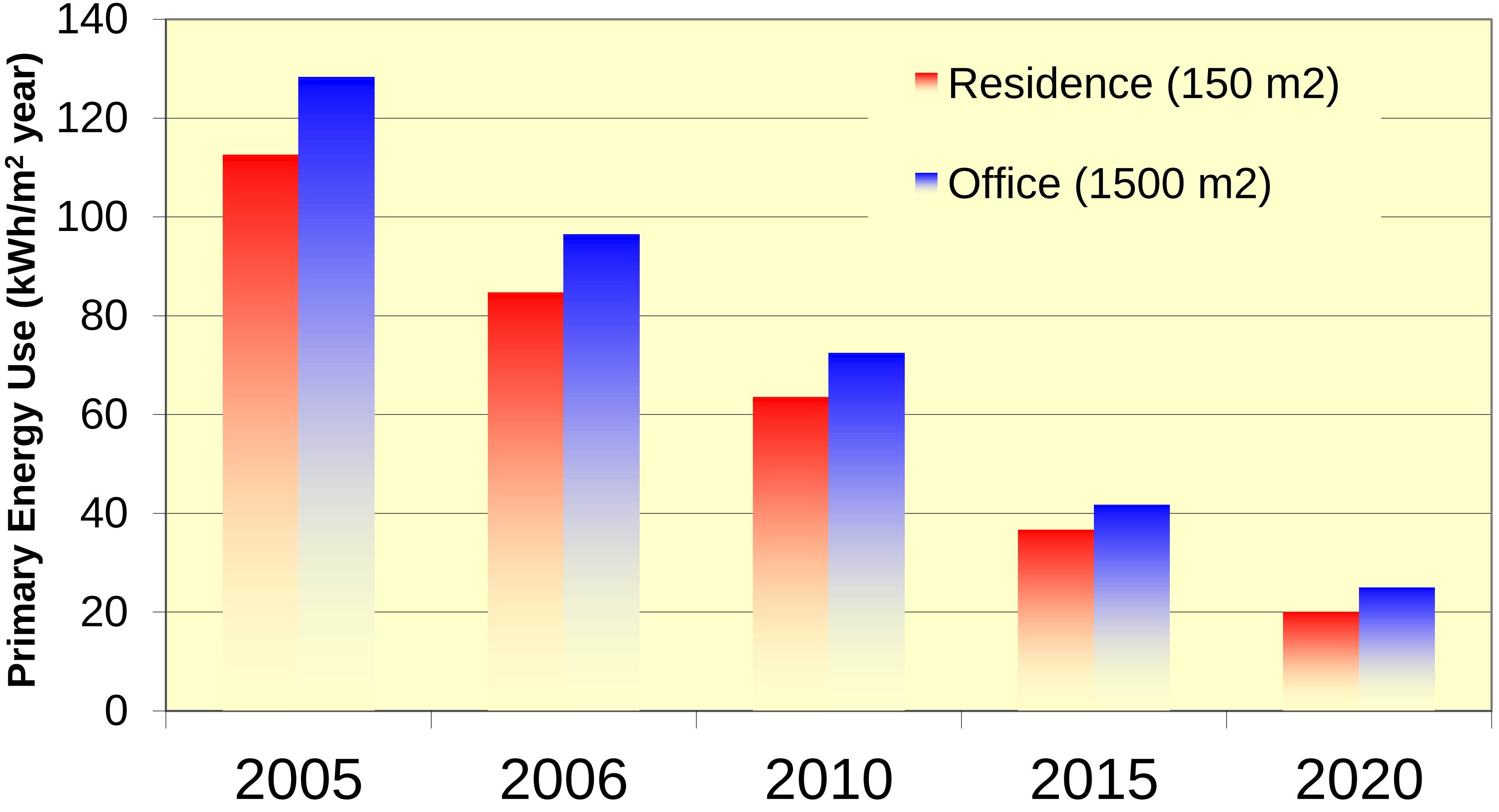
DEVELOPMENT IN MAXIMUM ENERGY USE IN NEW BUILDINGS IN DENMARK



WHAT DO WE HAVE TO DO?

REDUCE ENERGY NEEDS TO A MINIMUM (PASSIVE HOUSES ETC.).

USE CLEAN, RENEWABLE ENERGY TO COVER THE REMAINING NEED FOR THERMAL ENERGY (FOR HEATING AND COOLING).

USE RENEWABLE ENERGY TO COVER THE NEED FOR ELECTRICITY.

CONSIDER EMBODIED ENERGY AS WELL.

Source: Tor Helge Dokka, NTNU

WHAT DO WE GET ?

