Centre for Environment-friendly Energy Research (CEER/FME)
Zero Emission Buildings (ZEB)

WP 3 - Energy supply systems and building services systems

Grønn Byggallianse

Månedens tema

Energiforsyninger som gir passivhusnivå – Hvordan velge riktig lokal energiforsyning?

Oslo, 29.08.2012

FME-ZEB: Zero Emission Buildings

A national research centre that will put Norway in the forefront with respect to research, innovation, and implementation within the field of energy efficient Zero Emission Buildings.

FME-ZEB: Zero Emission Buildings

In February 2009, the Research Council of Norway assigned The Faculty of Architecture and Fine Art at NTNU to host one of eight new national Centres for Environment-friendly Energy Research (FME): Zero Emission Buildings (ZEB).

Duration: 2009 – 2016
Budget: approximately 38 mill Euro (300 mill NOK)

The ZEB research activities

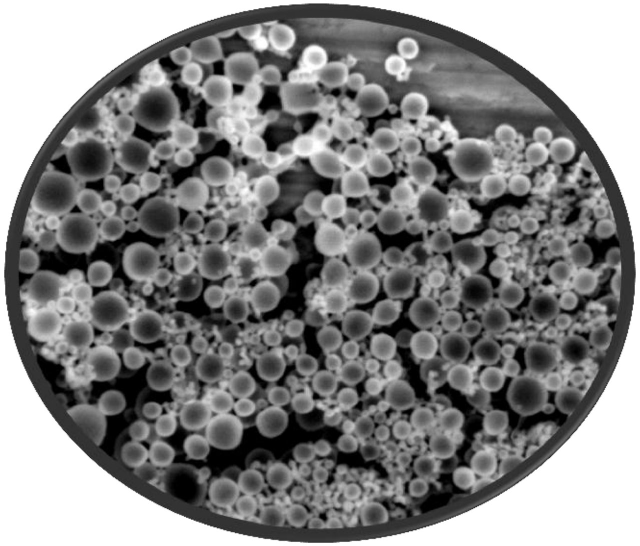
ZEB focuses its work in five areas that interact and influence each other:

- **WP-1: Advanced materials technologies**
- **WP-2: Climate-adapted low-energy envelope technologies**
- **WP-3: Energy supply systems and services**
- **WP-4: Use, operation, and implementation**
- **WP-5: Concepts and strategies**

WP1 - Advanced material technologies

Main goal:

Development of new and innovative materials and solutions, as well as improvements of the current state-of-the-art technologies



Subtasks:

- 1.1: New concepts
- 1.2: Opaque and transparent solutions
- 1.3: Controllable materials and solutions
- 1.4: Energy storage solutions
- 1.5: Energy converting materials and solutions

WP2 – Climate adapted, low energy envelope technologies

Main goal:

Develop climate adapted, verified, and cost effective solutions for new and existing building envelopes (roofs, walls and floors) that will give the least possible heat loss and at the same time a reduced need for cooling.

Marché International. Photo: A.G.Lien

Subtasks:

- **2.1: Optimal thermal performance**
- **2.2: Integration of active elements in the building envelope**
- **2.3: Daylight and solar shading systems**
- **2.4: Development of windows and glazing systems**

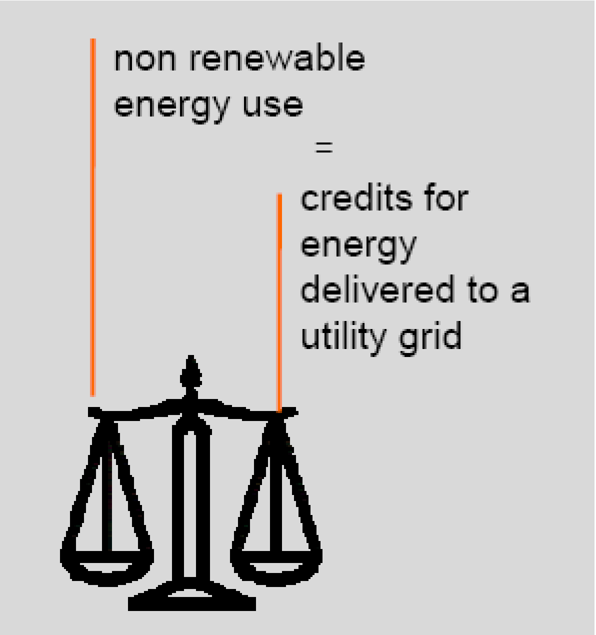
WP3 - Energy Supply Systems and Services

Main goal:

Develop new solutions for energy supply systems and building services systems with reasonable energy and indoor environment performance appropriate for zero emission buildings.

Subtasks:

- **3.1: Available technologies for renewable energy**
- **3.2: Interaction between user needs, energy supply, and building services**
- **3.3: Integration of technologies and solutions**
- **3.4: High performance building services**
- **3.5: Test and pilot buildings - Follow up**



Source: University Wuppertal, School of Architecture, Building Physics and Technical Building Services.
Prof. Karsten Voss

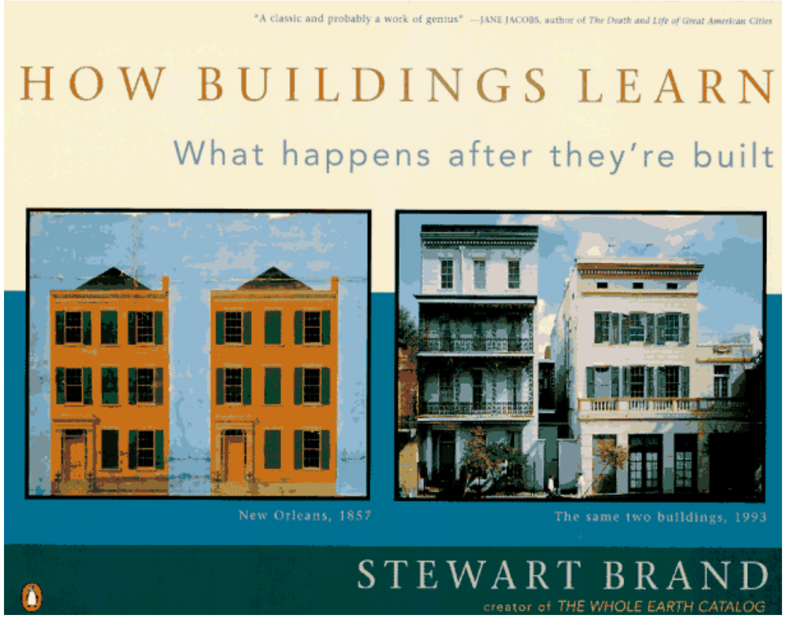
WP4 - Use, operation, and implementation

Main goal:

Provide knowledge and tools which assure usability and acceptance, maintainability and efficiency, and implementation of ZEBs.

Subtasks:

- **4.1: Use**
- **4.2: Operation**
- **4.3: Implementation**



WP5 - Concepts and strategies for ZEBs

Main goal:

Develop concrete concepts for zero emission buildings which can be translated into realized pilot buildings within the time frame of the Centre.

Subtasks:

- **5.1: Definitions of ZEBs**
- **5.2: ZEB concepts**
- **5.3: Pilot buildings**
- **5.4: Strategies and building processes**

WP3 - Energy Supply Systems and Building Services

Main goal:

Develop new solutions for energy supply systems and building services systems with reasonable energy and indoor environment performance appropriate for zero emission buildings.

Subtasks:

3.1: Available technologies for renewable energy

Goal: Investigating new solutions for energy supply systems, heating, ventilation, and air conditioning systems, and energy storage systems.

3.2: Interaction between user needs, energy supply, and building services

Goal: To develop new and to improve existing solutions for buildings with extremely low heating and cooling demands.

3.3: Integration of technologies and solutions

Goal: To develop optimal solutions for integration of new building materials, building envelope solutions, local and in-house energy supply systems, and building services systems.

3.4: High performance building services

Goal: Develop optimal solutions for highly efficient building services systems.

3.5: Test and pilot buildings - Follow up

Goal: Give support to building and study of test and pilot buildings.
Evaluate the performance of test and pilot buildings.

WP3 - Selected Research Activities 2009-2012

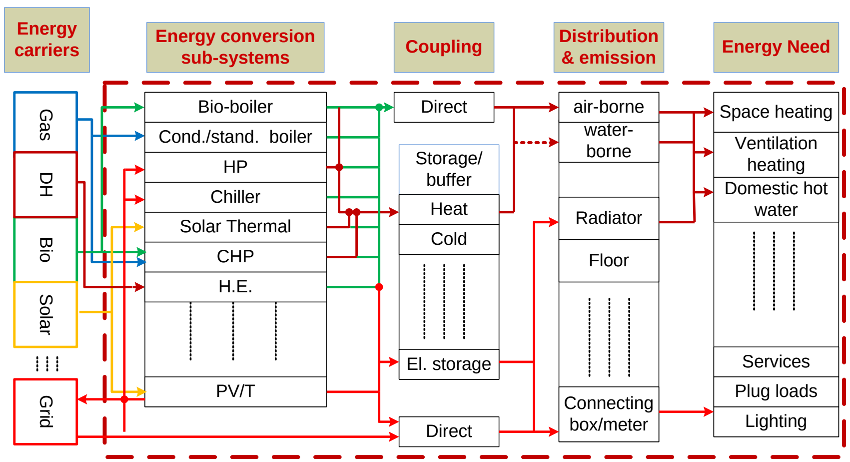
- **Available technologies for renewable energy (3.1)**
  - **A comprehensive state-of-the-art study of available energy supply technologies was accompanied at the beginning of the project and later updated**
    - **The report is frequently used by MSc and PhD students.**
  - **A qualitative survey based study among partners and other relevant players in the building industry discovered need for development of:**
    - **A simple decision support tool focusing on selection of energy supply solutions in an early project design phase, and**
    - **A database on energy supply technologies which are good and robust for the near future under Norwegian conditions**
    - **Development of the tool and the database, that will be linked in use, is planed to be accomplished late 2012**

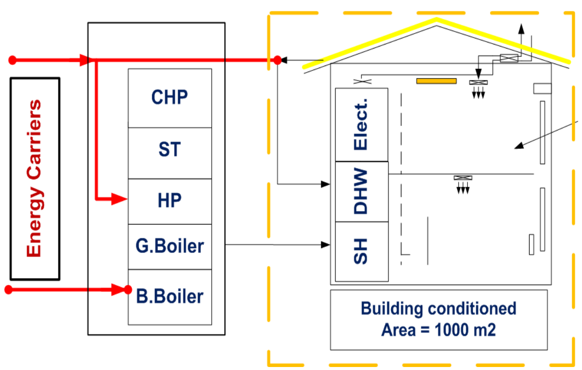
WP3 - Selected Research Activities 2009-2012

