Net Zero Energy House with Direct Electric Heating

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About me:

- Klaus Lund Nielsen
- Danfoss in Denmark
- Technology & Application Manager
  in the Heating Solutions Division
- DEVI is our brand for Electrical Heating products

Introduction to the project

- Electrical heating was banned in DK – 2006 allowed again
- 2002 Energy Performance of Buildings directive
  - New calculation methodology – Building may use a certain amount of energy
  - Primary energy factor 2.5 for electricity
  - Take into account - energy from renewable sources produced on-site.
- New houses require less and less energy for heating
- Solar power systems become cheaper and cheaper
- Grid-connected PV <= 6 kW: Seasonal energy storage in the power grid
- At some point:
  The power produced = heating requirement => nZEH
- *Zero Energy House*: The house produces (export) as much energy as it consumes (imports) for space heating and DHW.
- *Net*: The house uses the electrical power grid for seasonal energy storage to balance export and import of electricity over a yearly period.

Purpose and Objectives

- Project started up in 2010

- The purpose:
  Demonstrate that it is possible to build nZEH with electrical floor heating combined with PV solar power system and to investigate the financial attractiveness of the nZEH.

- Objectives:

  1. Find a suitable low energy house.
     Convert it into a nZEH with electrical Floor heating and PV system.
     Build it.
     Monitor energy production/consumption.
  2. Investigate and compare the initial investment and 30 years global cost of these two houses (the nZEH and the original low energy house).

