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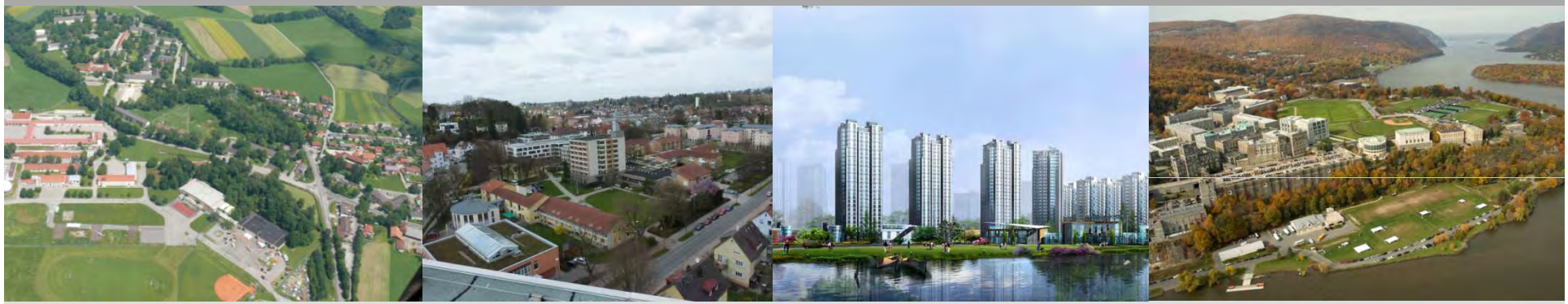
Dr. Alfred Kerschberger, RK-Stuttgart



Net Zero Energy (NZE) Communities
Concepts, Methods, Implementations

NZE - Principles

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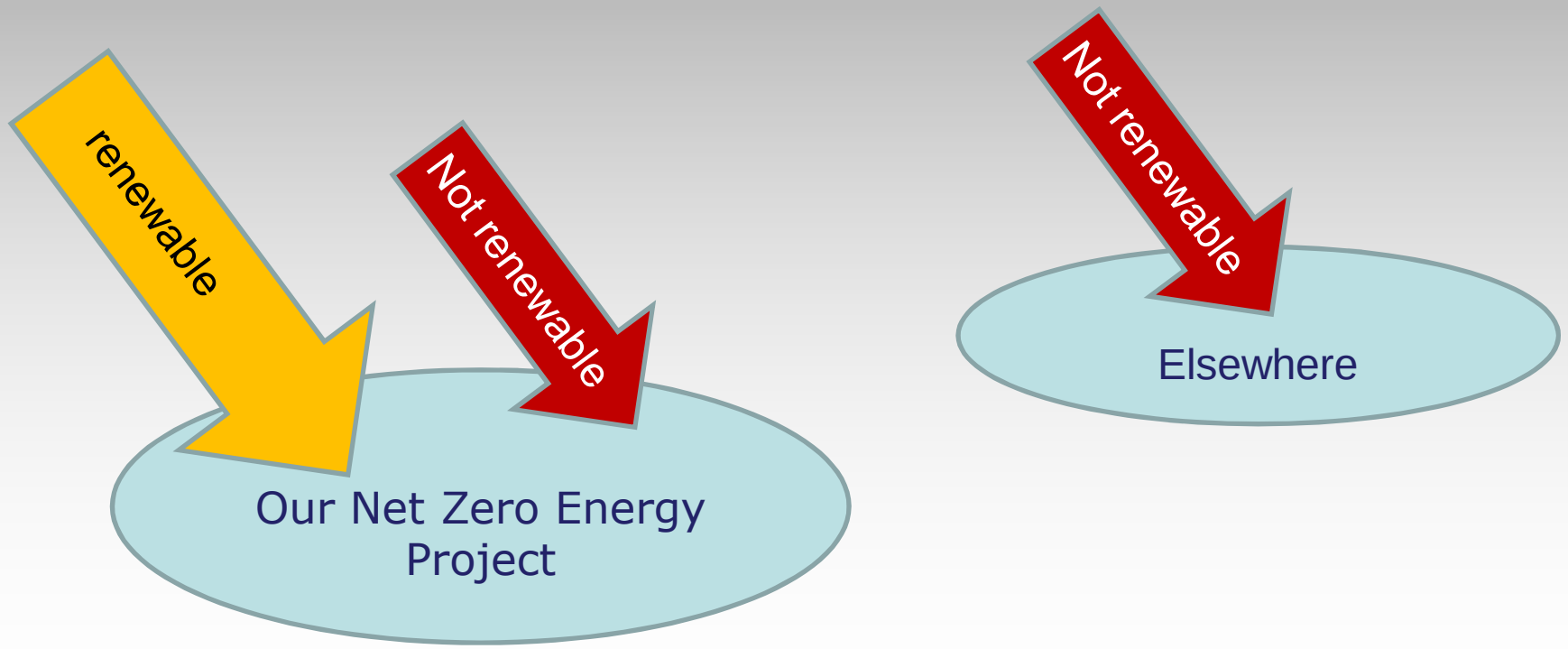
What is Net Zero Energy ?

- **It is an energy balance calculation = Zero fossil fuels consumption.**
- **Consumed fossil fuels can be offset by renewables, which are fed into the grid and substitute fossil fuels elsewhere.**



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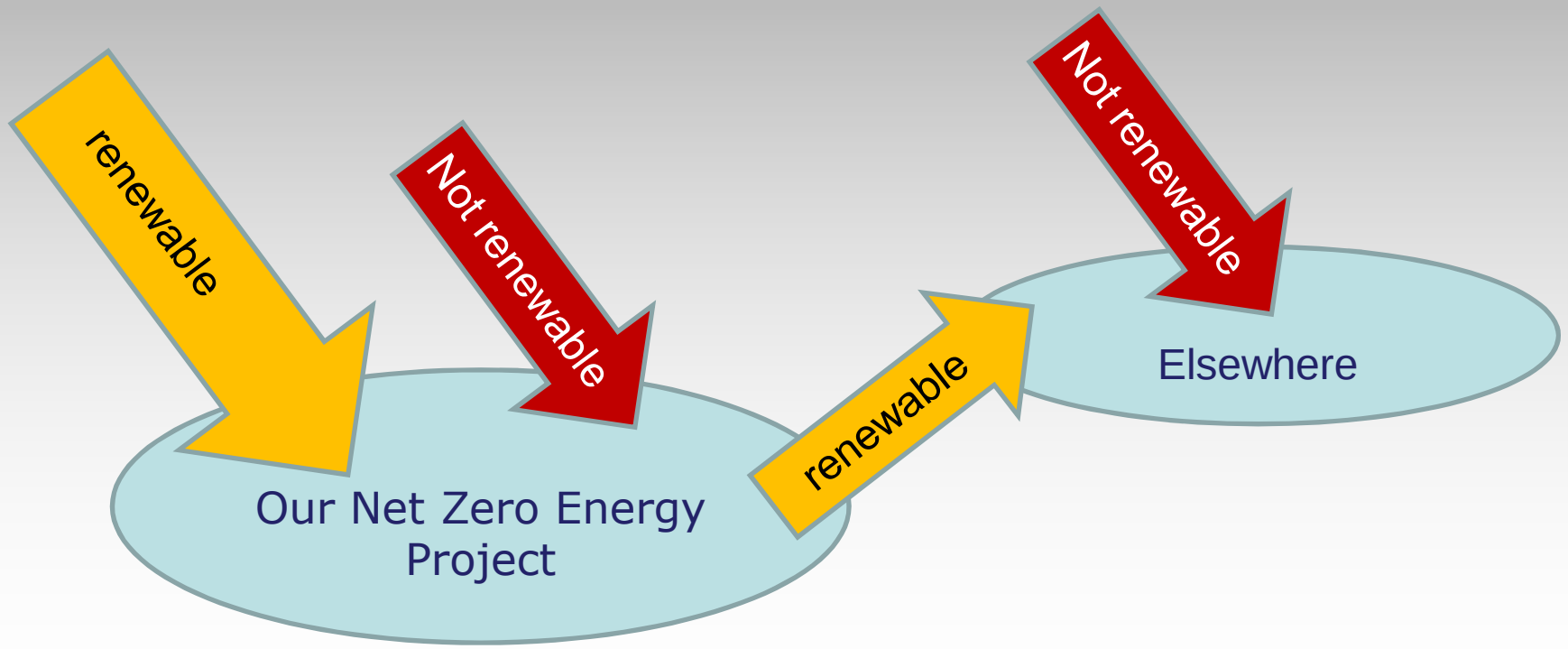