- Interaction between user needs, energy supply, and building services (3.2)
  - PhD-study: Optimal solutions for buildings with extremely low heating and cooling demands
    - Advanced simulation models for prediction of performance of buildings with extremely low heating and cooling demand. Started April 2010.
  - Multi-objective optimization at an early design stage – Introductory case study for a 1000 m^2 building
    - Objective functions: Minimum Annual cost and Total primary energy factor
    - Constraints: Annual zero CO2 balance and Limited roof area for Solar system (PV&ST)
    - Input: Simple - based on average, seasonal, fixed, norm values and simplified calculations
    - Output: Different combination possible, Optimal threshold using Pareto Front
  - Multi-objective optimization at detail design stage – through the above mentioned PhD study
    - Traditional energy systems are designed to cover peak loads and they are over-sized to cover uncertainties
    - In low energy building, this leads to system operation at part-loads or stand-by setting for major portion of time. That might lead to increase in auxiliary energy use.
    - Input: Precise – based on real values for efficiencies, demand profiles, energy prices, technology costs etc.
    - Output: Seasonal performance of different sub-system, Optimal configuration and sizing of system, Net-ZEB strategies may be explored

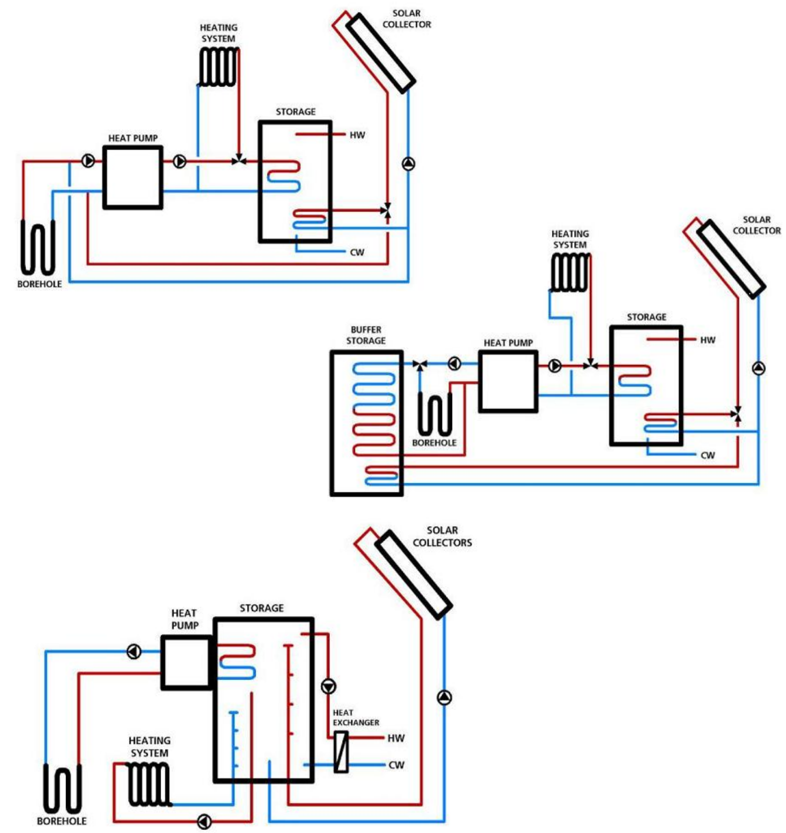
Multi-objective optimization at …

- early design stage





- detailed design stage



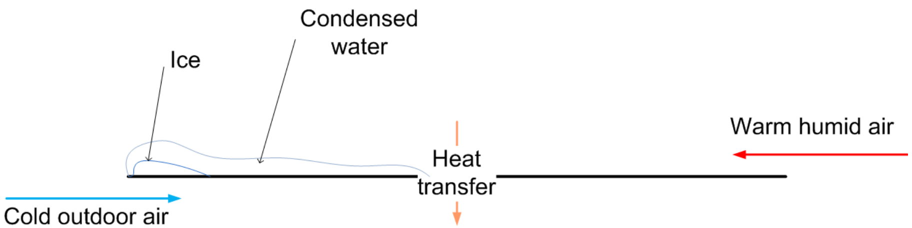
WP3 - Selected Research Activities 2009-2012

- **High performance building services (3.4)**
  - **A comprehensive state-of-the-art study of available technologies for highly efficient building services systems. The report is frequently used by MSc and PhD students.**
  - **New concepts for heat recovery including nano-materials**
    - **New type of a cross flow energy exchanger using membrane technology is under development.**
    - **Hygro-thermal properties of five different membrane samples have been investigated in laboratory and reported.**
    - **Laboratory setup for testing of the membrane based energy exchanger is developed and is ready for use with the selected membrane.**
    - **In addition CFD simulation study of air flow patterns in an exchanger is conducted aiming at improvement of design and efficiency**

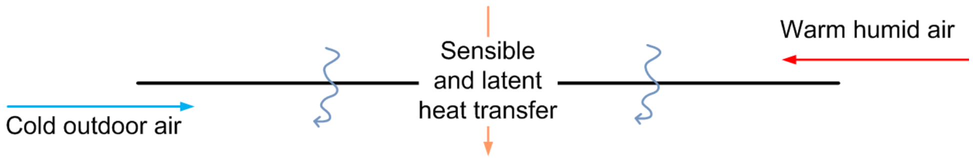
Counterflow exchangers

- **Conventional versus membrane exchanger**

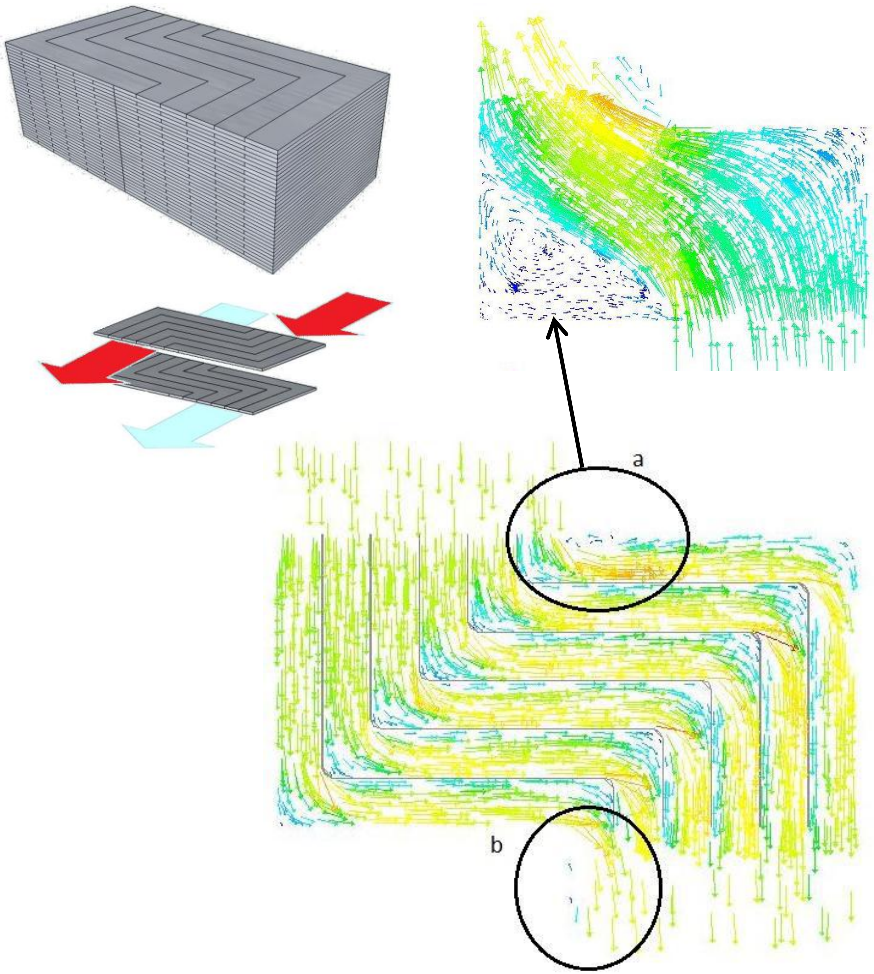
Conventional heat exchanger with aluminium exhanger surface



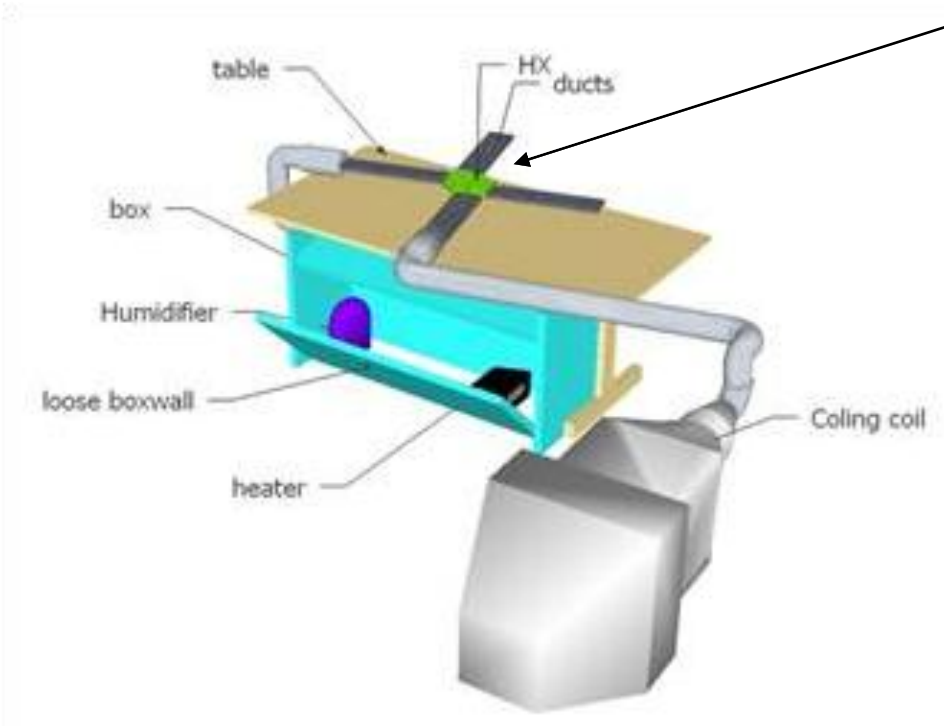
New energy exchanger with membrane exchanger surface