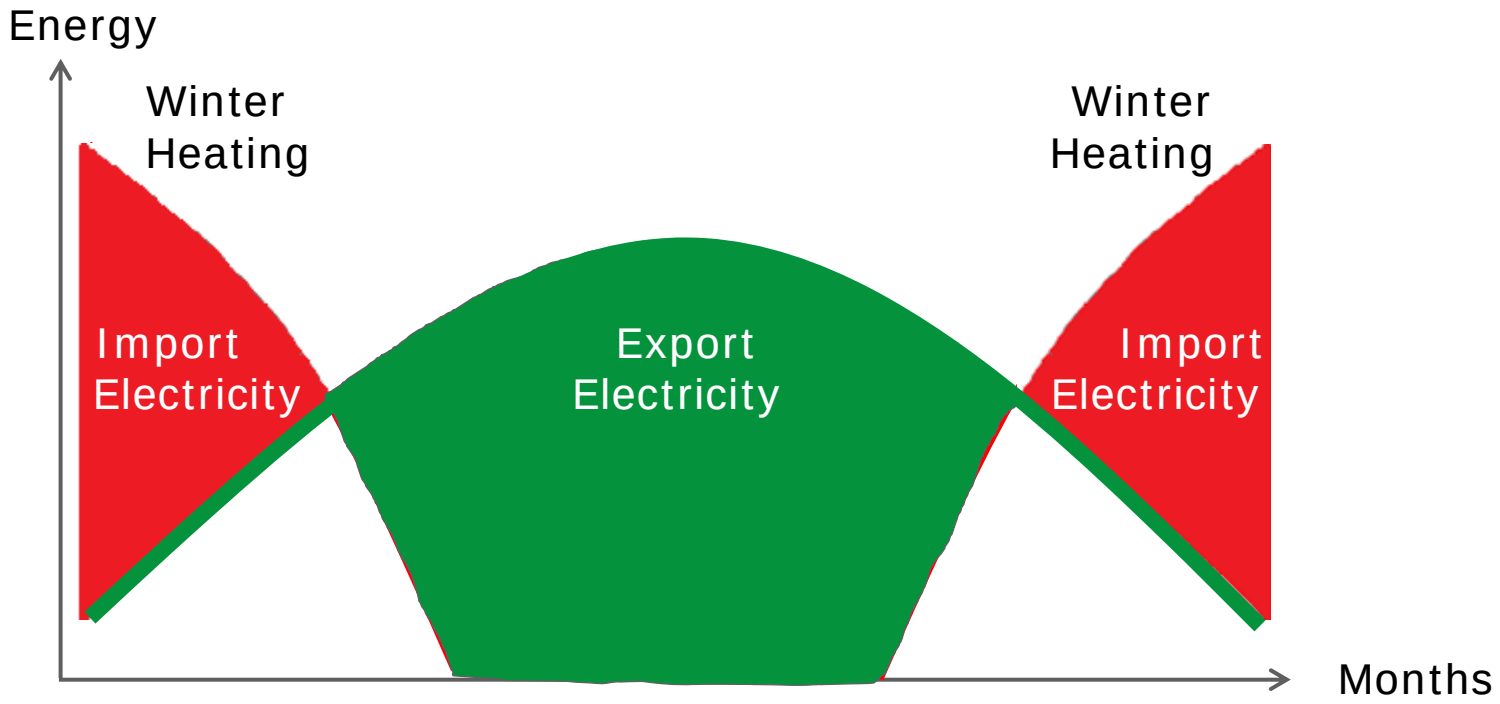
The Method

- Theoretical Energy Performance
  - Verified with official calculation tool Be10 (20° C)
  - BE10 calculates annual energy demand in primary energy
  - BE10 takes into account the contribution from local solar power/heat system.
  - Be10 with 22° C was used to estimate of energy consumption in practice.
- Financial analysis
  - EN 15459:2007 Economic evaluation of energy systems in buildings
  - 30 years energy costs (initial cost, annual costs and final value, present value)
  - Initial investment
- Empirical work
  - Find a buyer and build the nZEH
  - Do monthly readings: PV power production, space heating, DHW
  - Log energy consumption/production for 2 years. (12 months so far)

The Team

- House Building Company: Skovbo Danmark A/S
  - Sold the house
  - Built the house
- Solar power system: Gia Solar A/S (ZETECO ENERGY A/S)
  - Supplied the PV system and (Danfoss) inverter
  - Installed the complete system
- Danfoss
  - Supplied electrical floor heating, heat recovery unit and solar inverter.
  - Did the formal energy performance calculations.
  - Calculated/estimated the expected energy consumption in practice.
  - Do the monitoring of energy consumption.

How to achieve ”Zero Energy” in this project:



- Exported energy (green) >= Imported energy (red): Zero Energy house
- Price energy exported = Price energy imported: Zero energy cost

What we did:

In the theoretical part:

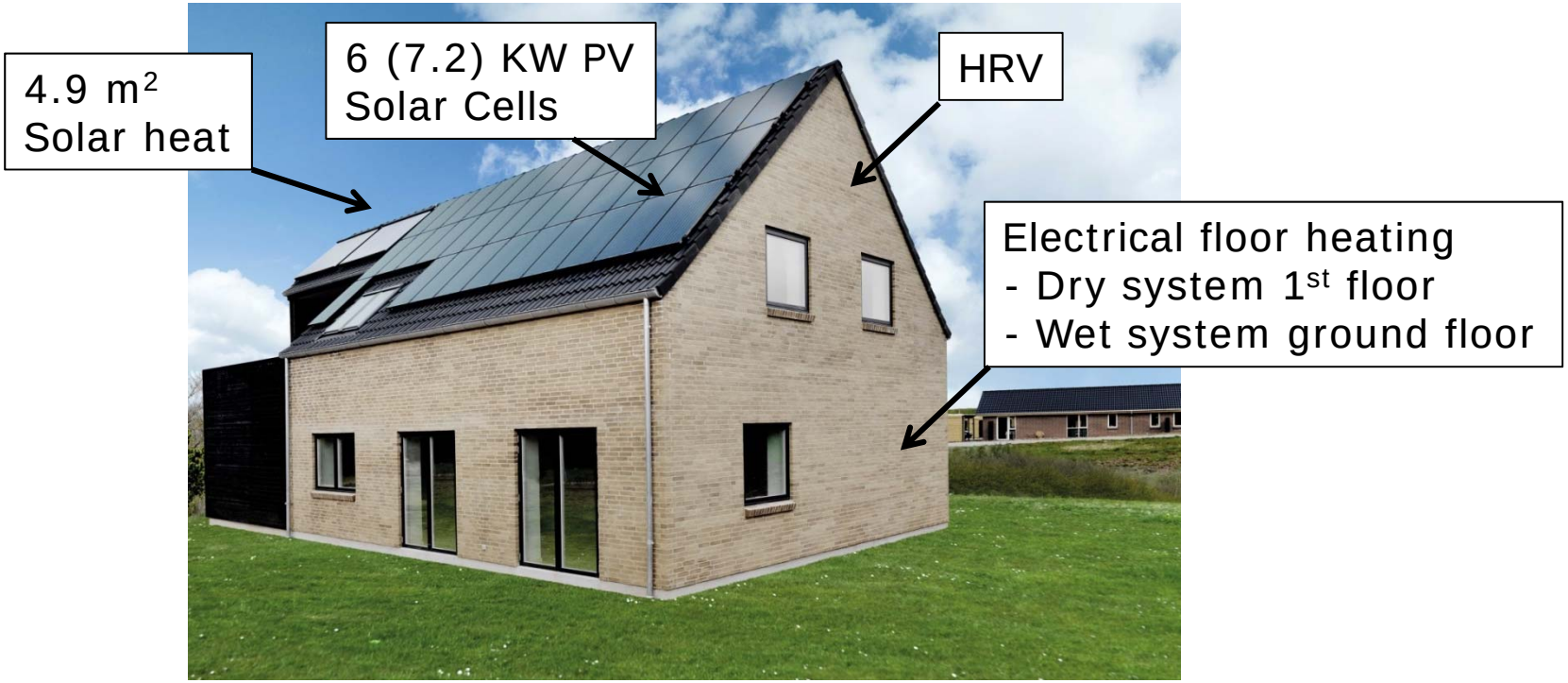
- Low energy house: 31.1 kWh/m^2
  - With HP and water based FH and Heat Recovery Ventilation
- Replaced heat pump with Electrical floor heating
- + 6 kW solar cells
- + 4.93 m^2 solar heat for DHW
  - Primary Energy Demand: -5.0 kWh/m^2 @ 20° C => “Energy+house”
- Estimated energy consumption: @ 22° C
  - Estimated primary energy demand: 7.5 kWh/m2 @ 22° C
  - 588 kWh per year for 196 m^2

In practice:

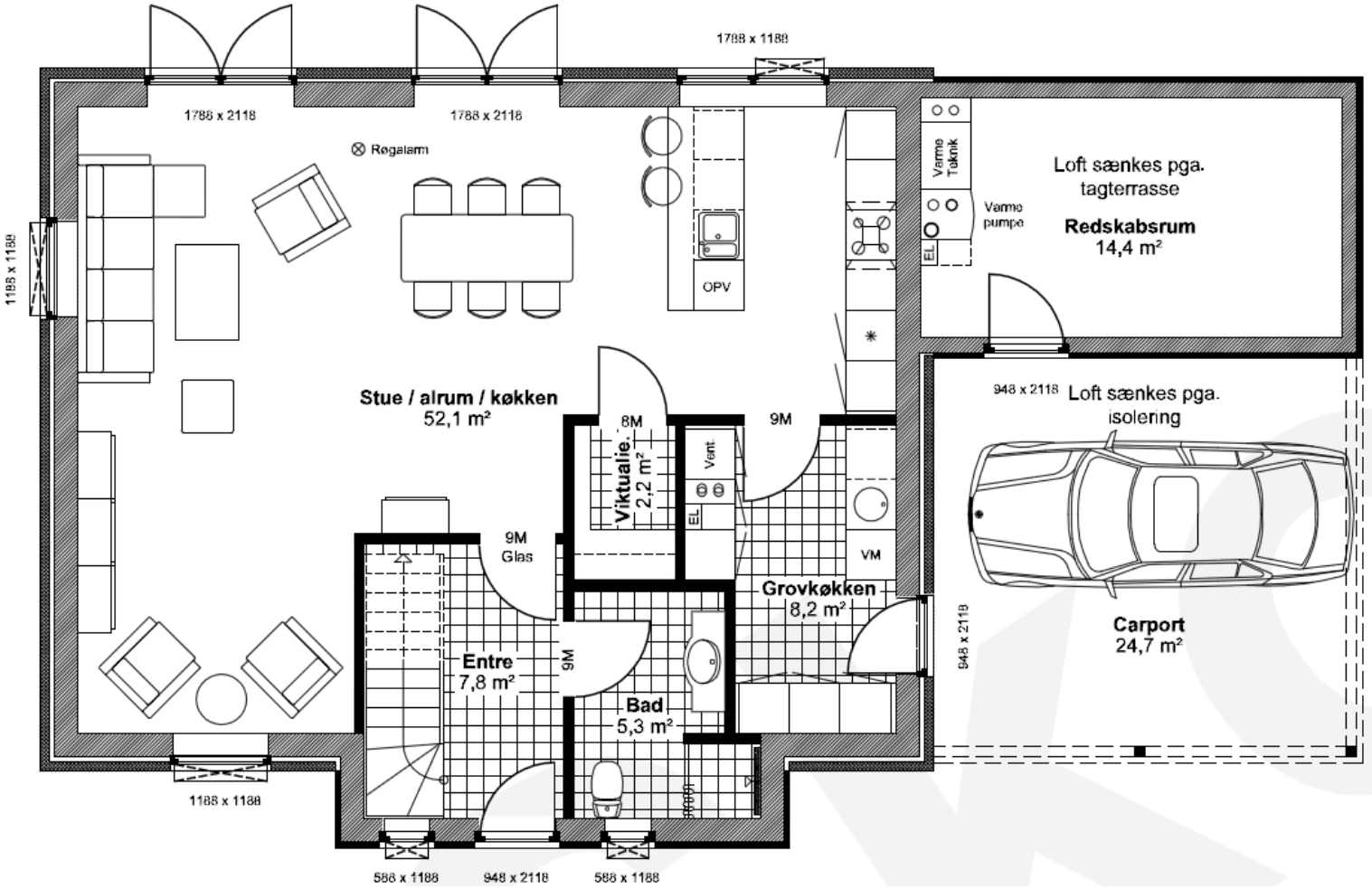
- + 7.2 kW solar cells
- + 7 m^2 bigger house