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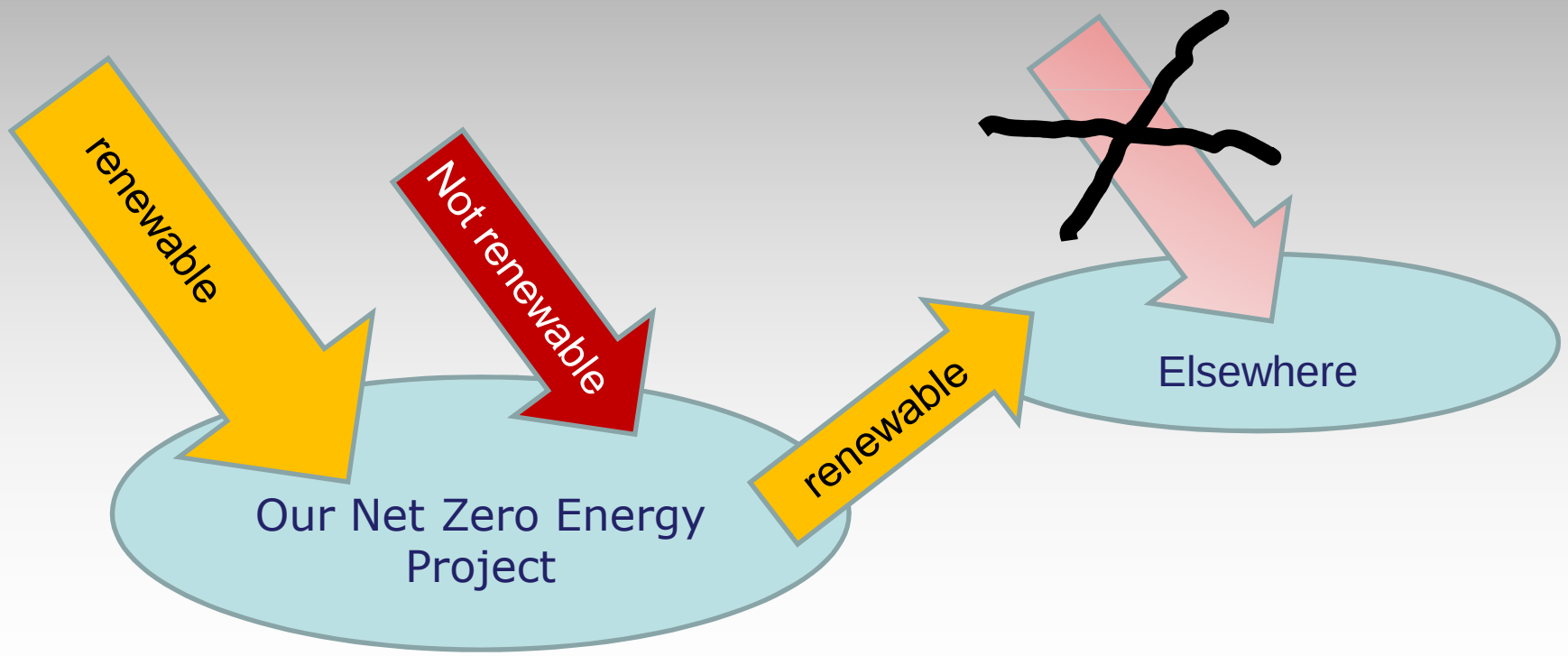

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Shared currency: fossil primary energy

- To offset energy consumptions against energy surplus generation, a shared „energy currency“ is necessary,
- Primary energy factor allows to compare different fuels and systems (Primary energy refers to not renewable energy)

Primary energy factors for room heating and DHW

- fuel oil, natural gas	1.1
- electricity	2.6 (3.2)
- heating grid fossil fuels	1.3
- heating grid renewable fuels	0.1
- Cogeneration with renewable fuels	0

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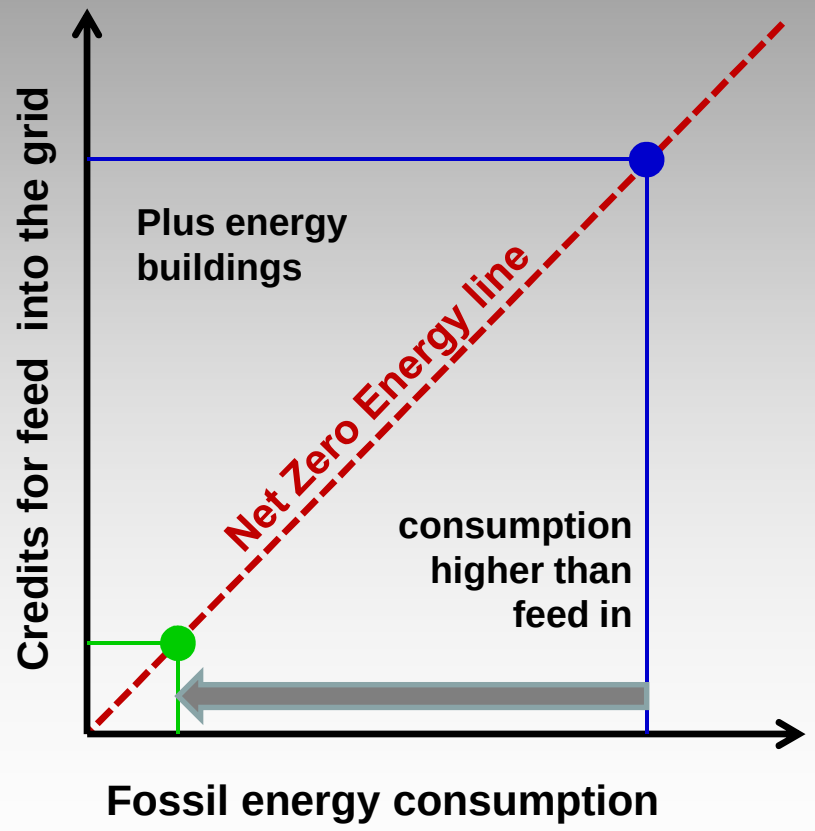
NZE: Consumption vs. Feeding into the grid



High consumption needs a lot of renewables fed into the grid

Zero Energy projects are much easier to implement if there are buildings with low energy consumption