- **CFD simulation study of air flow pattern**



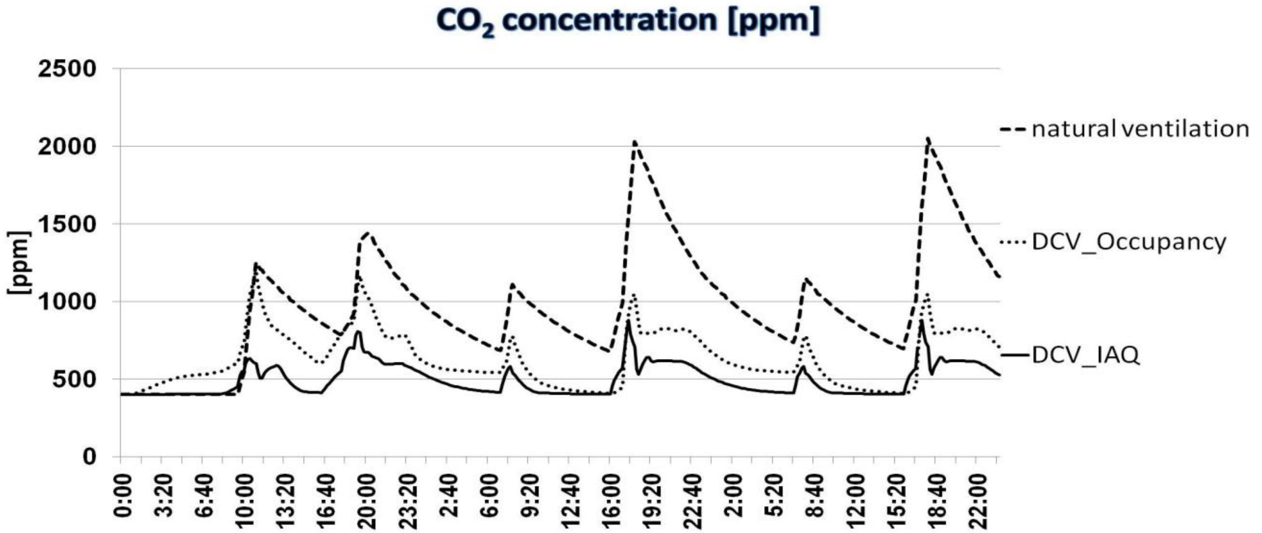
Laboratory setup for testing of the membrane based energy exchanger



Traditional counterflow exchanger

WP3 - Selected Research Activities 2009-2012

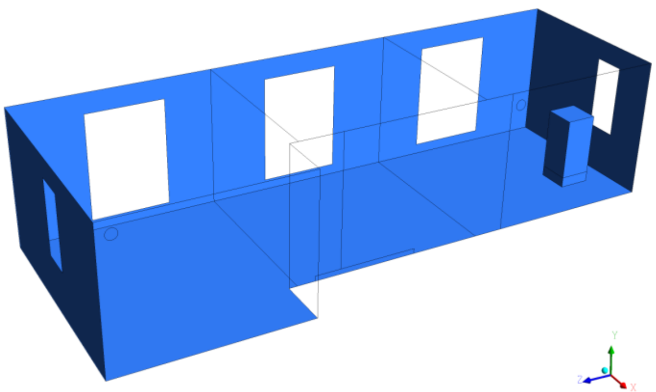
- **High performance building services (3.4)**
  - **New concepts for Demand Controlled Ventilation**
    - **Comparison of different ventilation strategies in a house conducted in E-Coniiaq project**
    - **Natural ventilation, Demand Controlled Ventilation (occupancy), smart DCV (CO2/TVOC)**
    - **Two common partner workshops have been arranged in collaboration with the reDuCeVentilation project (SINTEF Byggforsk). Main topics for the workshops have bee:**
    - **Improved control of fans and motors; Improved SFP-factor for the whole system; and**
    - **Occupancy Pattern in Office Buildings - Consequences for HVAC system design and operation**

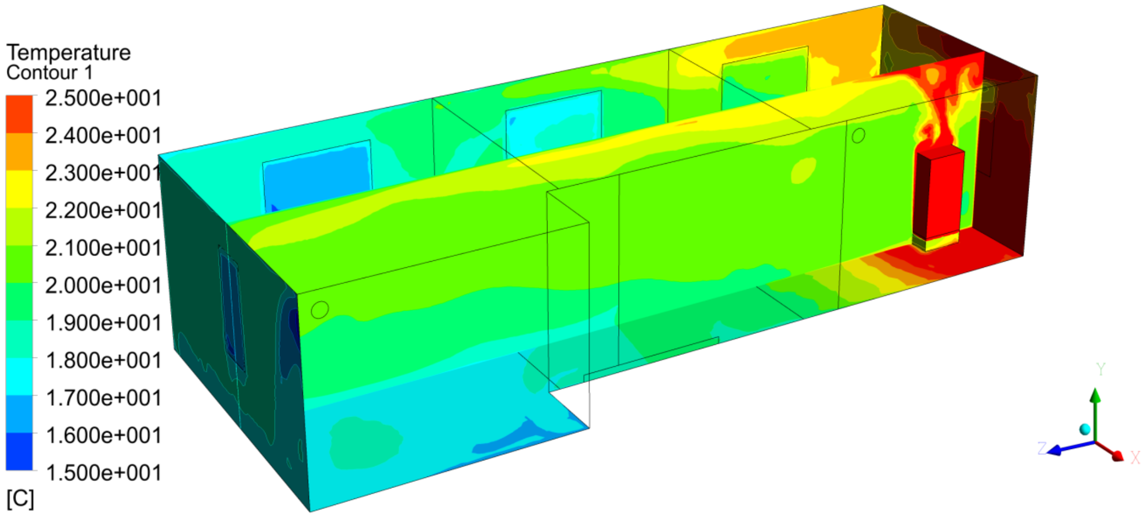


E-Coniiaq project results

WP3 - Selected Research Activities 2009-2012

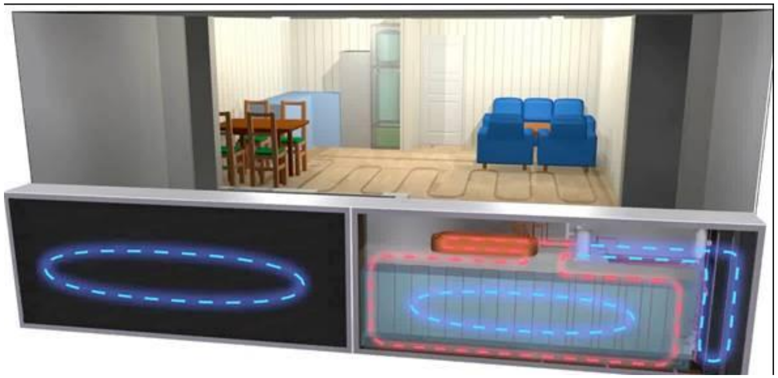
- **High performance building services (3.4)**
  - **New concepts for wood fired furnaces**
    - It is conducted a simulation study of the temperature response of a test case family house building when using downscaled wood fired furnace.
    - Comparison is made for typical conditions in Norway, Germany and Belgium. Improved modeling of the wood fired furnace is conducted in cooperation with the SINTEF Energy Bio Group and the KMB Stablewood.
    - This creates the simulation platform for further generic investigation of efficiency and thermal comfort of the heat emission and distribution of sub-systems in super-insulated envelopes.

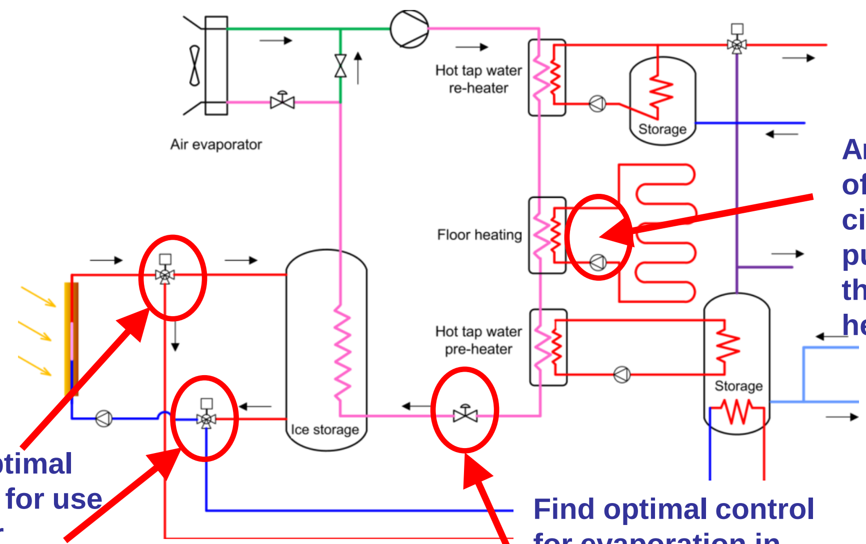




WP3 - Selected Research Activities 2009-2012

- **High performance building services (3.4)**
  - **New concepts for internal exchange of heat energy in buildings:**
    - Heat pump (with CO_2 as working fluid) combined with a diurnal heat storage. Continuing the activity of 2011 on measurements on installed prototype
    - Developed simulation model for dynamic analyzes of performance and development of control strategies
    - Participation in the new IEA HPP Annex 40: "Heat pump concepts for near zero-energy buildings"





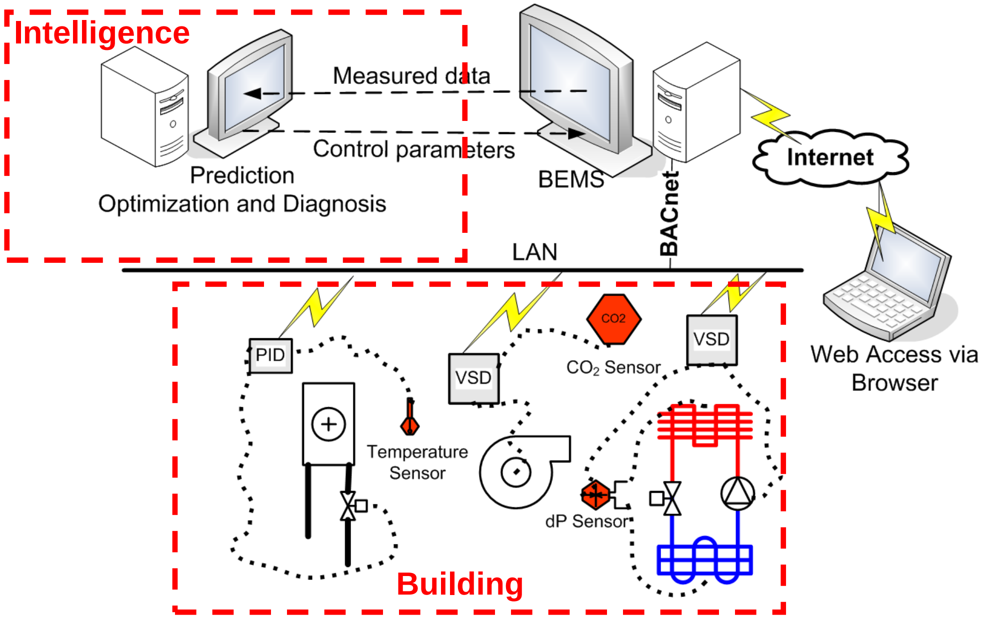
Analysis of circulation pump for the floor heating