1. BUILDINGS WITH (VERY) LOW ENERGY USE
2. BUILDINGS, WHICH CONSUMES ENERGY AND GENERATES ENERGY FROM RENEWABLE SOURCES (”PROSUMING” BUILDINGS)
3. BUILDINGS, IN WHICH THE ANNUAL BALANCE BETWEEN CONSUMPTION AND GENERATION IS CLOSE TO ZERO (NEAR ZERO, NET ZERO OR PLUS)
4. BUILDINGS, WHICH IS CONNECTED TO ENERGY INFRASTRUCTURE AND INTERACT WITH IT

NEAR ZERO ENERGY BUILDINGS

NEW CHALLENGES/OPPORTUNITIES FOR THE BUILDING SECTOR

IDENTIFY AND PUSH THE OPTIMUM BALANCE BETWEEN ENERGY SAVINGS AND RENEWABLE ENERGY PRODUCTION - FOR BOTH NEW CONSTRUCTIONS AND EXISTING BUILDINGS

+BOLIGER

57°03´35´´N 9°54´49´´Ø

Fremtidens energineutrale etageboliger i Aalborg

TEAM+ appointed winner 28.09.09

Architects ARKITEMA,
Leif Hansen Consulting Engineers A/S,
Esbensen Consulting Engineers A/S,
FAKTOR 3 Aps,
DONG Energy,
Thornton Thomassetti,
Housing Organisation Ringgården,
BAU-HOW Denmark.

54321

PRIMARY ENERGY USE LEVELS OF NET ZEB

LEVEL 0 – BR20

$$\boxed{22\ \ kWh/m^2 year}$$

LEVEL 1 – BR15

$$\boxed{30 + \frac{1000}{A}\ kWh/m^2 year = 30.5\ kWh/m^2 year}$$

LEVEL 2 – BR10

$$\boxed{52.5 + \frac{1650}{A}\ kWh/m^2 year = 52.7\ kWh/m^2 year}$$

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RENEWABLE ENERGY SUPPLY OPTIONS

On-site RES

1. PV-HP:

   Photovoltaic installations and a ground source heat pump.
2. PV-MiCHP(biogas):

   Photovoltaic installations and a micro fuel cell biogas CHP.
3. PV-MiCHP(biomass):

   Photovoltaic installations and a micro Stirling biomass CHP.
4. PV-MiCHP(H_2):

   Photovoltaic installations and a micro fuel cell CHP fuelled with hydrogen.
5. PV-DH:

   Photovoltaic installations and connection to the district heating grid.

Off-site RES

1. WM-HP:

   Off-site windmill and a ground source heat pump.
2. SofW-HP:

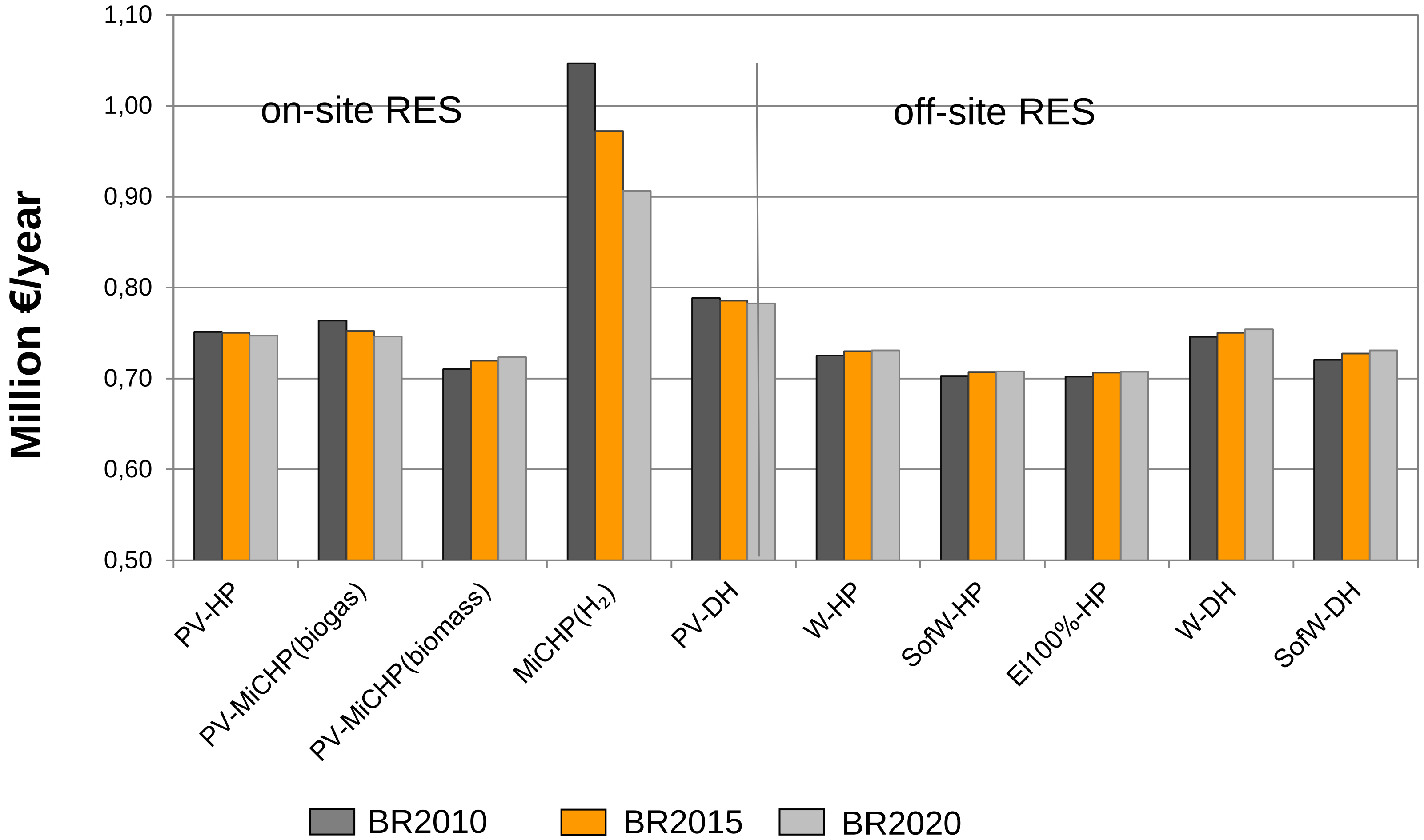
   Owning share of a windmill farm and a ground source heat pump.
3. El100%-HP:

   Building connected to power grid, which in 100% is supplied with renewable energy sources and a ground source heat pump.
4. W-DH:

   Off-site windmill and connection to the district heating grid.
5. SofW-DH:

   Owning share of a windmill farm and with connection to the district heating grid.

TOTAL ANNUAL COST OF NETZEB



Source: Marszal, A., Heiselberg, P., Jensen, R.L., Nørgaard, J.
Renewable Energy 44: p. 154-165, 2012.

FUTURE WORK ON ENERGY EFFICIENT BUILDINGS

PUSH THE LIMIT FOR ENERGY-EFFICIENCY IN BUILDINGS

- Future work will focus on development of adaptable and intelligent building solution that can adapt to the changing outdoor environment and occupant needs

DIMINISH THE GAB BETWEEN EXPECTED AND ACTUAL ENERGY USE

- Future work will focus on improving quality of construction and commissioning of buildings and systems
- Future work will investigate user practices and their understanding and interaction with building systems

EXISTING BUILDINGS

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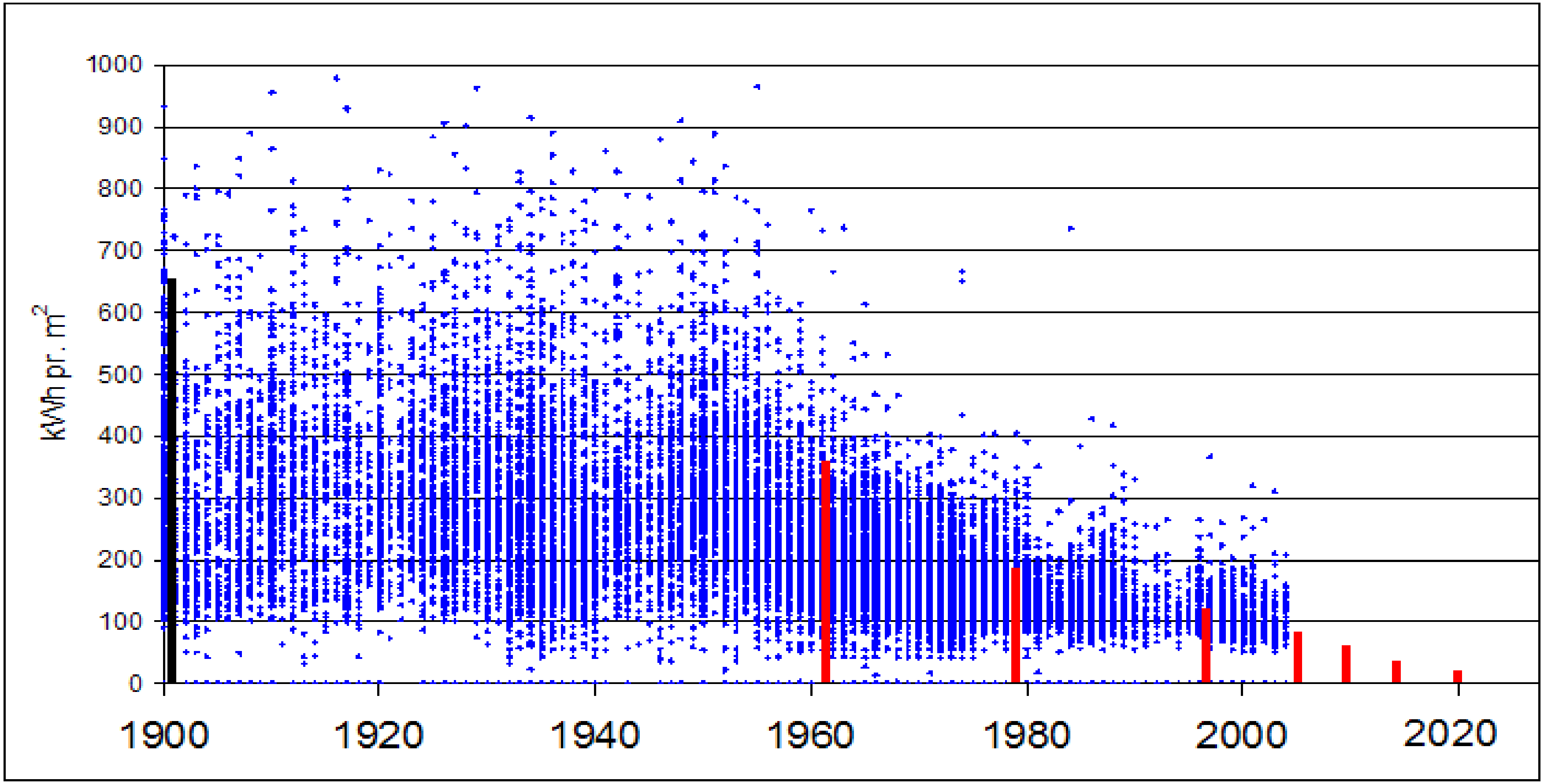
ENERGY USE IN DANISH SINGLE FAMILY HOUSES – BY YEAR OF CONSTRUCTION