Low consumption can e.g. be covered by solar thermal + PV

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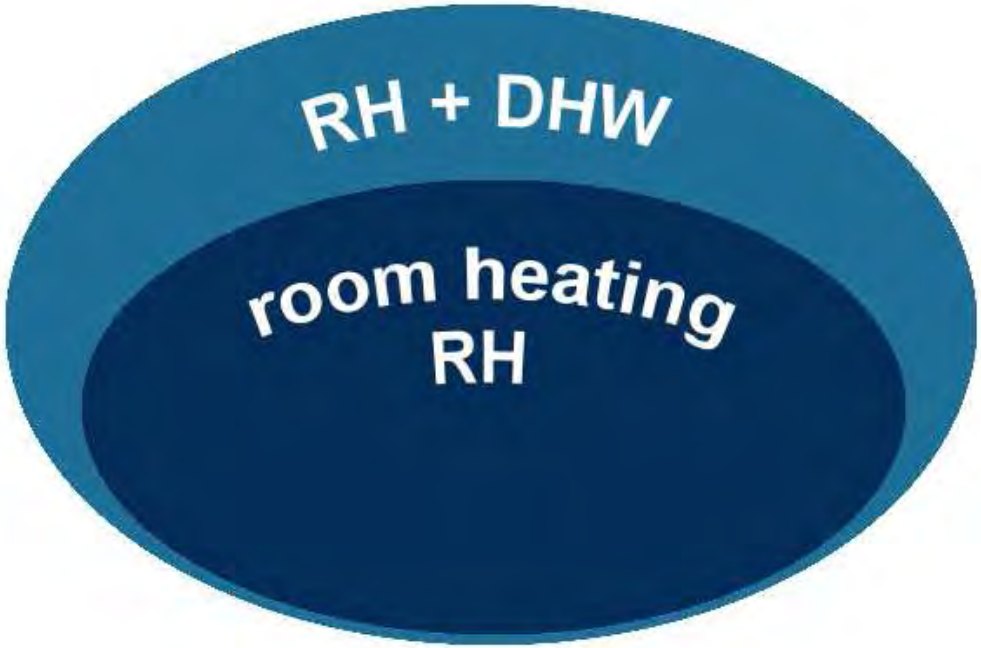
NZE – Balance frames

Balance – : Consumption of fossil fuels

Balance + : Feed in of renewably generated energy

Consumption side (balance -)

Consumption side (balance -)



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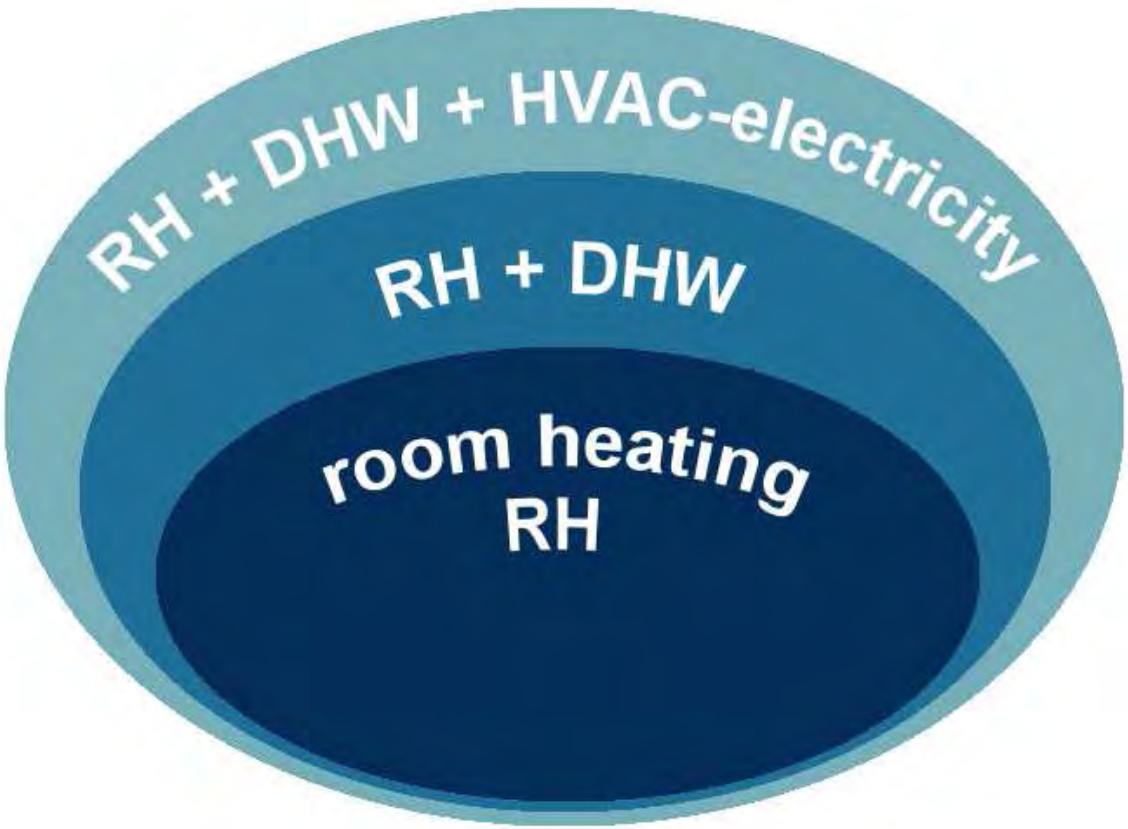

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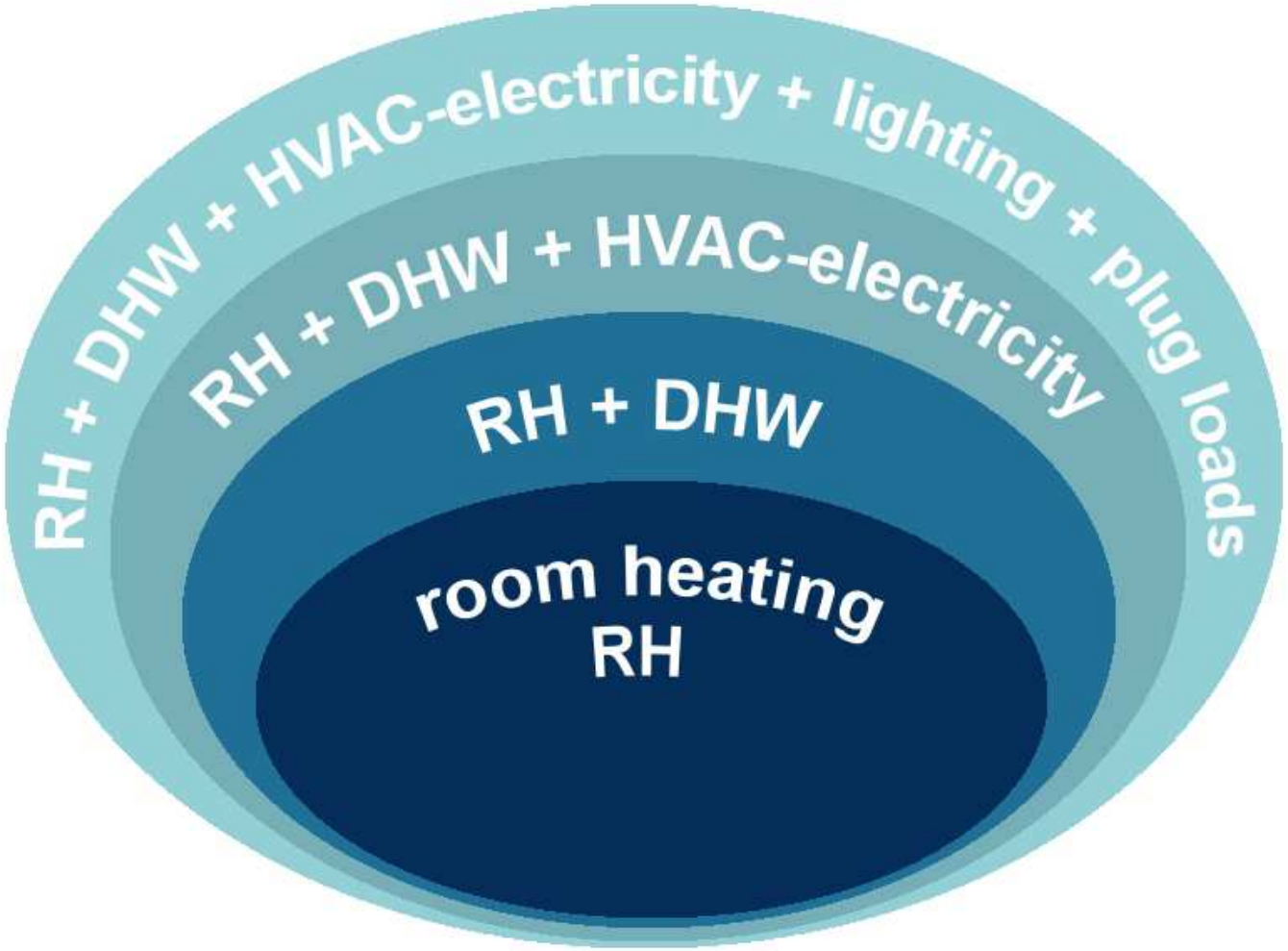