The House: 203 m²

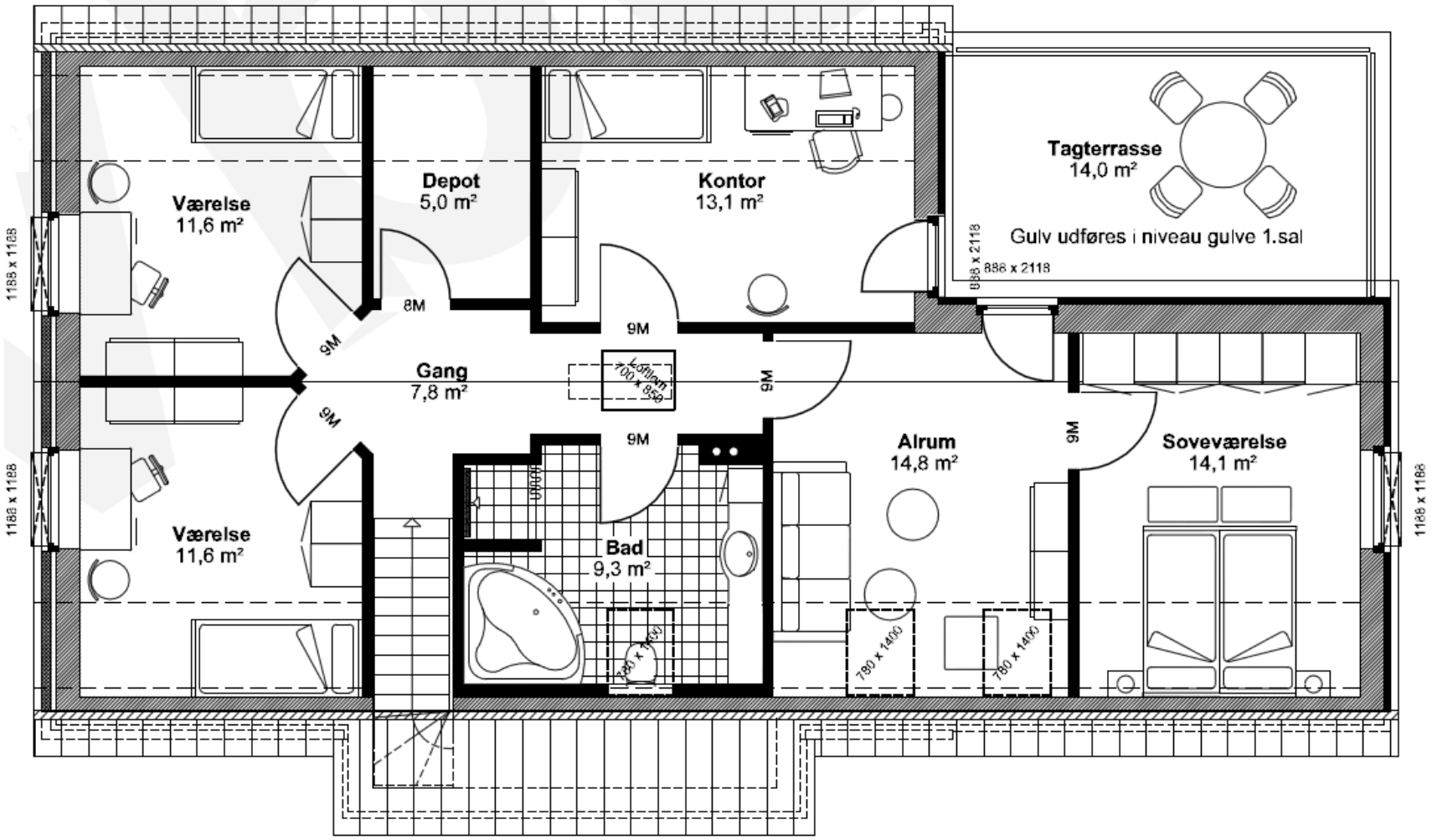
- Structural wood-frame inner wall, brick siding outer wall.