Find optimal control for use of solar thermal energy

Find optimal control for evaporation in the ice storage or in the air evaporator

WP3 - Selected Research Activities 2009-2012

- **Evaluation and quality assurance of the performances of ZEBs (3.1 and 3.5)**
  - **ZEB Life-Time Commissioning procedures**
    - **Procedures for energy measurement and cost benefit for two case buildings has been developed based on the previous work in the National project Life-Time Commissioning for Energy Efficient Operation of Buildings (PFK) and IEA ECBCS Annex 40 and 47.**
    - **This work documents need for extended collection and integration of data , e.g. from design, manufacturer data, monitoring and BEMS fata, for proper documentation of performances of ZEBs.**
    - **Participation in IEA ECBCS Annex 53: "Total Energy Use in Buildings – Analysis & Evaluation Methods"**



WP3 - Selected Research Activities 2009-2012
Ongoing PhD research

- **Candidate: Usman Dar (3.2)**
- **Optimal solutions for buildings with extremely low heating and cooling demands**
  - **Advanced simulation models for prediction of performance of buildings with extremely low heating and cooling demand.**
    - » **Started April 2010, 4 years track**

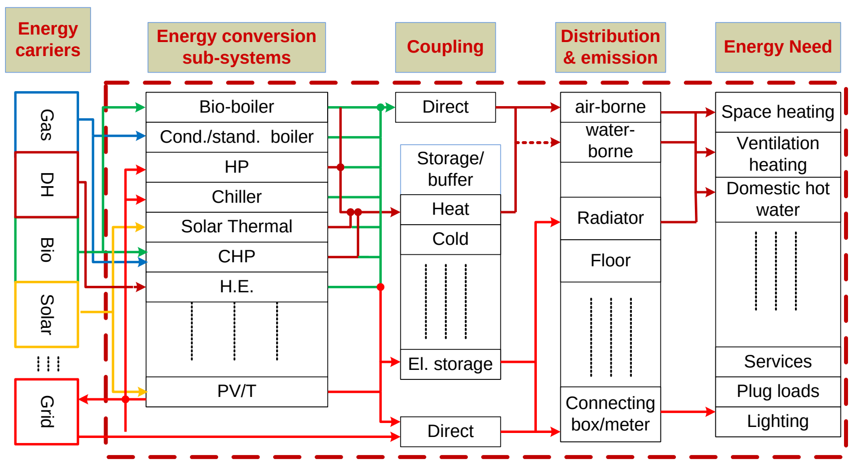
- **Candidate: Jens Tønnesen (3.4)**
- **Highly efficient building services systems**
  - **Identifying electric energy losses from building automation components Life cycle assessment.**
    - » **Started March 2011, 3 years track**

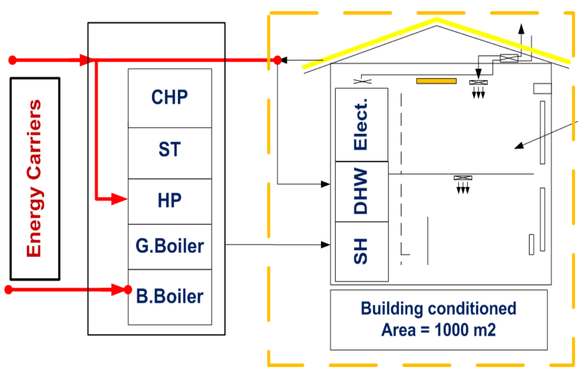
- **Candidate: Magnar Berge (3.3)**
- **Energy use and indoor environment in relation to heating and ventilation (cooling) of super insulated buildings**
    - » **Started August 2011**

- **Candidate: Karen Byskov Lindberg (3.2)**
- **Inpact of ZEBs on the energy system through smart-grid and demand-side-management**
    - » **Started September 2011**
    - » **50% in collaboration with FME CenSES**

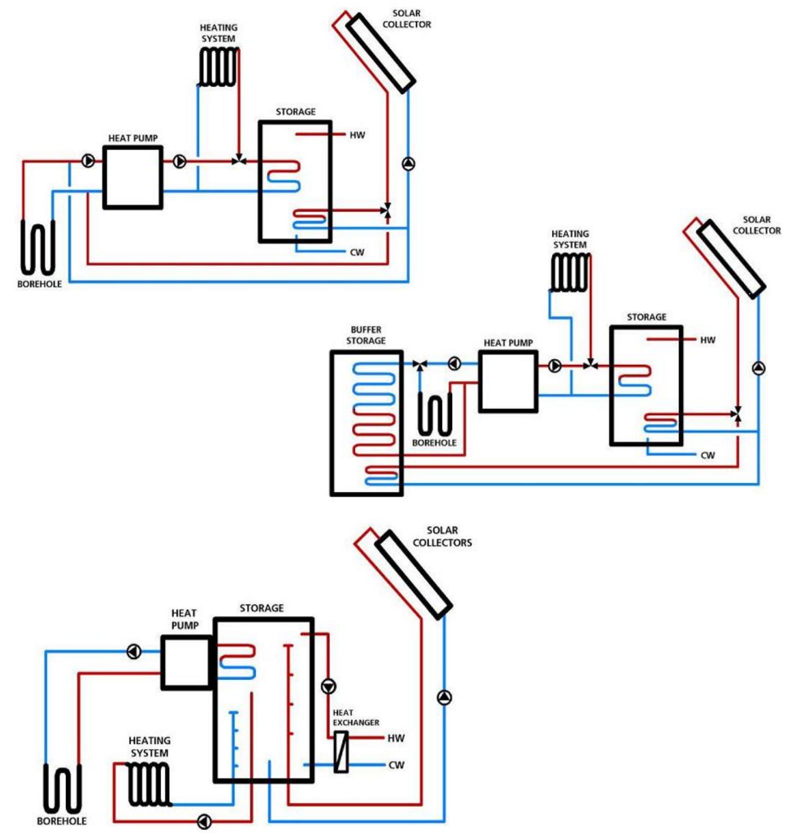
Multi-objective optimization at …

- **early design stage**





- **detailed design stage**

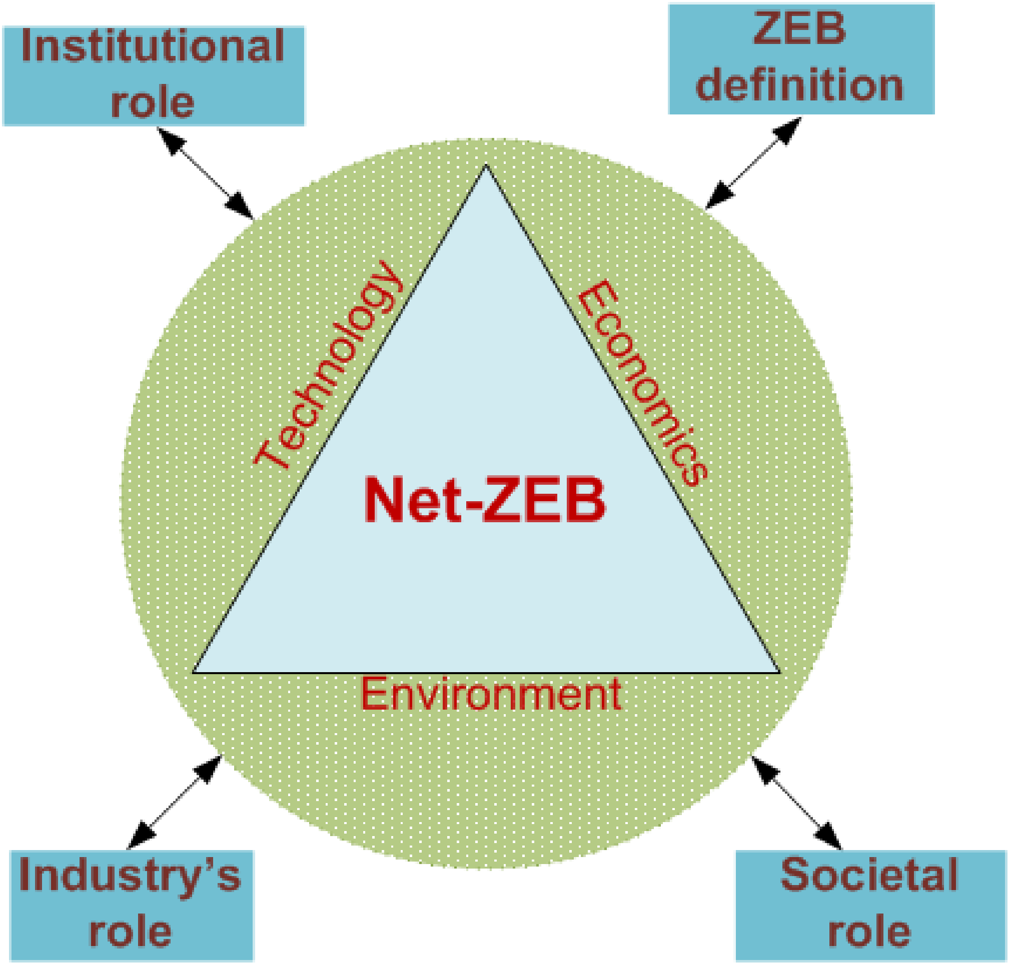


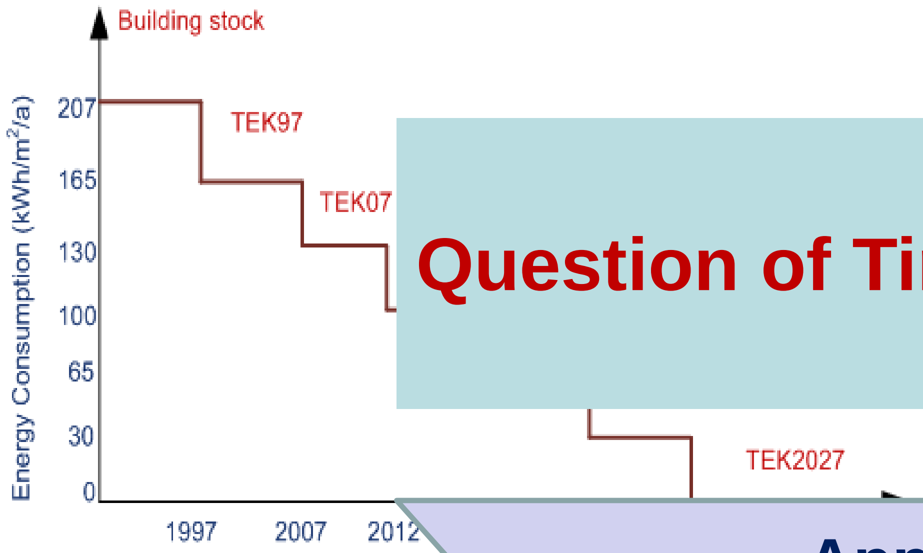
3.2: Interaction between user needs, energy supply, and building services