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Renewables fed into the grid (balance +)

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Renewables fed into the grid (balance +)

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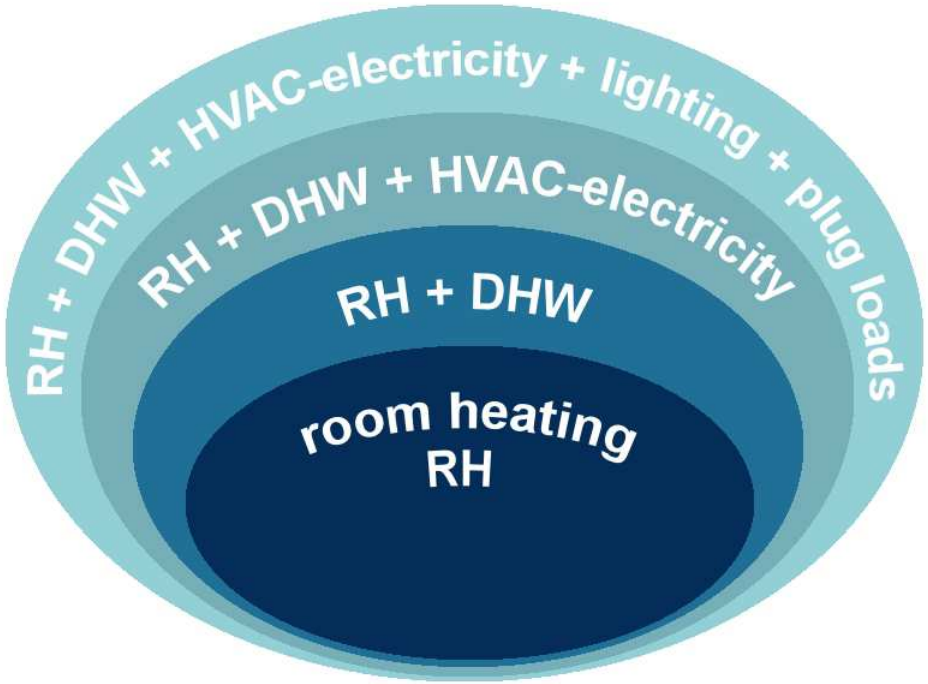

Renewables fed into the grid (balance +)

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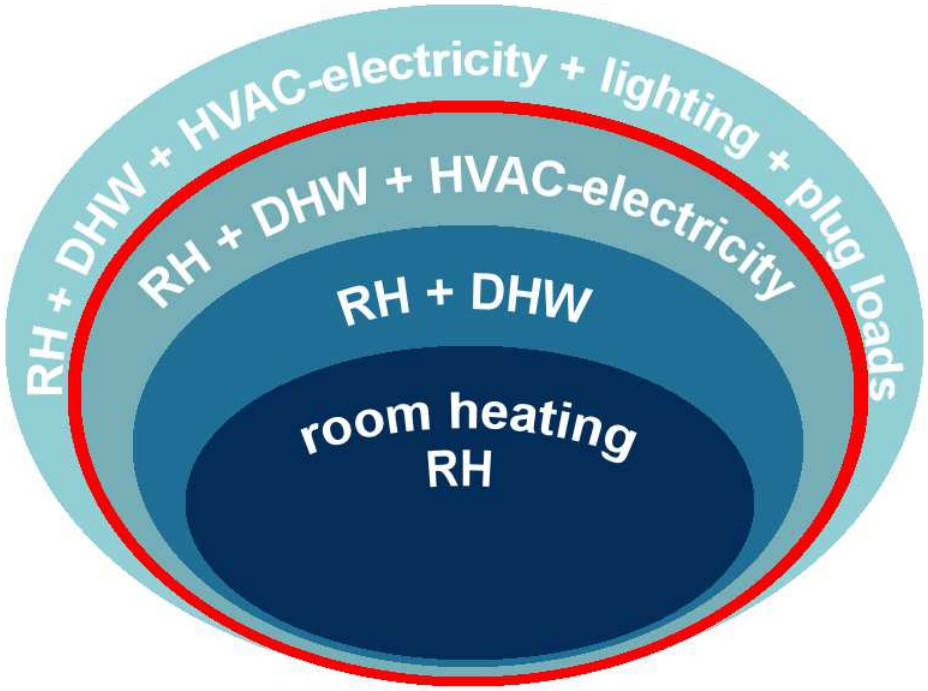
Consumption side (balance -)

Renewables fed into the grid (balance +)



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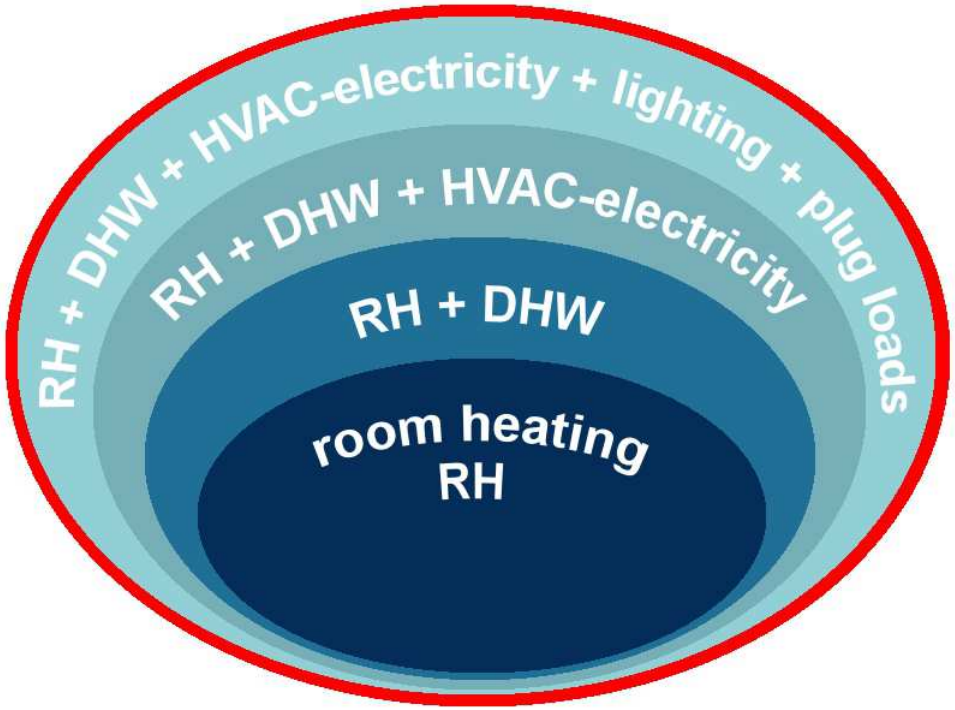