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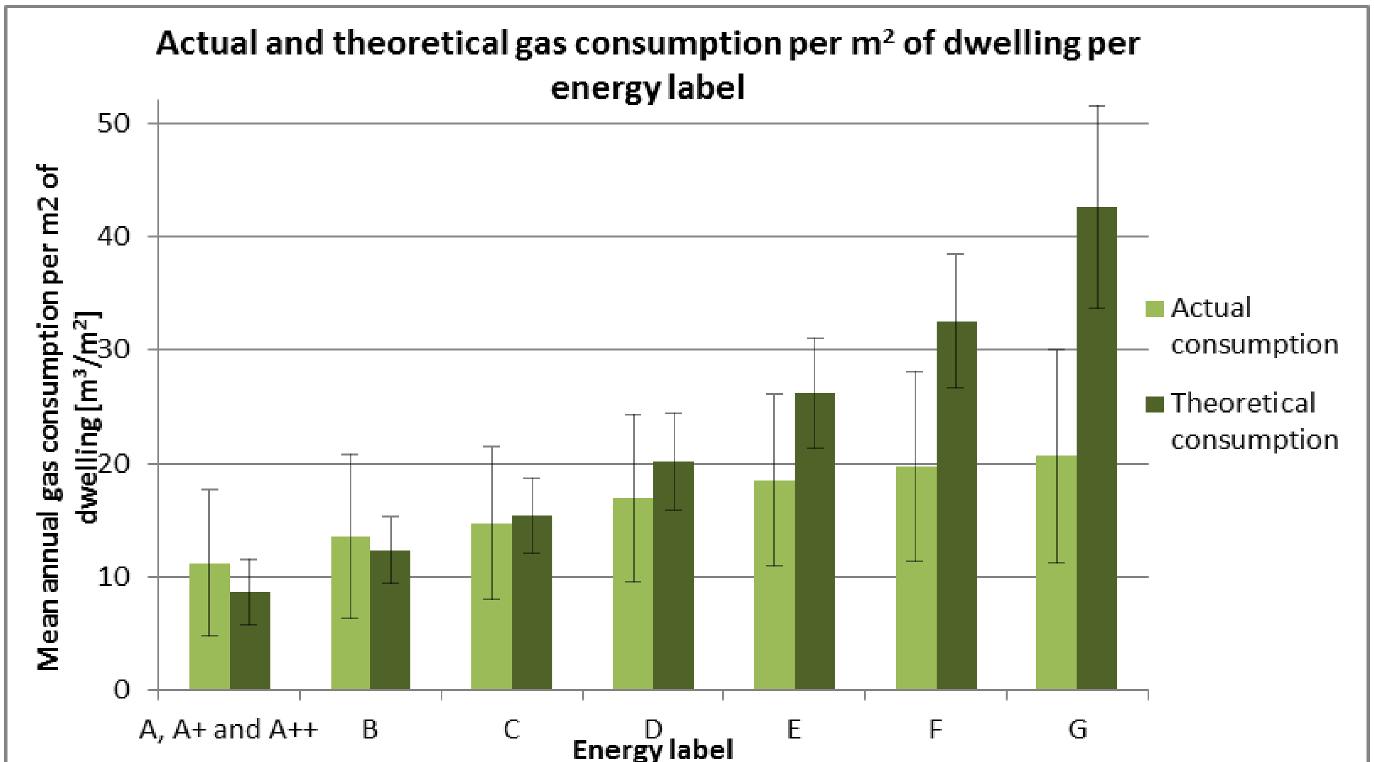
Kilde SBI/Erhvervs- og Byggestyrelsen