The House: 203 m²



The House : 203 m²



The House

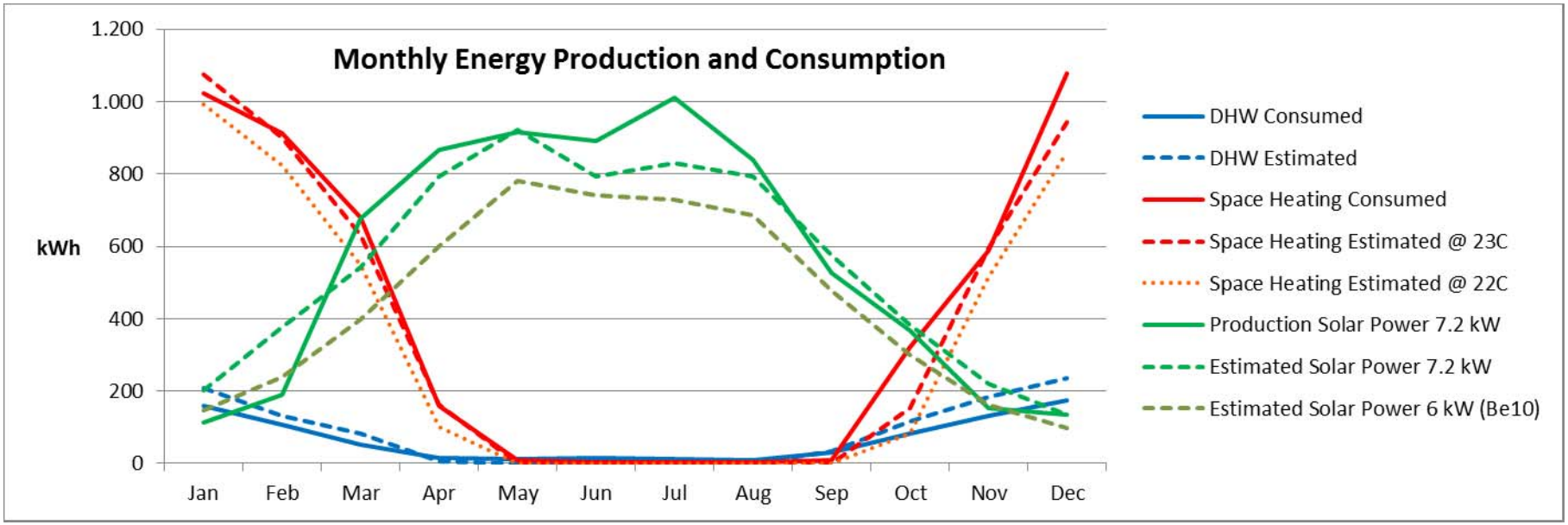
- U-values

Building part	W / m²K
Outer wall (wall facing utility room)	0.13 (0.15)
Ceiling (sloped ceiling)	0.08 (0.15)
Ground deck	0.09
Windows (roof windows)	0.83 (1.00)
Outer doors (Terrace doors)	1.14 (1.16)

- Thermal Bridges

Building part	W / mK
Foundation	0.1

Emperical Findings:



- 7.2 kW PV system produces 25% more than calculated with 6 kW
- Energy for space heating is 14% higher than expected (= calc @ 23C)
  Wrong heat capacity of house, extra 7 m^2, less internal gains.
- Domestic Hot Water is 21% lower than expected
  In Be10 DHW is proportional to m^2 but here small family in big house.

Emperical Findings :

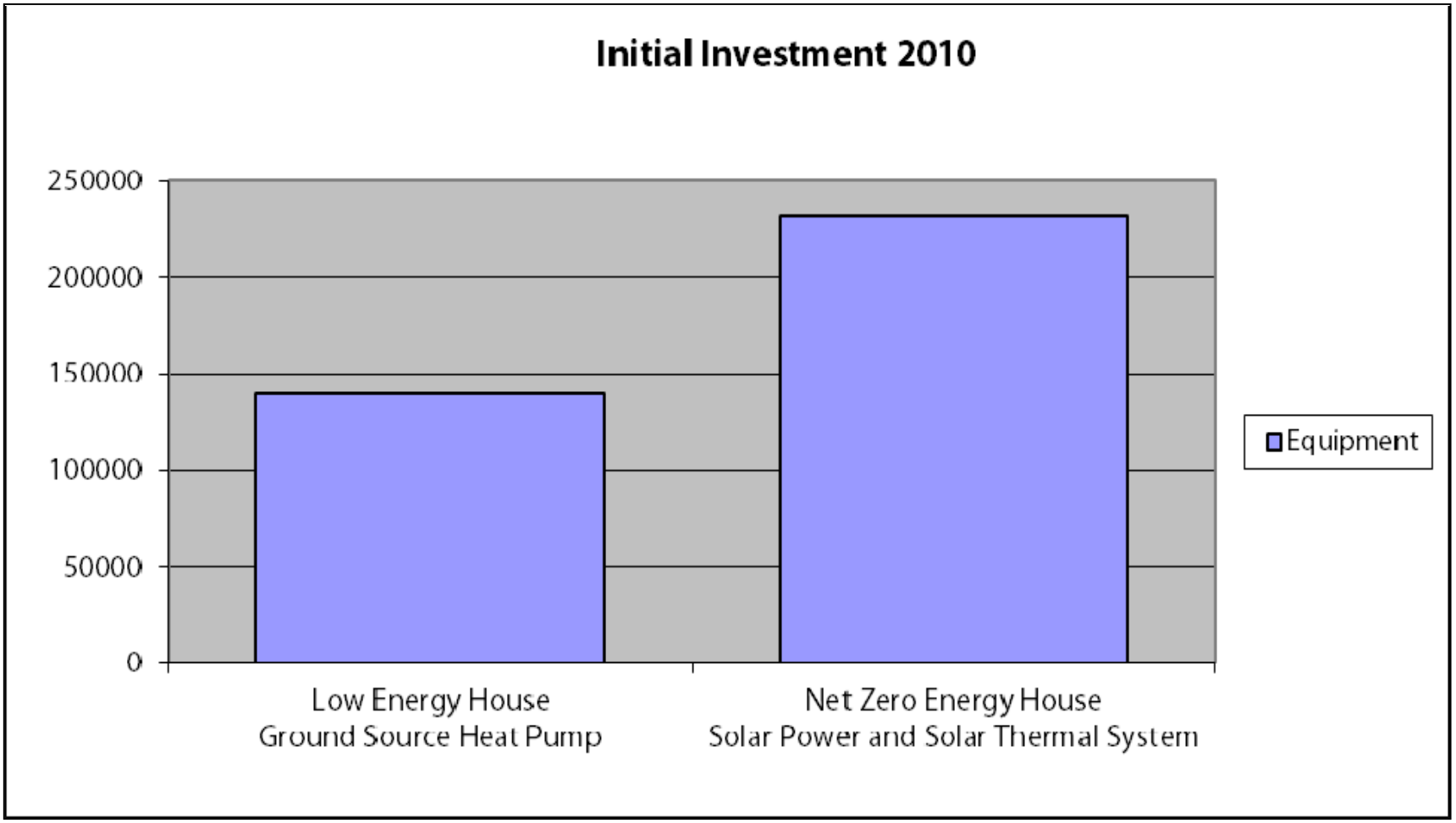
- Annual solar power production: 6,686 kWh
- Annual space heating: 4,789 kWh
- Annual domestic hot water: 793 kWh
- Result: surplus energy (20%) 1.104 kWh