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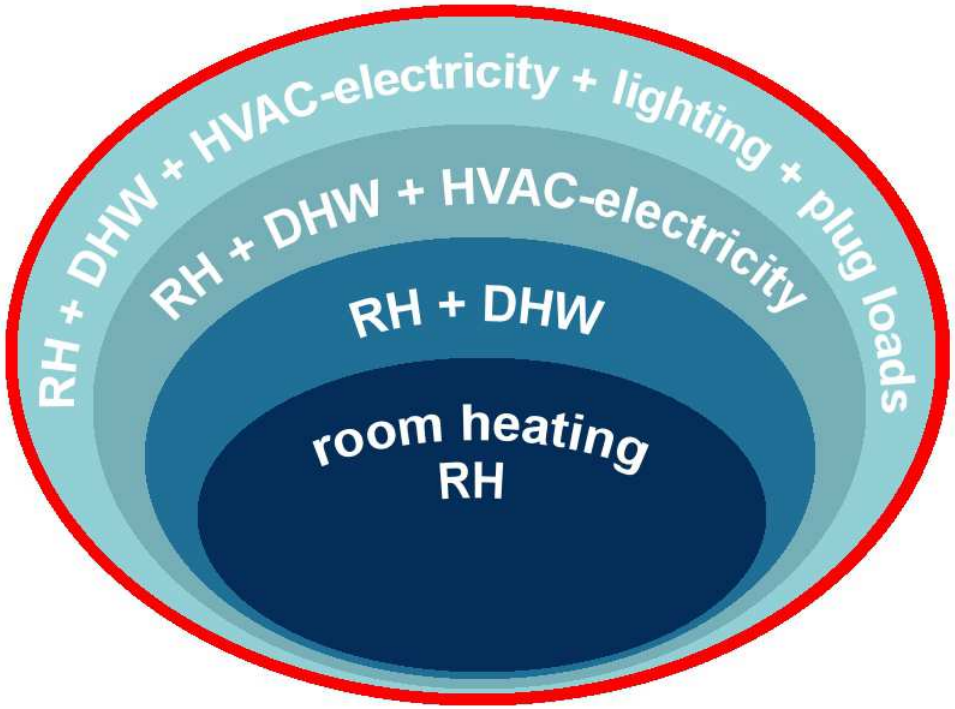

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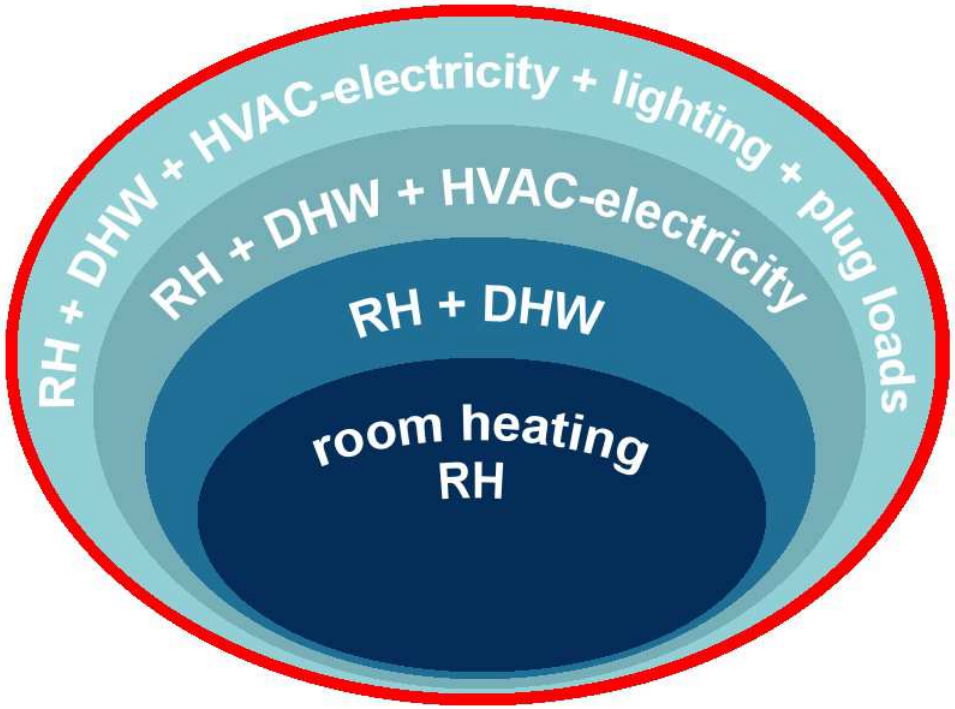