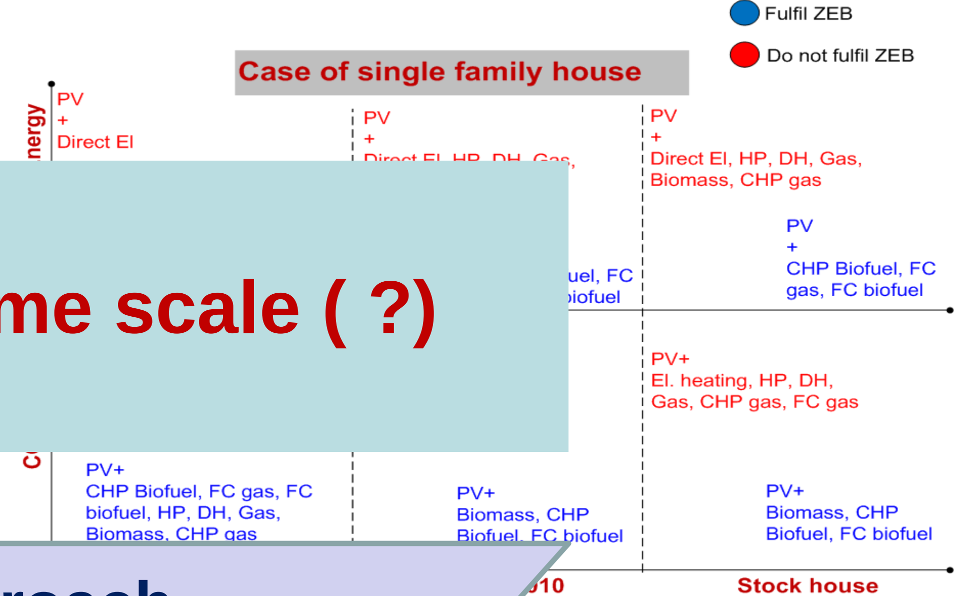
Decision support for energy supply systems

- Energy supply system overview
- Optimization at early design stage
- Optimization at later design stage

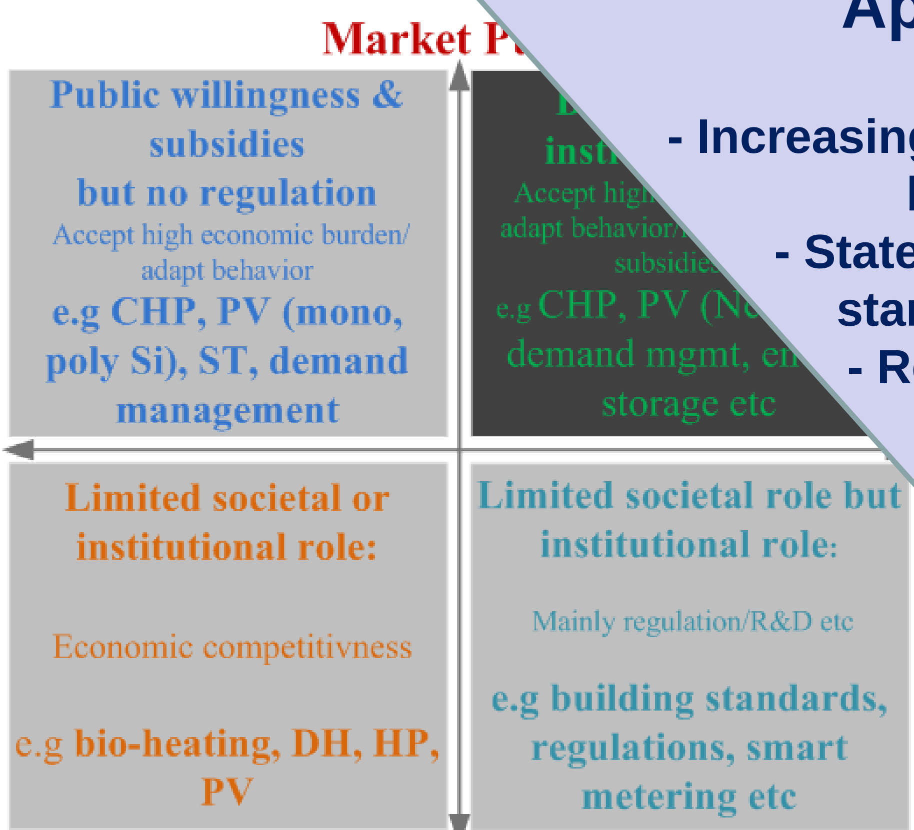
- A simple decision support tool for selection of energy supply solutions in an early project design phase with a database on energy supply technologies which are good and robust for the near future under Norwegian conditions

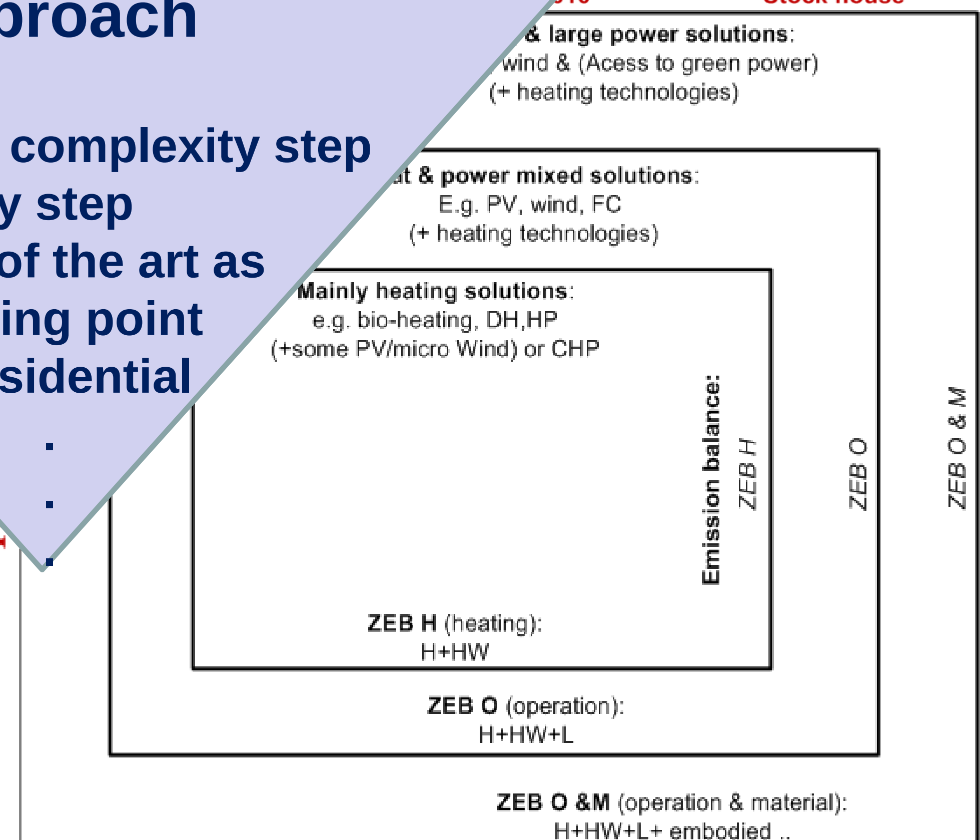

Institutional role
ZEB definition
Technology
Economics
Net-ZEB
Environment
Industry's role
Societal role





Question of Time scale (?)





Approach

- Increasing complexity step by step
- State of the art as starting point
- Residential

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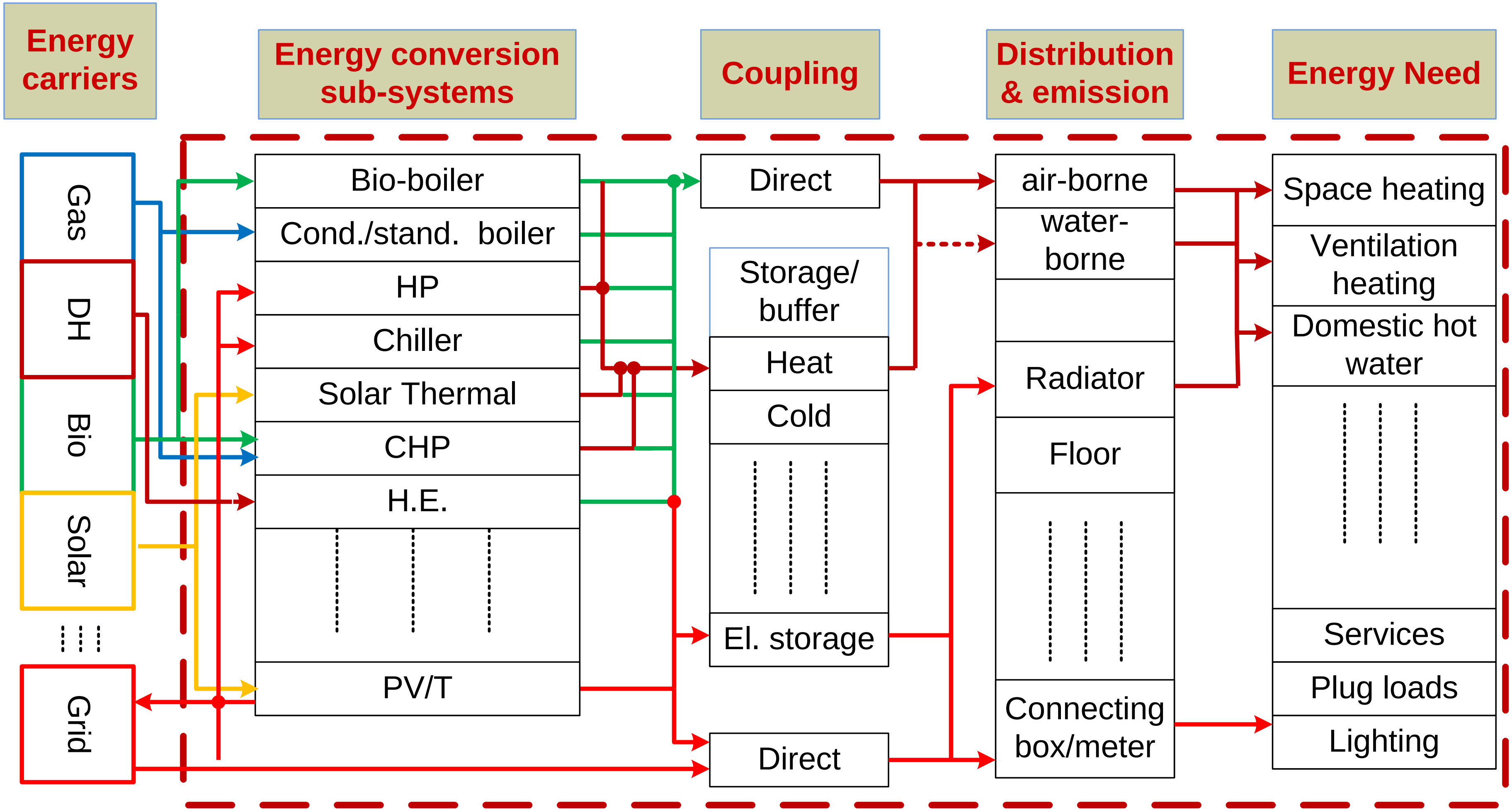
Energy supply solution