Financial Attractiveness: 6kW PV @ 22° C

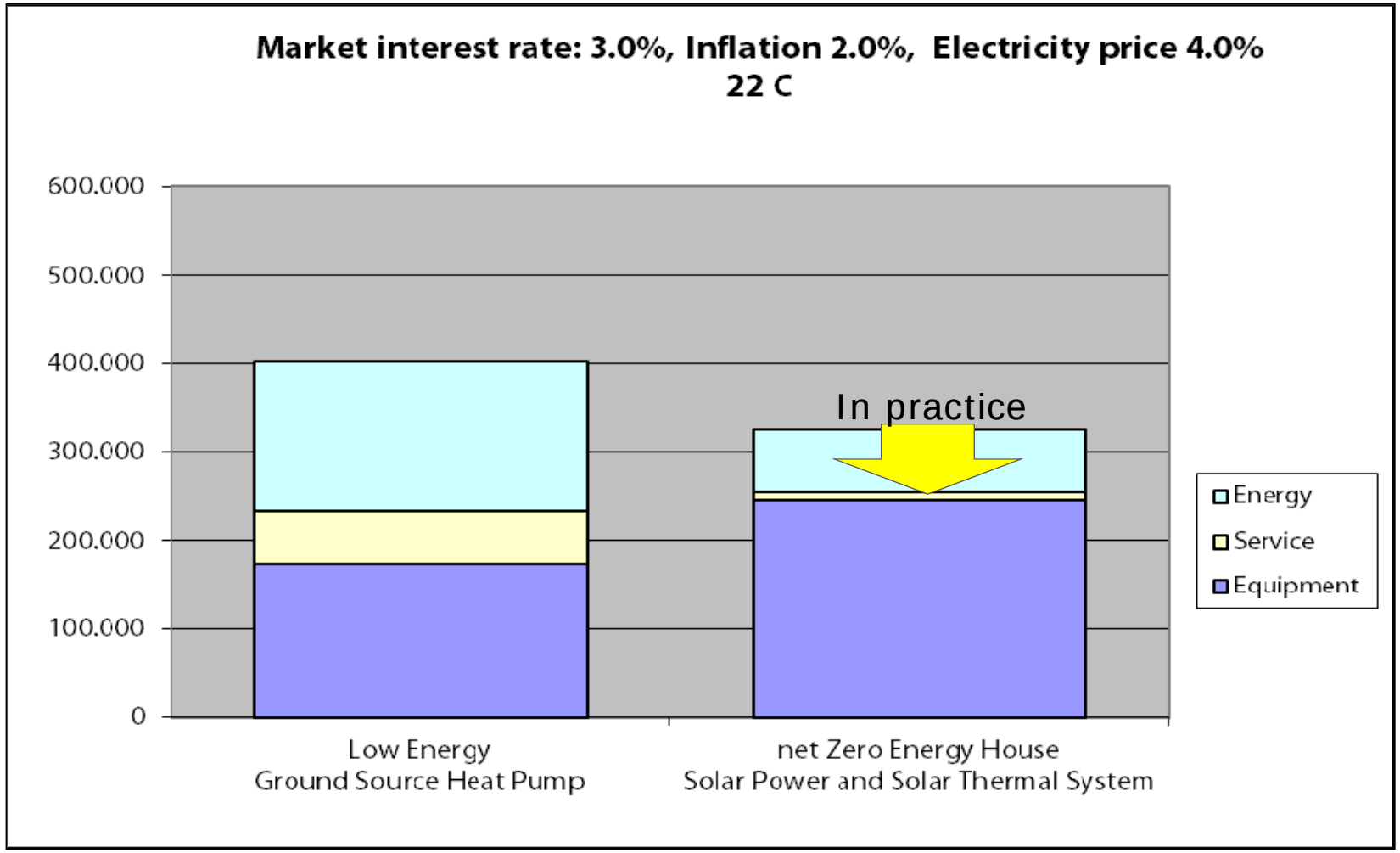
- Only difference between the original Low Energy House and nZEH
  - Heat pump and water based heating system in LE House is replaced by Solar power system, solar heat system and electric floor heating Syst.