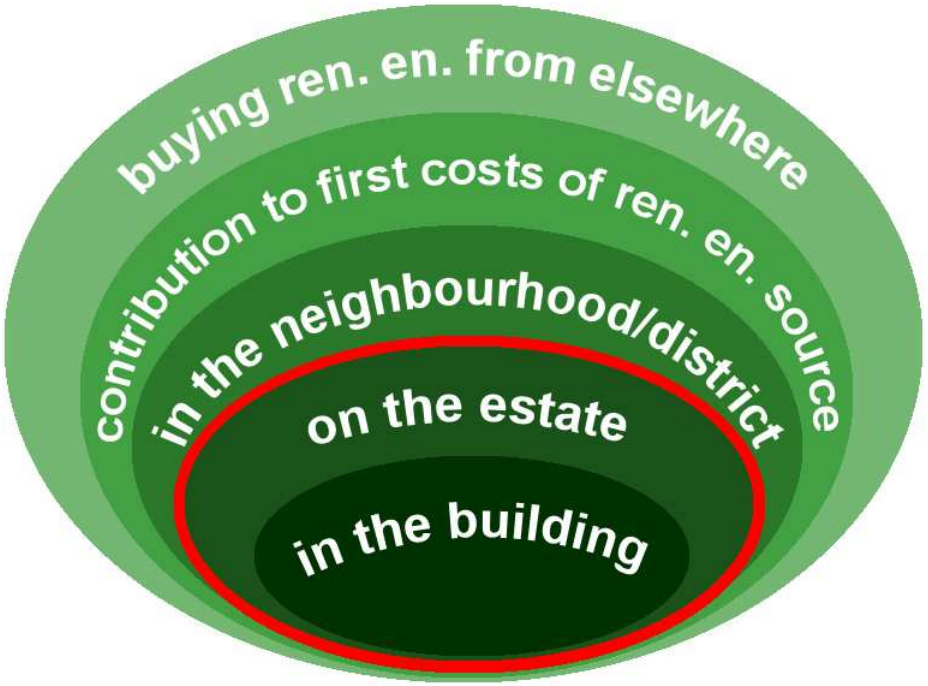

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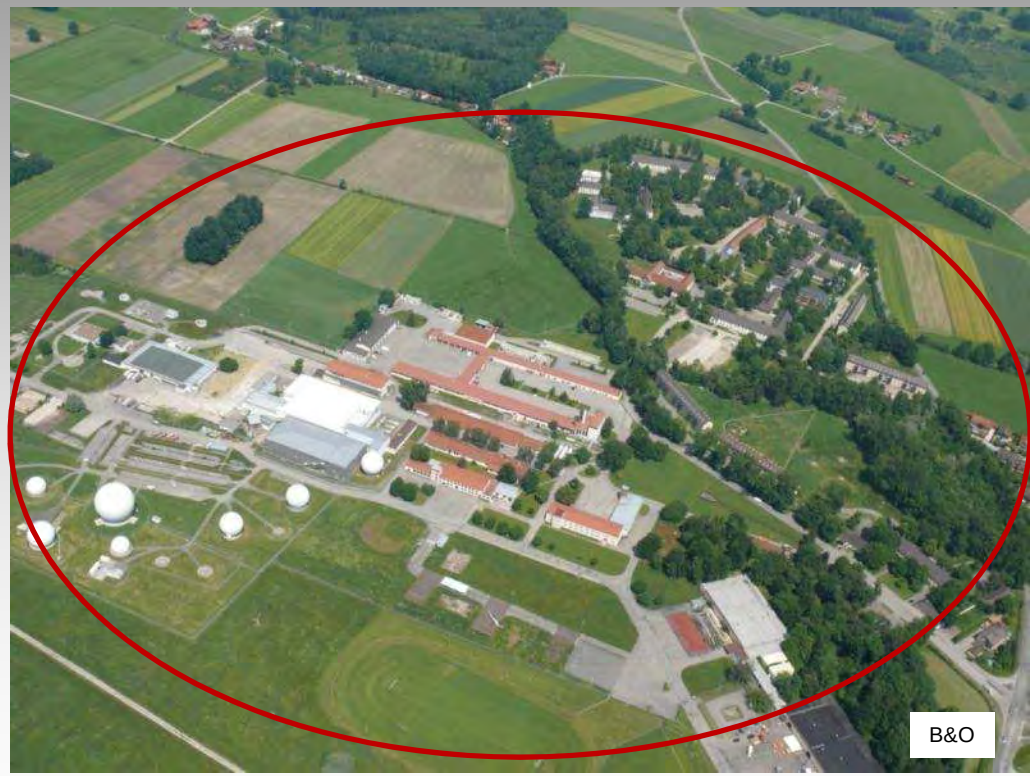
NZE – Examples

Bad Aibling
From military base to zero energy community

- Total area 170 acres = 70 hect.
- 3-Reich German air base occupied by U.S.Army after WW II
- Radio communications and intelligence base
- 1,400 employees and residents
- 52 building complexes, 72,000 m^2 (~775 ksqft) usable area
- District heating system fuel oil

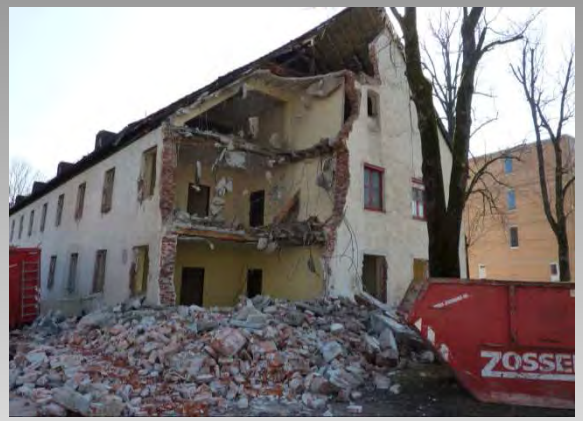
- Abandoned in 2004
- Bought by B&O in 2006



Ways to optimize existing buildings

- Room heating target:
  25 … 75 kWh/m2a
  ~8 … 24 Mbtu/sqft
- Insulation 15-30 cm (6-12 in) thick
- Windows with triple glazing
- Ventilation systems with 80 – 90% air heat recovery
- Partly solar roofs with thermal collectors
- Highly efficient heating / hot water technology with heatpumps, storage tanks and intelligent controls

In the center of the area: New buildings replacing old ones

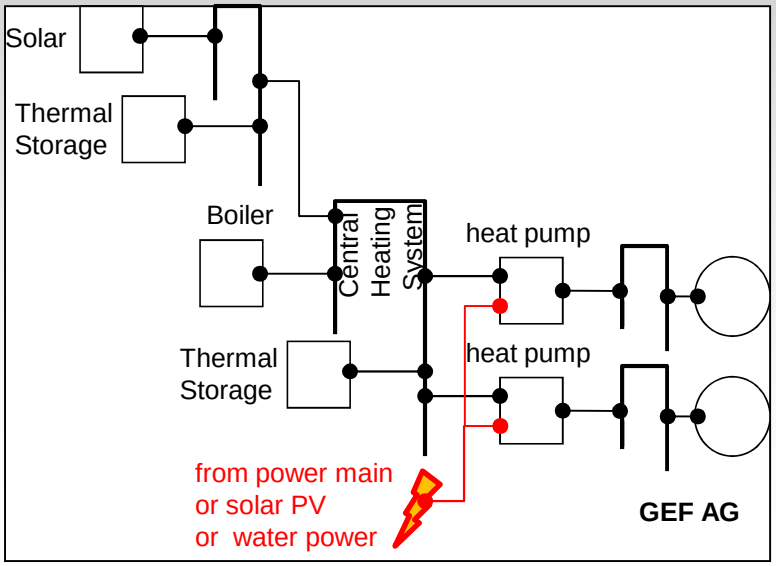


- **Detached houses in PH-standard 15 - 30 kWh/m2a = 5 – 10 Mbtu/sqft**
- **Multifamily houses close to PH-Standard**
- **Built with innovative prefabricated wooden construction**
- **Easy and fast to assemble**
- **Appropriate for housing companies to enhance their building portfolio**