Multi-objective optimization at an early design stage

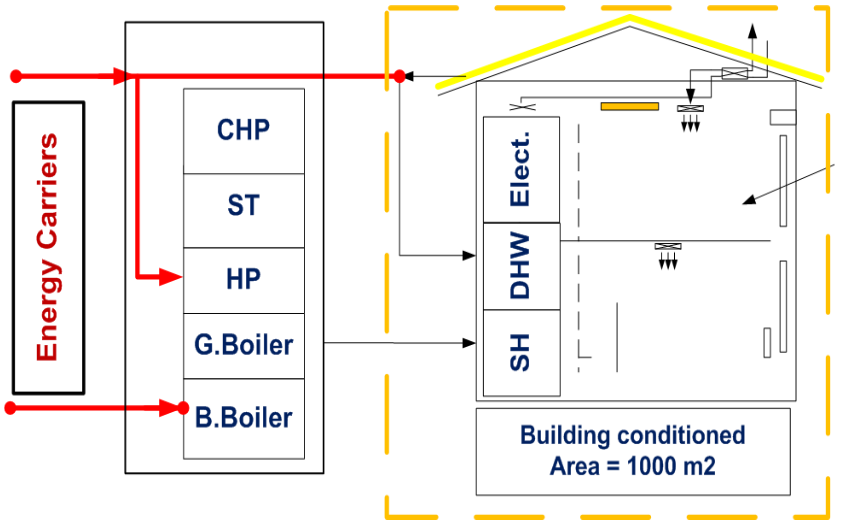
Sizing of system for a building

Objective function

- ❑ Annual cost
- ❑ Total primary energy factor

Constraint

- ❑ Net-ZEB building (annual zero CO_2 balance)
- ❑ Limited roof area for Solar system installation (PV & ST)



Multi-objective optimization at an early design stage

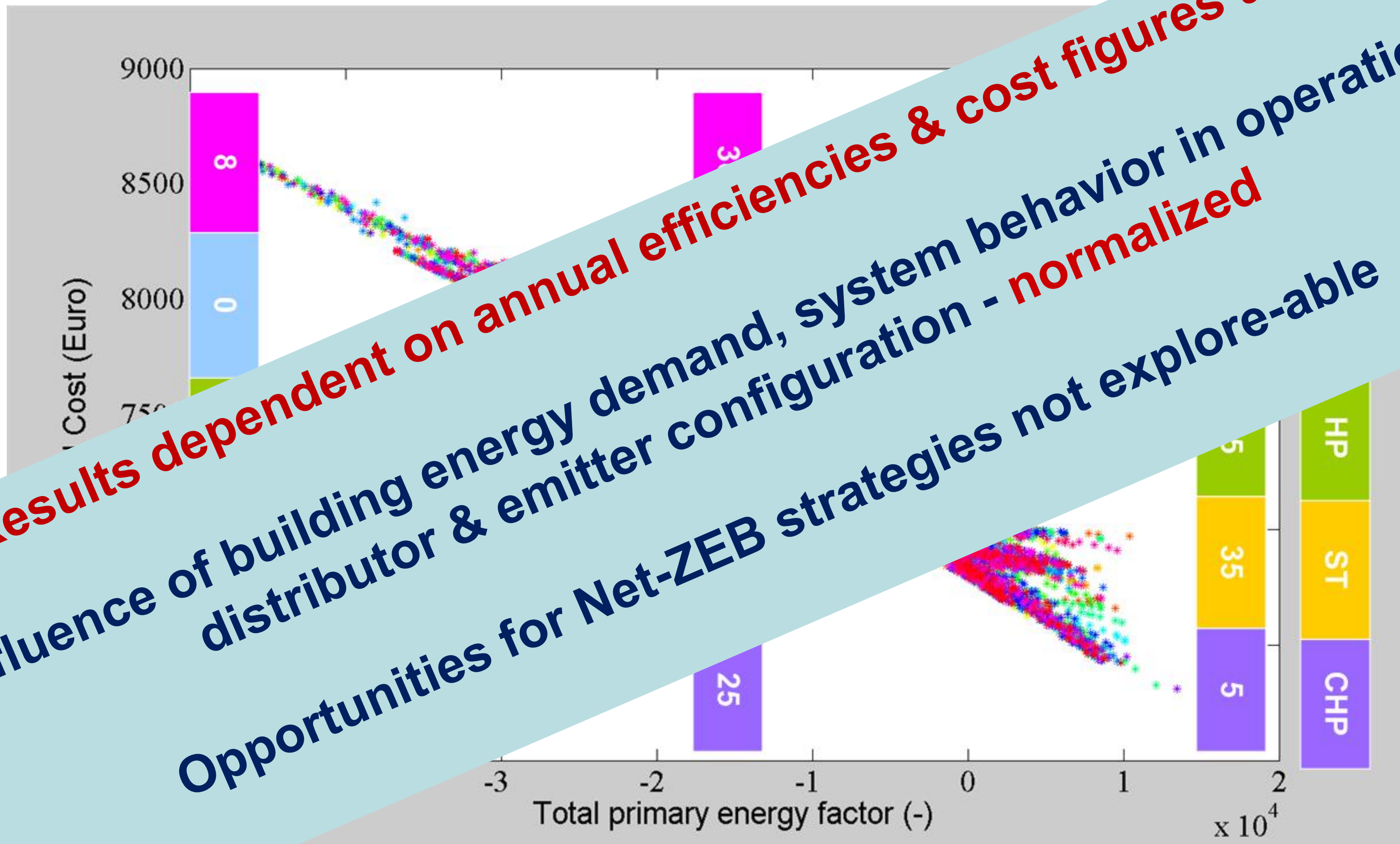
Input

- Annual / Seasonal efficiency: from standard & norms
  - Sub-systems
  - Distribution and emitters
- Building energy demand: Calculated / norm-values
- Fixed CO_2 , PE factors – NS 3031 & NS3700
- Fixed - average utility/fuel rates -
- Technology cost

Output

- Different combination possible
- Optimal threshold using Pareto Front

Net-ZEB Pareto-frontier



Results dependent on annual efficiencies & cost figures used

Influence of building energy demand, system behavior in operation, distributor & emitter configuration - normalized

Opportunities for Net-ZEB strategies not explore-able

Bio boiler	250 €/kW	Solar therm.	600 €/kW
Gas boiler	100 €/kW	CHP	580 €/kW
Heat pump	250 €/kW	PV	6000 €/kW
Conn. box	100 €/kW		

Multi-objective optimization at detail design stage

In low energy buildings, system might perform different than in conventional setup ?

- ❑Energy systems are designed to cover peak loads + (over-sized to cover uncertainity)
- ❑ In low energy building, this leads to system operation at part-loads or stand-by setting for major portion of time
- ❑ That might lead to increase in auxuliary energy use
- ❑ But, particular strategies could be used to enhance total system performance
- ❑ How ??

Multi-objective optimization at detail design stage

Input

- ❑ Sub-systems steady state peformance
- ❑ Different system-distribution-emitter configuration
- ❑ Real building energy demand profiles
- ❑ CO_2 , PE factors – still ’fixed’ or ’hourly profile’ possible
- ❑ Hourly utility/fuel rates
- ❑ Technology cost

Output

- ❑ Seasonal performance of different sub-system
- ❑ Optimal configuration and sizing of system
- ❑ Net-ZEB strategies may be explored

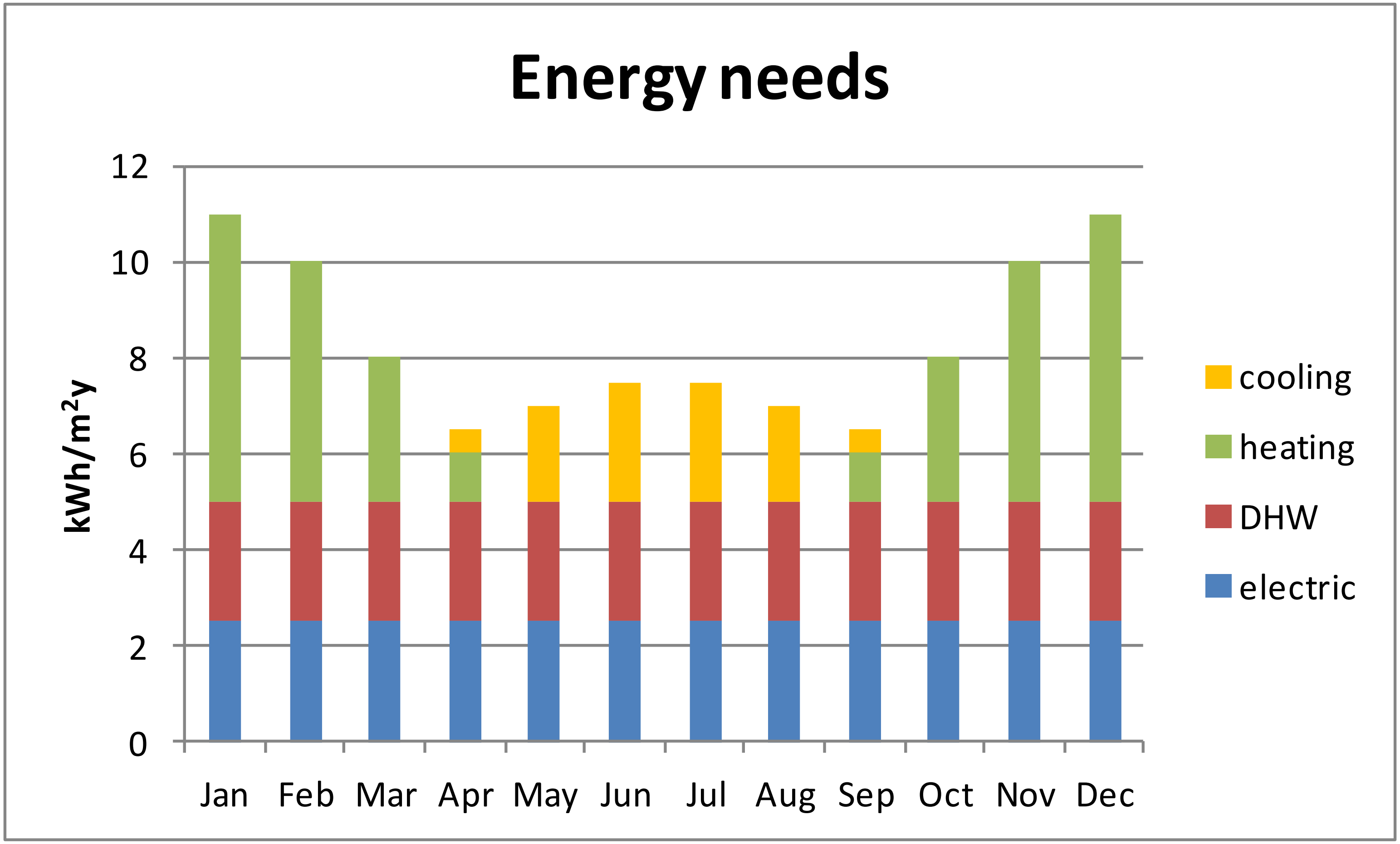
Selection of energy supply solutions in an early project design phase