REAL ENERGY USE COMPARED TO EXPECTED – EXPERIENCES FROM THE NETHERLANDS

ENERGY PERFORMANCE CERTIFICATES AND ACTUAL ENERGY USE

- Data: National E-label data base (2010) + actual yearly energy use (2006, 2007, 2009) – 200.000 cases



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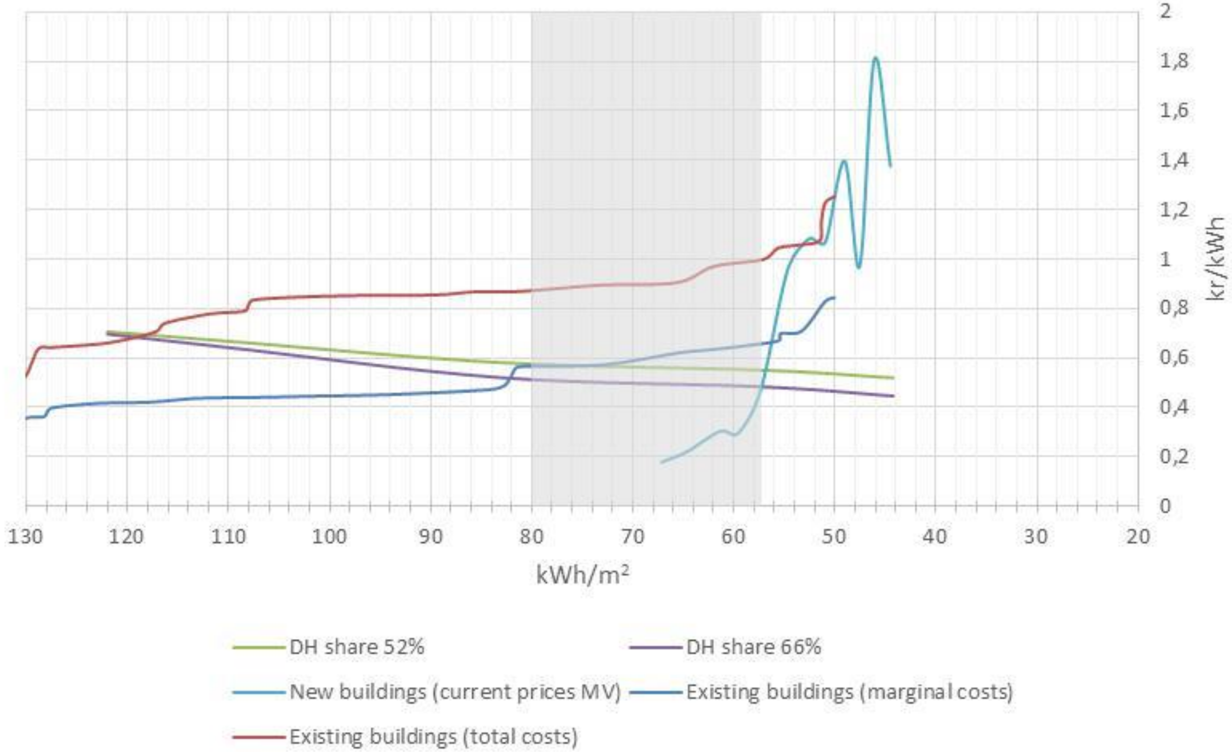
Ref.: Henk Visscher, TU Delft

DET SAMLEDE BILLEDE?



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strategisk forskningscenter for
ENERGINEUTRALT BYGGERI

SUMMARY – EXISTING BUILDINGS

THERE IS A LARGE GAB BETWEEN PREDICTED ENERGY SAVING POTENTIAL THROUGH "REASONABLE" TECHNICAL MEASURES (70-80%) AND COST EFFECTIVE MEASURES IN REALITY (20%- 30%)

EVEN IF RENOVATION IS COST EFFECTIVE (AS DEFINED BY BR10) THE PAY BACK TIME IS OFTEN TOO LONG AND A MAJOR BARRIER

THERE IS AN OPPORTUNITY FOR THE BUILDING SECTOR TO UN-LOCK THE SITUATION

IF BUILDING OWNERS CAN BE MOTIVATED:

- More focus on non-energy benefits

AND IF RENOVATION COST CAN BE REDUCED

- More industrial production (lower cost and higher quality)
- Development of larger buildings part (faster construction time)
- Integration of technical systems (avoid rehousing)

BUILDINGS AND THE ENERGY SYSTEM

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NEAR ZERO ENERGY BUILDINGS

NEW CHALLENGES/OPPORTUNITIES FOR THE BUILDING SECTOR

EVALUATE AND "DESIGN" THE INTERACTION BETWEEN THE ENERGY PRODUCING BUILDINGS AND THE ENERGY SUPPLY SYSTEM TO EXPLOIT THE BENEFITS OF BUILDINGS BEING AN INTEGRATED PART OF THE SYSTEM