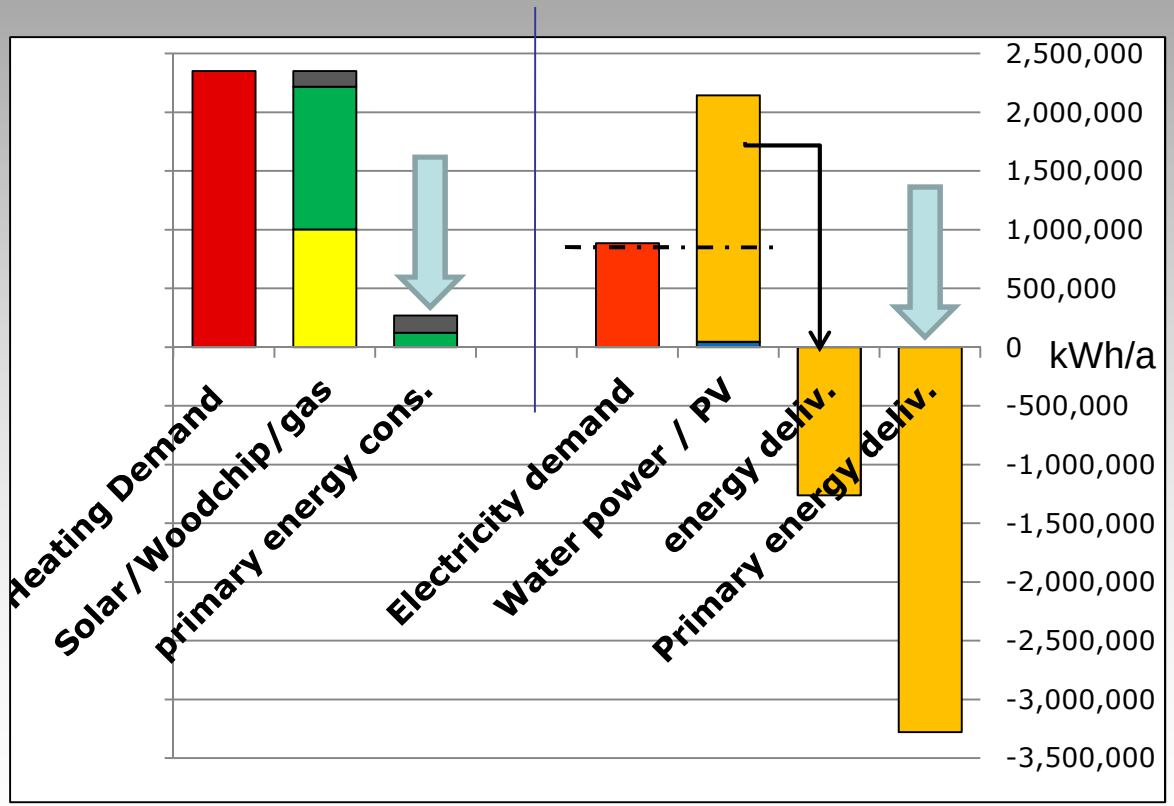
Northern Part

Selected supply option – Solar Central System - not yet fully implemented -

- About 3,600 m² (39,000 sqft) solar collectors feeding the solar heat into the heating grid
- 30–40 m³ (8,000-10,000 gal) central solar storage tank
- Heat pumps in every building to make better use of solar energy
- Central woodchip heating 500 kW (1,7 Mil Btu/h)
- Peak load heating with gas fired boiler
- Small water power station
- 20,000 m² (215,000 sqft) Photovoltaik area in western part of the site



Energy balances – Northern area



15 buidlings with 26,800 m² (290 ksqft) usable area

3,600 m² (39 ksqft) solar collect.

15,000 m² (161ksqft) PV-modul.

Primary energy consumption

Without PV: 92 kWh/m²a = 29 Mbtu/sqft

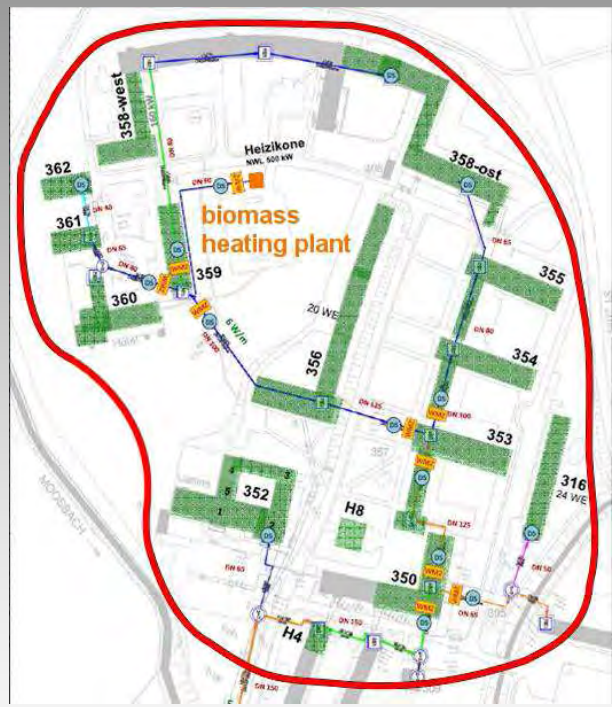
With PV: - 112 kWh/m²a = - 36 Mbtu/sqft

Costs and Economics

Woodchip heating 500 kW , gas peak load 500 kW
1.4 Million $ including taxes
Woodchip heating against gas h. ROI : 7 – 12 years

High efficient building retrofit: 60 – 90 $ / sqft
ROI normally: 20 – 30 years
In Bad Aibling additional benefit by repair/overhaul
Cheaper prices because investor is construction company with a high leverage on the market

PV array 15.000 m2 = 160.000 sqft: 5.2 Million $
ROI: 8 – 12 years, high subsidies in Germany



Implementation

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Master plan Community Center, Biberach

Mixed pattern of use, many retirement homes

Owner: Public foundation
Today: 10 buildings, total 15,000m² (161 ksqft)
2020: 16 buildings, total 28,000m² (300 ksqft)

Targets:
- **Minimize energy consumption in all buildings**
- **Carbon-emission neutral heating supply**

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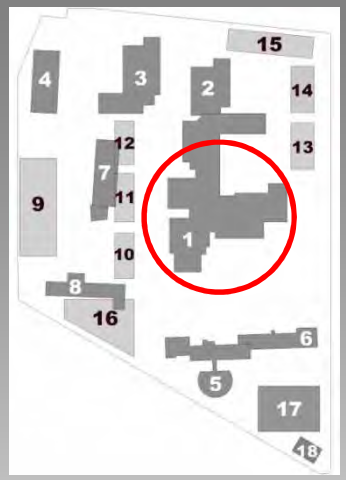

Demand side: Optimization of buildings. Example Bldg. 1 / retrofit

- **Outer wall: 16 cm insulation. Roof: > = 20 cm insulation**
- **Windows: Highly efficient triple glazing (U-value < 1.0 W/m2K)**
- **Walls / ceilings between warm and cold rooms: > 8 cm insulation**
- **Ventilation systems with air heat recovery**
- **Maximum use of daylight, sophisticated control system for artificial light**
- **Water-saving technologies in kitchens and bathrooms**
- **Special measures to keep building cool in summer without air-condition**

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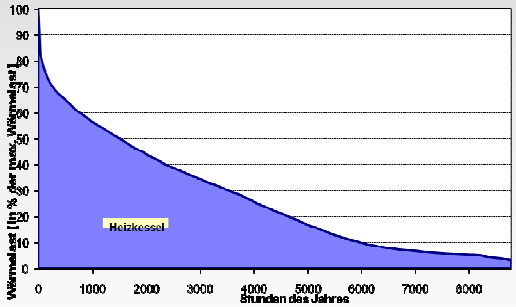
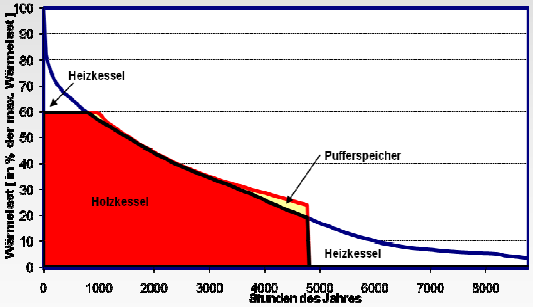
Heating supply system: 6 options

1. Gas heating plant = basic reference point
2. Woodchip heating + gas boiler for peak load
3. Woodchip heating + gas-fired cogeneration + gas boiler for peak load
4. Woodchip heating + rapeseed oil-fired cogeneration + gas boiler for peak load
5. Woodchip heating + wood gas-fired cogeneration + gas boiler for peak load
6. Woodchip heating + biogas-fired cogeneration + gas boiler for peak load

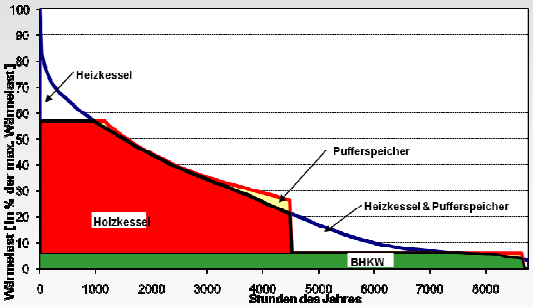
Annual load duration curves



Option 1: Gas heating



Option 2: woodchip heating



Option 5: woodchip h. + wood gas cogen.