- Today in Norway is based on use of software tools for calculating the building energy need:
  - SIMIEN
  - TEK Sjekk

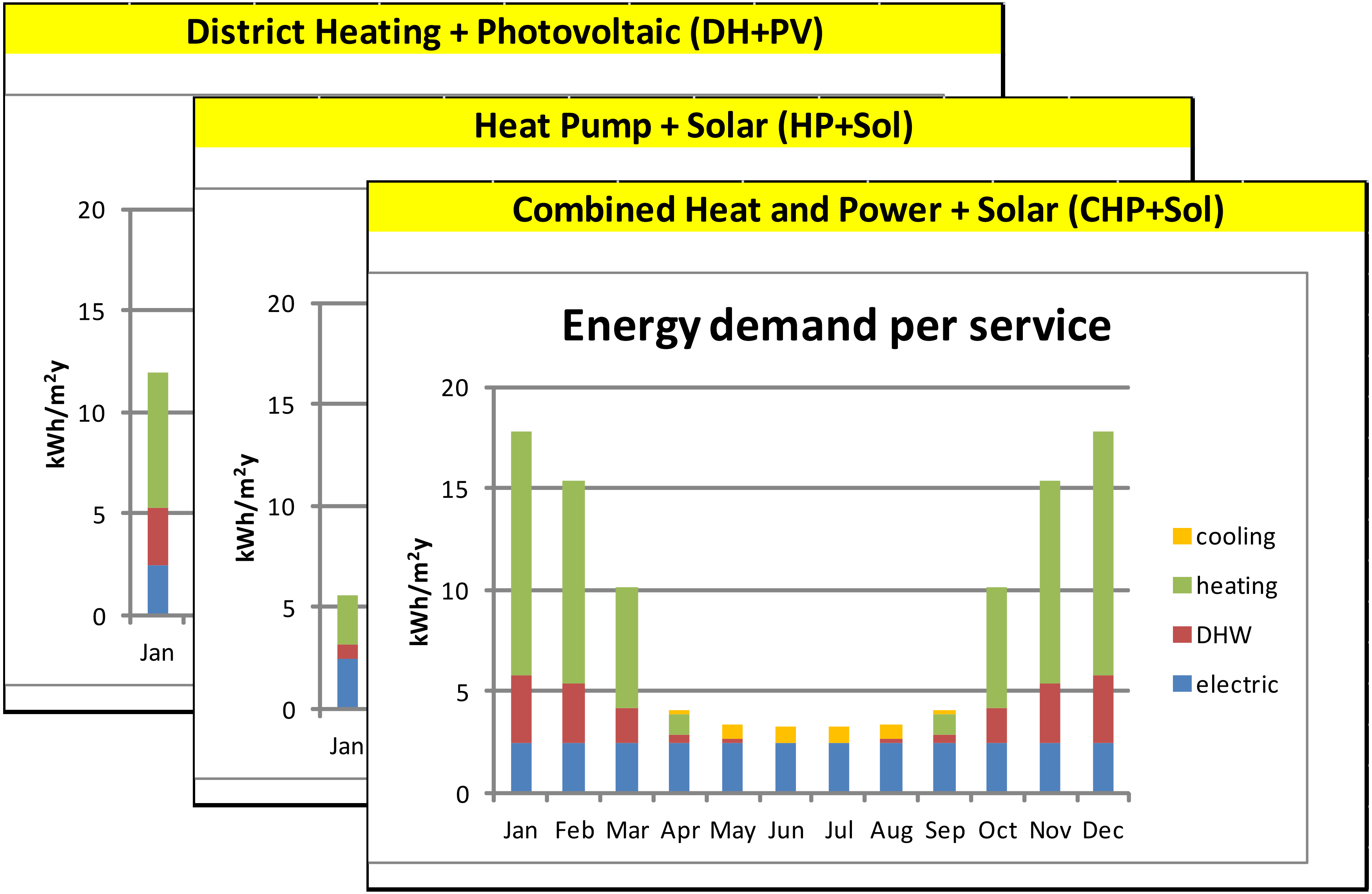
- Cover the building physics part
- BUT
- the energy system part is oversimplified

- It is only possible to define:
  - share of total load covered
  - OR
  - max capacity (constant = ideal system)