- To determine financial attractiveness, thus only mentioned equipment is taking into account.
  - Initial Investment
  - 30 years global cost (initial cost, annual costs and final value, present value)

Financial Attractiveness: 6kW PV @ 22° C



Financial Attractiveness: 6kW PV @ 22° C



Financial Attractiveness :

- In Denmark the possibility to “store” energy in the grid in a financial attractive way have recently been closed.

- New grid-connected PV systems need to balance within one hour.
  Surplus energy need to be sold at low price during summertime.
  In wintertime electricity need to be bought back at high price.

- My financial calculations does therefore not apply for new systems in DK.
  Here attractiveness also depends on electricity consumption apart from heating and must be calculated on an hourly basis.

- People are still interested in and buying this concept.

Conclusion:

- It is possible to built nZEH with electric FH and Solar Power
  - Result: 1.104 kWh surplus energy (20%)

- Financial attractiveness
  - Initial Investment: 90,000 DKR (12,000 EUR) more expensive
  - 30 years global cost: 75,000 DKR (10.000 EUR) cheaper
- Financial attractiveness depends on:
  - Possibility to “store” energy in the grid in a financial attractive way.
  - Whether owners focus on initial investment or long term investment
  - Price development of electricity
  - Price development of solar power systems

Discussion:

- The EPBD defines:
  Nearly zero-energy building as buildings with very high energy performance.
  The nearly-zero amount of energy should be covered by energy from renewable sources, including energy from renewable sources produced on-site.
- In this project we have demonstrated that a house can easily produce more renewable energy on-site than it need for heating on an annual basis with well-known technologies that people trust and is ready to buy.
- Easy reach zero energy balance but difficult to make it financial attractive.
- Because the heat demand and renewable energy production are seldom synchronised and therefore require storage and balancing.
- Bring down heat/cooling demand vs Renewable energy production on-site
  - Overheating problems
  - insufficient heating capacity
  - Storage
  - Balancing
  - Price (import, export)
- What is the optimum mix?
  Do “we” focus to much on insulation and to little on renewable energy?