Calculations: Steinborn

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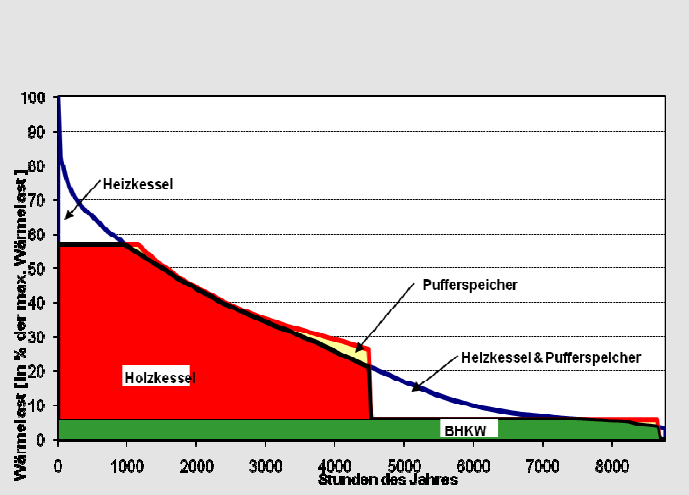

Selected for Pilot Project

We focus on woodchips heating + wood gas cogeneration

Annual load duration curve shows high percentage of renewable energy usage

Principle: Combustion motor using wood gas from smoldering woodchips at 1,400 F without oxygene

Heating power: 70 kW
Electric power: 30 kW

Maintenance: 150 h/a
Market penetration: „Early adopters“ phase

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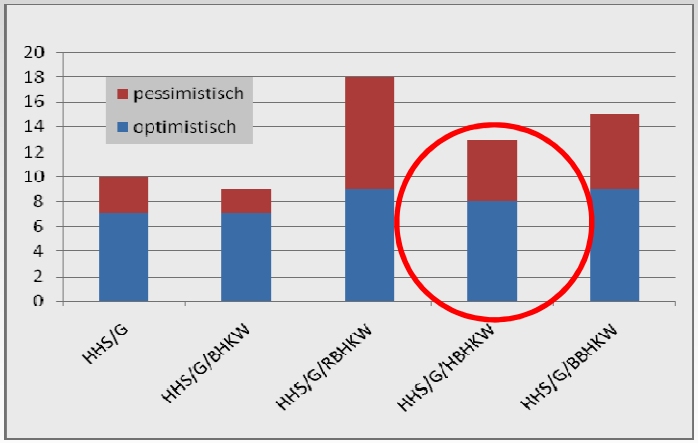
Costs and Economics

Woodchip cogeneration 70 kW_{therm}/ 30 kW_{el}:	290,000 $
Woodchip heating plant 600 kW including building shell:	1,200,000 $
Gas fired peak load boiler 700 kW:	240,000 $
Costs for planning, engineering etc.	260,000 $
TOTAL COSTS:	1,990,000 $



Though investment costs are 1.6 million $ higher than a simple gasfired heating,
ROI is only 8 to 12 years (using dynamic cost calculation).

CO2-Emissions are 93 % less than of a normal, modern gas heating,
500 m^2 (5.4 ksqft) PV for neutral balance

NZE – Lessons learnt

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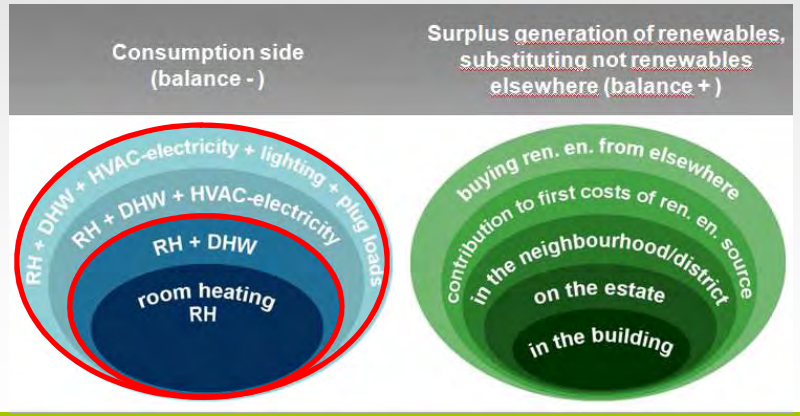
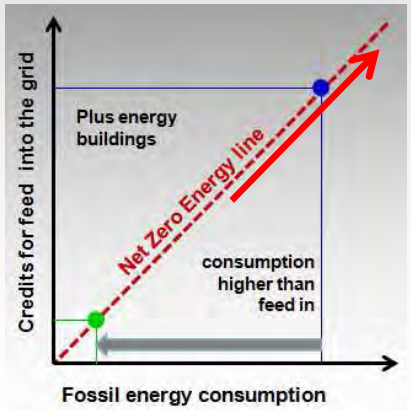
Some experience and lessons learnt (1)

- **Bad Aibling: Decentralised feed in of solar gains into the main feed line turned out to be a challenge for controls and operating schedules.**
- **For large projects we recommend today: Use decentralised solar roof gains only in the „own“ building or have extra solar piping to a central storage tank (but then beware of piping losses!)**
- **Biberach and West Point: A very low demand is not possible.**
  → Biberach (BC): Limiting the NZE goal to heating and DHW balance
  → West Point (WP): Installing cogeneration with renewable fuel





Some experience and lessons learnt (2)

- **Projects in existing building stock often have no optimal solar exposition**
  → Cogeneration with biomass is often the better way
  → Because solar thermal and cogen compete economically, the solar thermal systems tend to be omitted totally, if cogen is chosen.
- **Solar PV is less efficient than solar thermal, but it does not suffer piping losses and is more useful for being offset against fossil fuels consumption**
- **All in all: Large NZE projects with heating grid will rather build on biomass + PV then on solar thermal supply.**
- **Coming from „One building projects“ it turned out to be quite different when tackling large installations or city districts:**
  → We dont see the final success at end of the project because those projects often take 10 to 20 years to be implemented comprehensively.
- **That means: „Open solutions“ are needed, which help to integrate technologies and approaches of the future.**

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NZE – West Point roadmap

Roadmap for NZE West Point masterplan

- Describe the exact outline of the NZE area
- Check boundary conditions (climate, river temperatures, solar and biomass potentials, budget plans, development schedules, retrofit programms etc.)
- Compile inventory of existing buildings, distribution and supply systems Check needs for repair and modernization,
- Check town planning, define building improvements and target consumptions.
- With a target situation inventory: Compile annual load duration curves
- Develop alternatives for the overall solution (including buildings, distribution, supply systems)
- Assess the alternatives, decide for one solution and optimize it

Basic ideas for conducting NZE West Point project

- **Begin with energetic upgrade of buildings (=reduce consumption)**
- **Switch to hot water instead of steam distribution, replace some of the old boilers by biomass cogen**
- **With more buildings improved and lower loads:
Reduce power output of old boilers step by step**
- **Final target: All buildings are in the best energy standard which is reasonable, powered completely by biomass cogen, fossil fuels are only used for peak loads.**
- **With some additional measures like PV
a Net Zero Energy balance should be possible !**