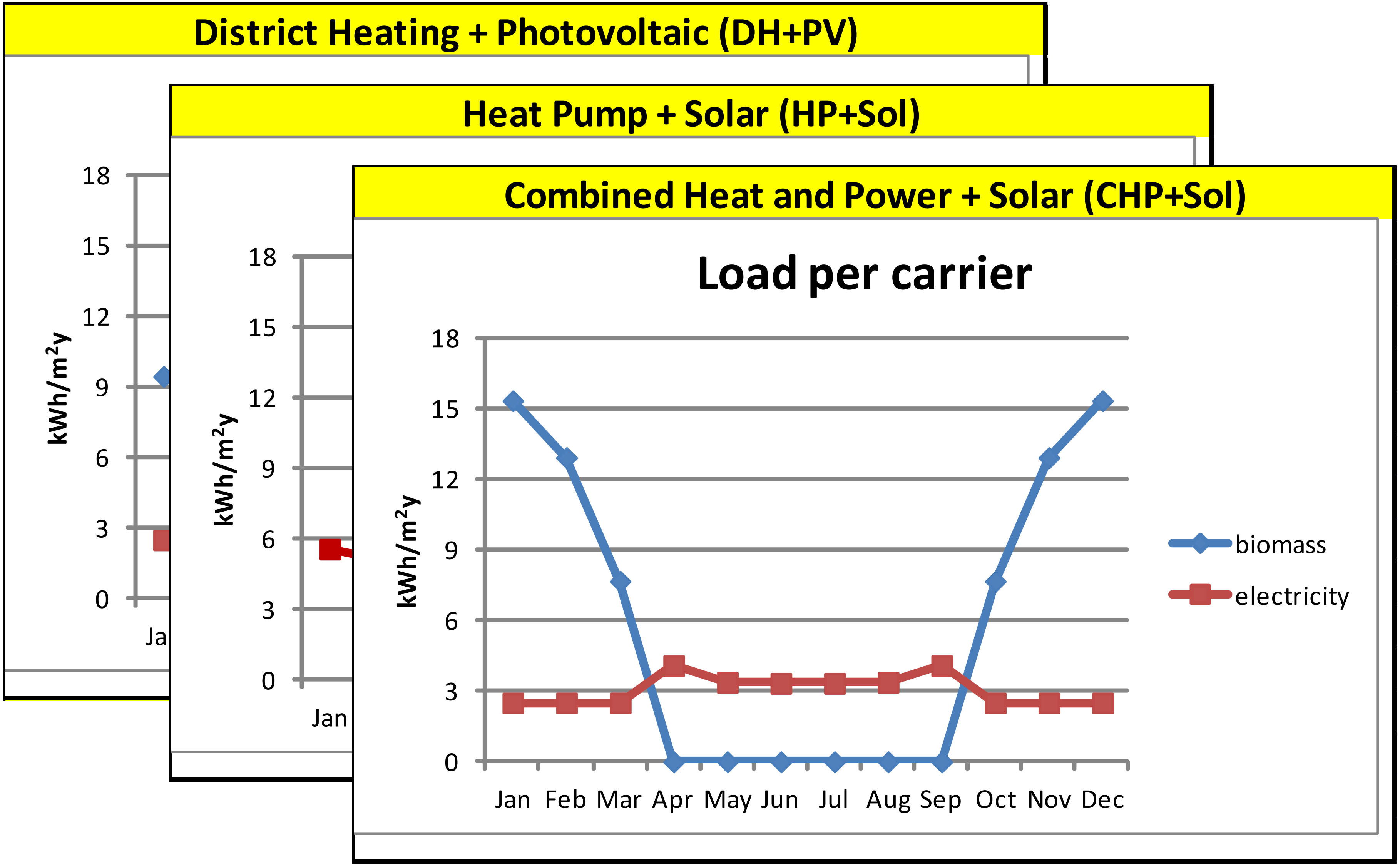
Example energy need in input



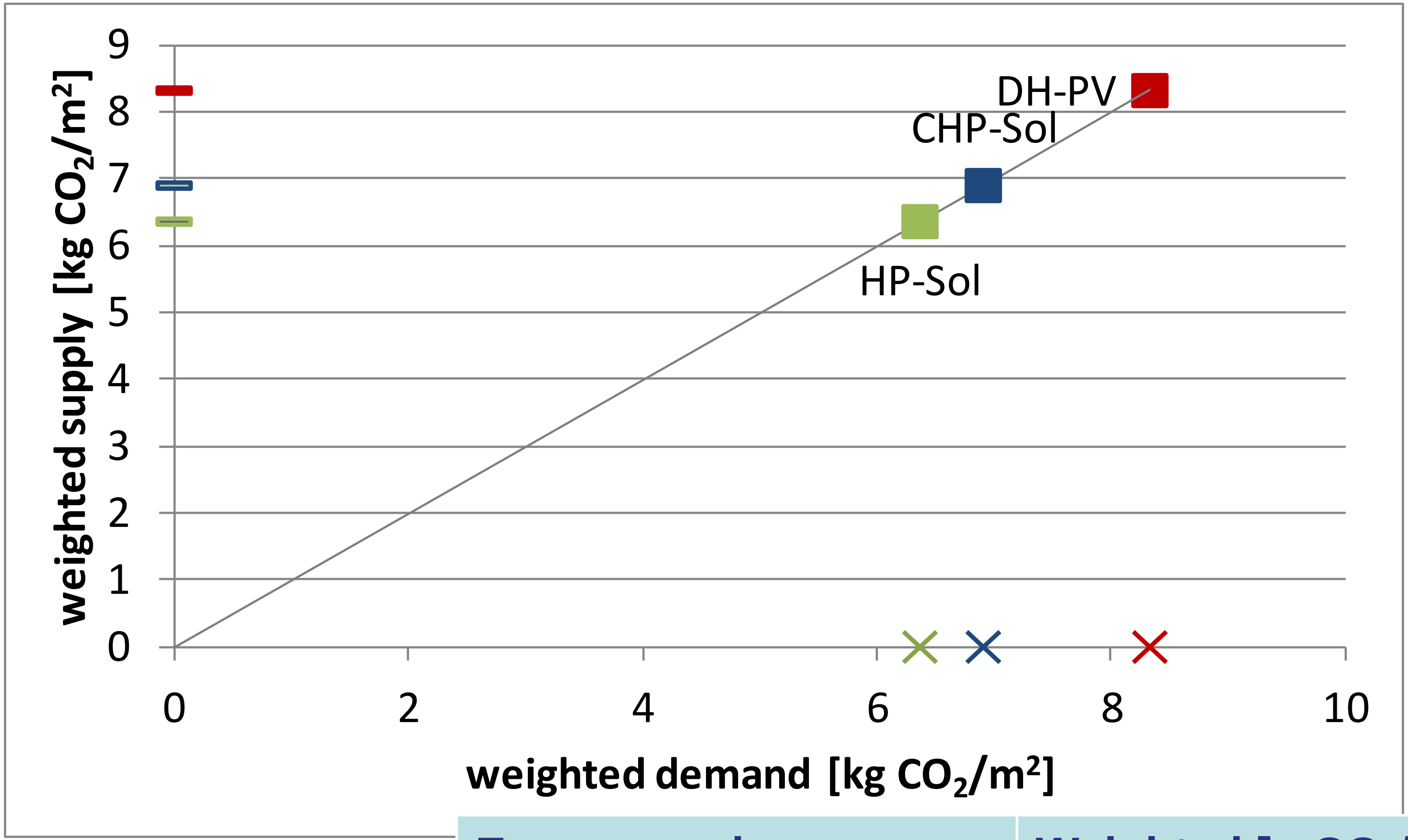
Example outputs: energy demand



Example outputs: load per energy carrier

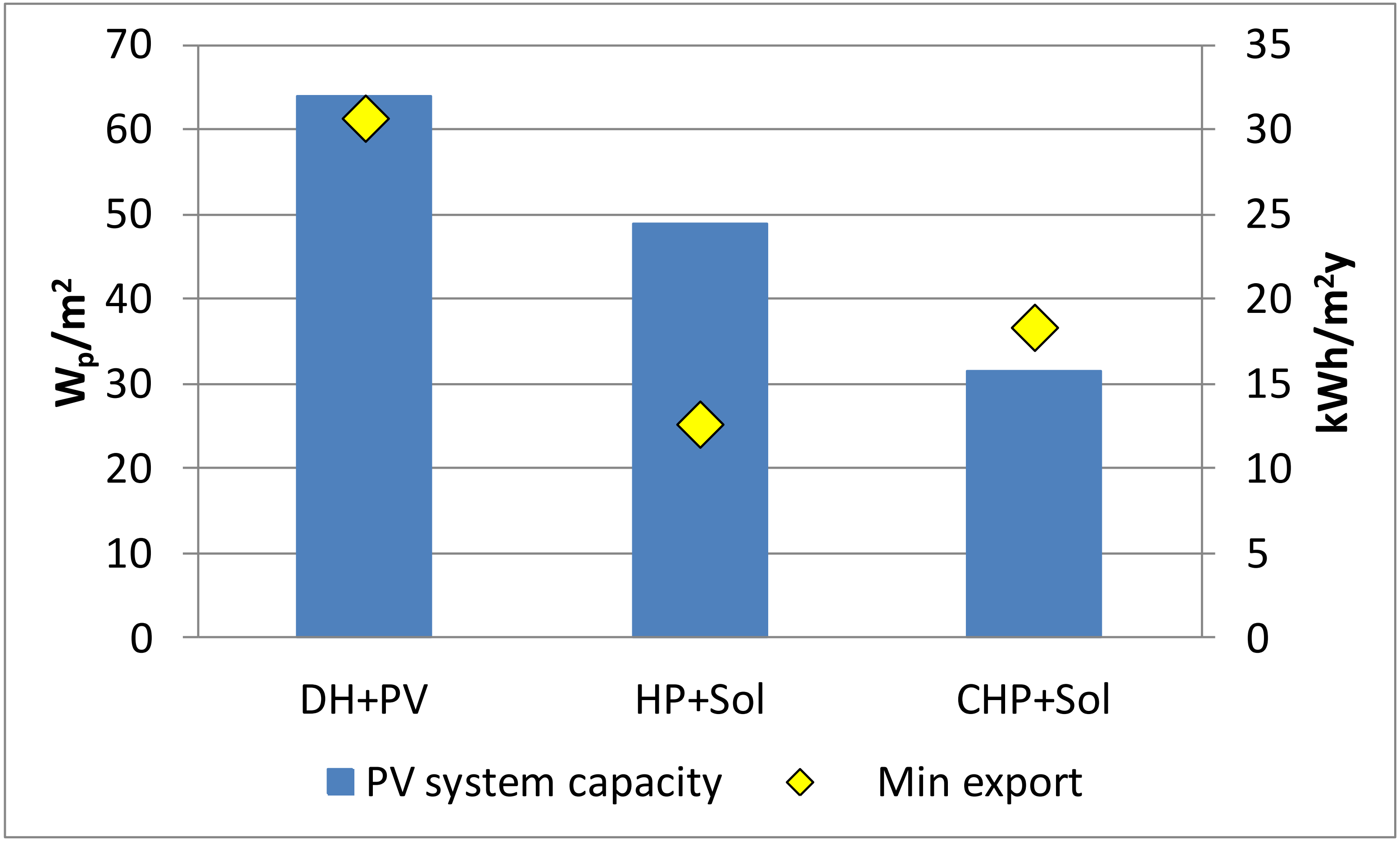


Example output: annual load vs. generation

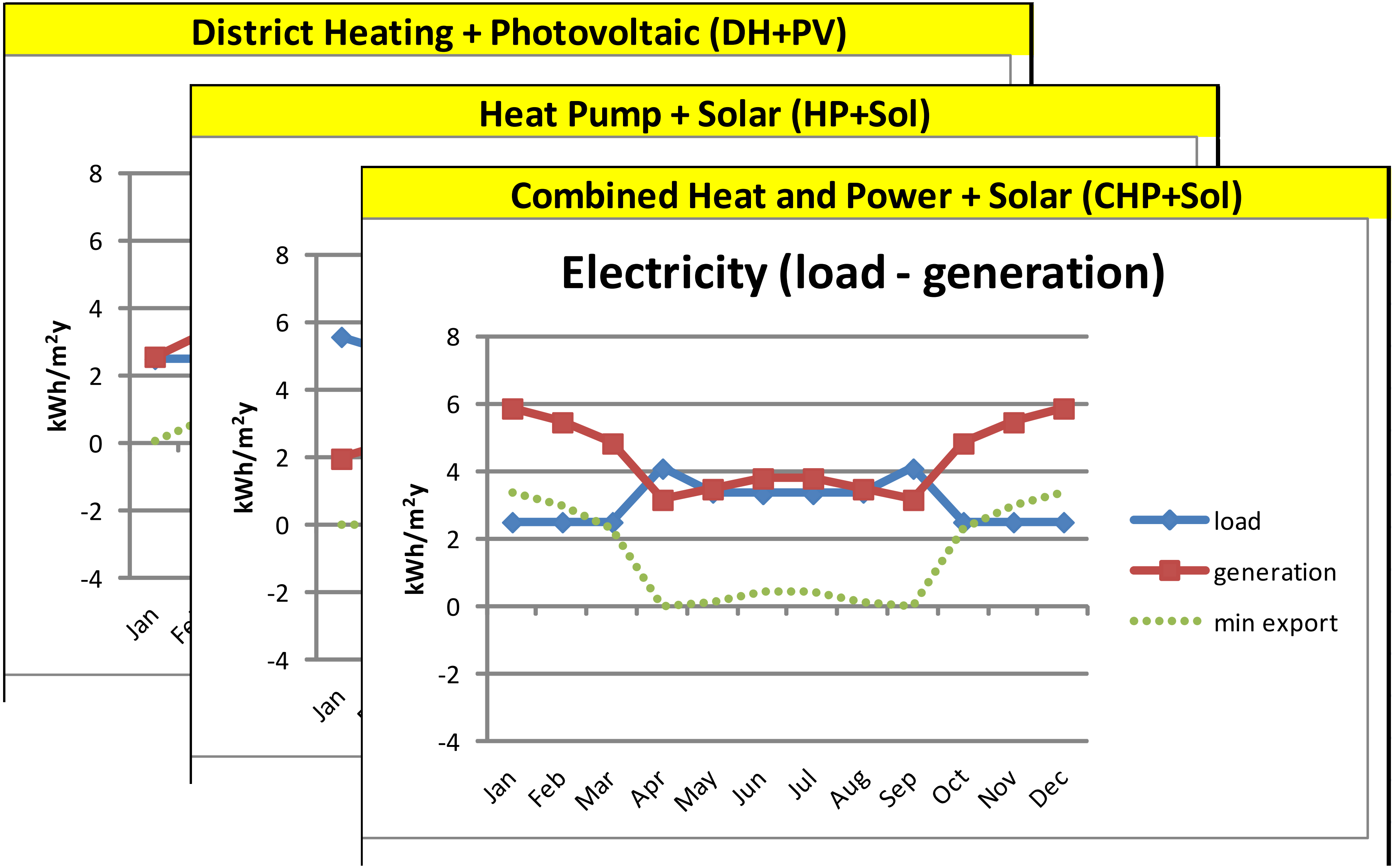


Energy carrier	Weighted [g CO_2/kWh]
Electricity	130
District heating	60
Biomass	30

Example Results: generation capacity, el. export



Example output: monthly load vs. generation



WP3 - Energy Supply Systems and Services

Main goal:

Develop new solutions for energy supply systems and building services systems with reasonable energy and indoor environment performance appropriate for zero emission buildings.

Subtasks:

- **3.1: Available technologies for renewable energy**
- **3.2: Interaction between user needs, energy supply, and building services**
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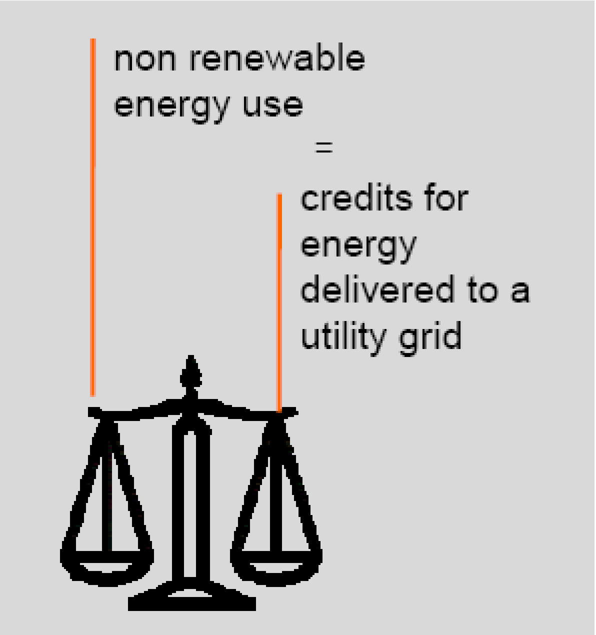

Source: University Wuppertal, School of Architecture, Building Physics and Technical Building Services.
Prof. Karsten Voss