THE “PROSUMING” BUILDING

Domestic hot water: 18,3 kWh/m2 year

Space heating: 15 kWh/m2 year

Electricity for operating the house: 6,7 kWh/m2year

Electricity for household 13,2 kWh/m2 year

PV electricity production: 29,1 kWh/m2 year

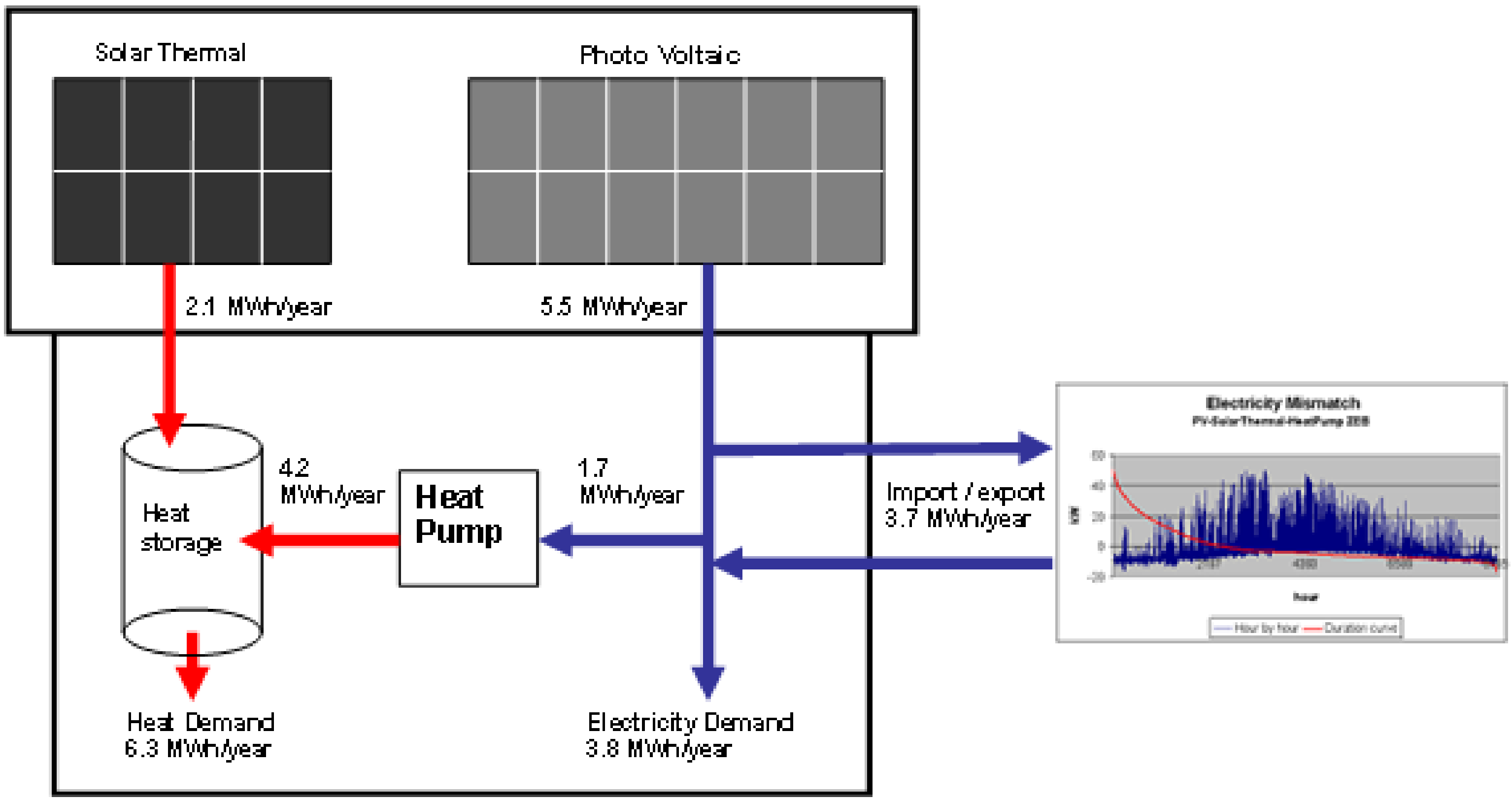
Solar thermal: 11 kWh/m2 year

Heat pump thermal output: 22,4 kWh/m2 year

Source: Ellen Katrine Hansen, VKR Holding

ENERGY IMPORT/EXPORT

PV-SolarThermal-HeatPump ZEB



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Source: Henrik Lund, AAU

INVESTIGATION OF IMPACT OF ENERGY STORAGE ON ENERGY DEMAND FLEXIBILITY

WHAT ARE THE ENERGY SYSTEM EFFECTS OF INDIVIDUAL HEAT PUMPS AND DIFFERENT HEAT STORAGE OPTIONS

- Ability to increase wind power utilization
- Ability to provide cost-effective fuel savings
- The fuel saving potential of flexible heat pump operation

TWO ALTERNATIVE HEAT STORAGE OPTIONS IS COMPARED

- Heat accumulation tanks
- Passive heat storage in the construction

LARGE SCALE IMPLEMENTATION OF HEAT PUMPS

- Existing buildings with oil boilers and electric heating in areas not covered by district heating.
- Only detached houses (90% of potential buildings)

Hedegaard, K., Mathiesen, B.V., Lund, H., Heiselberg, P..
Energy. Vol. 47, No. 1, pp 284-293, 2012

INVESTIGATED ENERGY STORAGE POSSIBILITIES

Scenario	Description
NOHP	No heat pumps in households.
HP-NOSTOR	Heat pumps installed in detached houses with oil boilers and/or electric heating without investment in heat accum. tanks or passive heat storage.
Tank300/500/1000	Inv. in 300/500/1000 litre heat accum. tanks in all houses where heat pumps are installed.[a]
PasLow	Inv. in passive heat storage assuming low end passive heat storage cap. (60 $Wh/K/m^2$)[a]
PasHigh	Inv. in passive heat storage assuming high end passive heat storage cap. (120 $Wh/K/m^2$)[a]
1C	Allowing an indoor air temp var. of $\mp 1\ ^\circ C$ when utilising passive heat storage
2C	Allowing an indoor air temp var. of $\mp 2\ ^\circ C$ when utilising passive heat storage

[a] Heat pump installation as in HP-NOSTOR.

Hedegaard, K., Mathiesen, B.V., Lund, H., Heiselberg, P..
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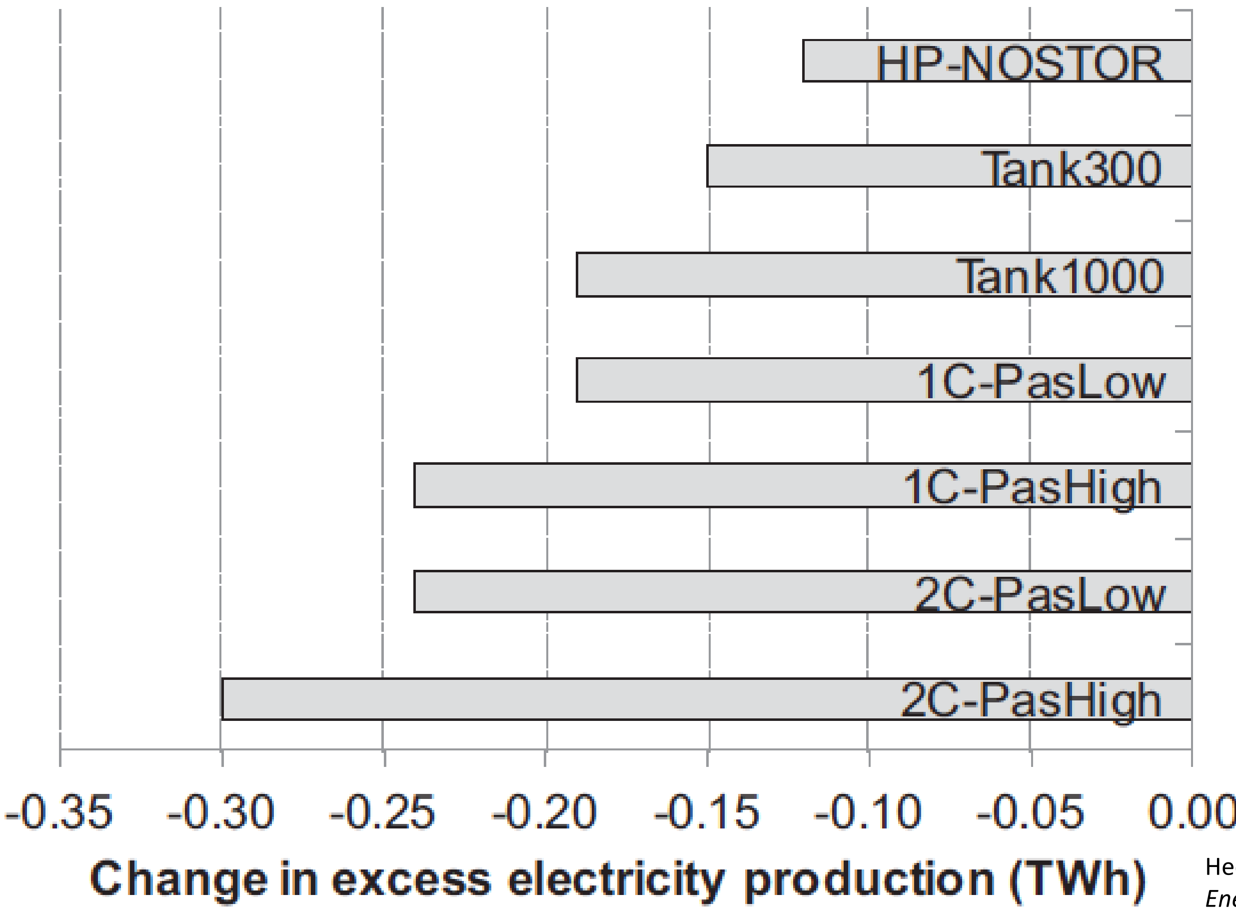
CHANGE IN EXCESS ELECTRICITY PRODUCTION



8 %

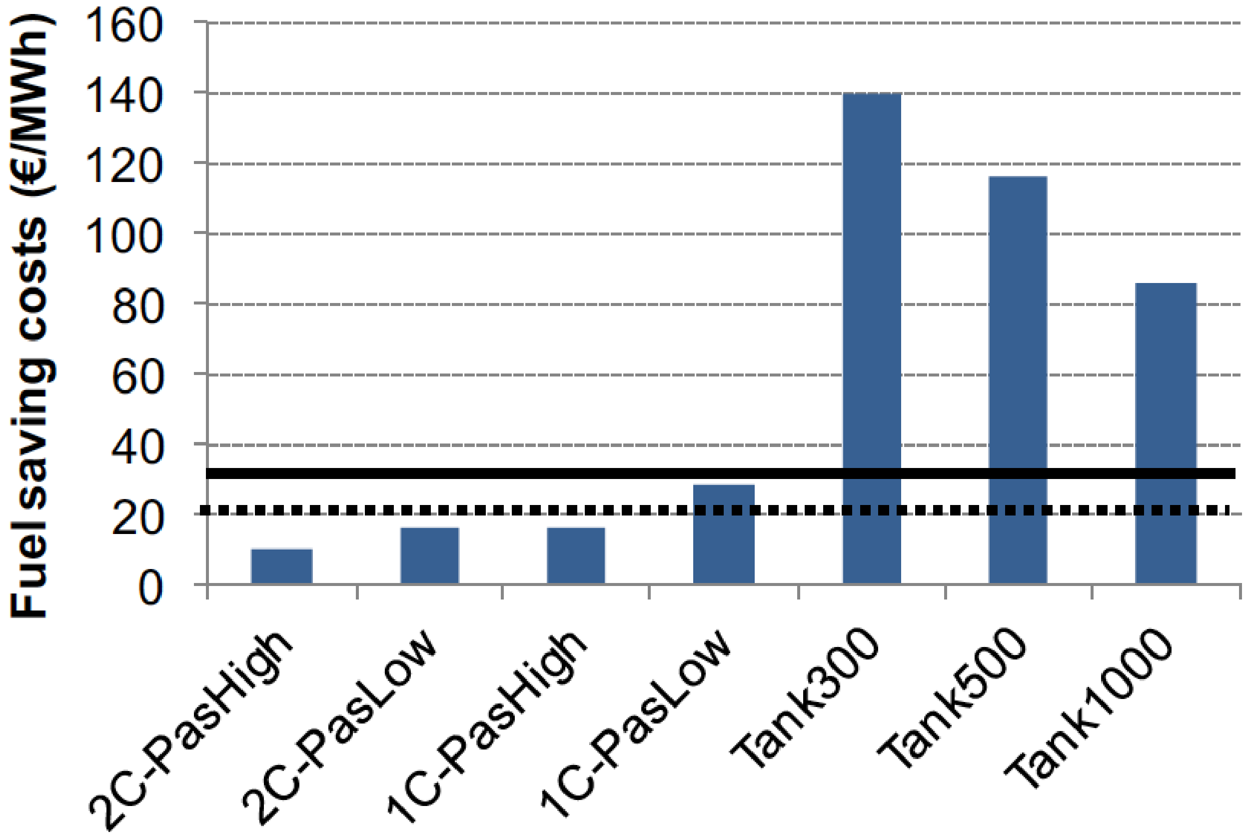
12 %

19 %

Hedegaard, K., Mathiesen, B.V., Lund, H., Heiselberg, P..
Energy. Vol. 47, No. 1, pp 284-293, 2012

AVERAGE ANNUALISED COSTS PER FUEL SAVED FOR DIFFERENT HEAT PUMP STORAGE OPTIONS

For comparison, the expected coal price, 20 €/MWh (dashed line) and natural gas
price, 33 €/MWh (black line) in 2020, including CO2 costs and fuel and handling costs,
is indicated



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FUTURE WORK ON ENERGY FLEXIBLE BUILDINGS

ASSUMPTIONS REGARDING PASSIVE ENERGY STORAGE IN THE CONSTRUCTION WERE SIMPLIFIED (AND WE THINK CONSERVATIVE)

- Future work will investigate the passive storage potential (capacity and speed of charging/discharging) in more detail

IN THE PRESENT WORK ONLY A SMALL PART OF THE STORAGE CAPACITY OF THE CONSTRUCTION IS ACTIVE

- Future work will look into measures and technologies to enhance the storage effectiveness
- Further work will look into the influence on building and HVAC design and how to include "flexibility" into design optimization

IN THE PRESENT WORK IT IS ASSUMED THAT OCCUPANTS WILL ACCEPT VARIATIONS OF THE OPERATIVE TEMPERATURE WITHIN THE STANDARD COMFORT CATEGORIES

- Future work will look into occupant acceptability of variations in setpoint temperature

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Thanks for your attention