Aalto University
School of Engineering

Energy efficiency of the heat pump solutions in nZEBs

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Juha Jokisalo and Tuomo Niemelä

HVAC-group
Department of Energy Technology
Aalto University

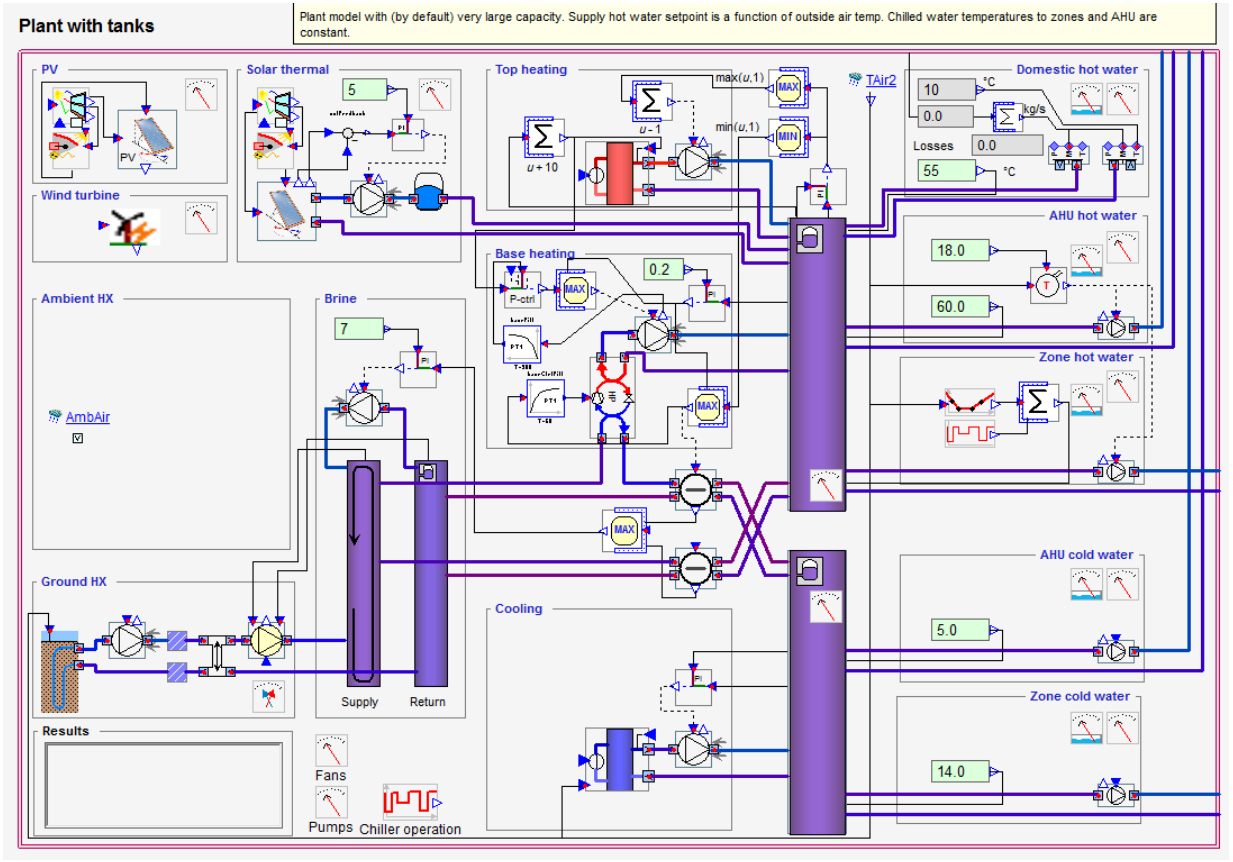
Background

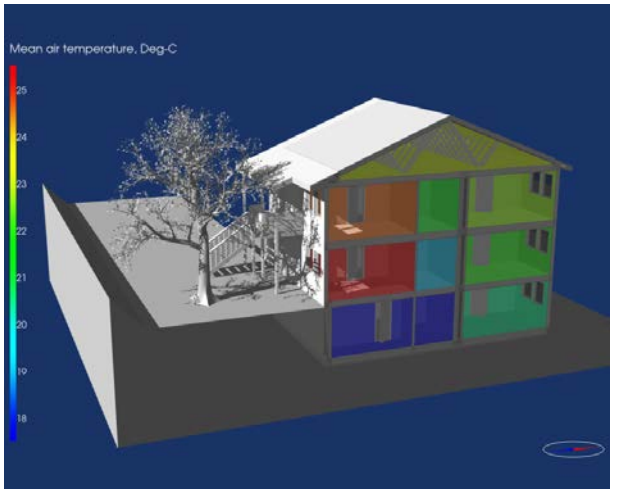
- Proposal for the Finnish nZEB levels for new buildings was defined by Finzeb project.
- Studied heat pump solutions were carefully selected by Aalto, Greennet Finland, SULPU and VTT together with participating companies.

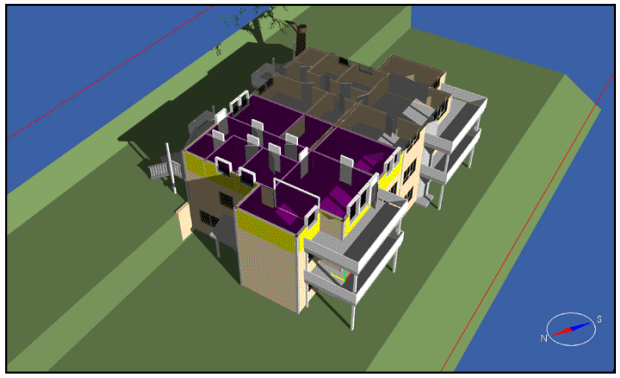
IDA-ICE 4.6 building simulation tool

(IDA – Indoor Climate and Energy)

- Detailed simulation of heat pump and hot water storage system by ESBO-plant







Source: http://www.equa.se/

New detached house

- Net heated floor area 180m²
- U-values, W/m²K
  - Ext wall: 0.08
  - Roof: 0.05
  - Base floor: 0.1
  - Windows: 0.8
- Air tightness q_{50} = 0.6 m³/m²h
- Mec. supply and exhaust ventilation system (HR 80%)
- Supply and exhaust air flow rate 0.4 dm³/s,m²

System concepts for detached house

	CONCEPT			
	1: GSHP	**2: AWHP**	**3: EAHP**	**4: AAHP**
Main heating system	**Ground source heat pump**	**Air to water heat pump**	**Exhaust air heat pump**	**Outdoor air to ventilation supply air heat pump**
Heating power and COP	8.9kW COP: 4.85 (0/35°C)	8.0kW COP: 4.4 (+7/35°C)	4.9kW COP: 3.0 (20/35°C) (min. temp. of extract air -15°C)	1.9 kW COP: 3.8 (-10/37°C)
Backup heating	Electricity	Electricity	Electricity	Electricity (reheat coils in the supply ducts)
Heat distribution system	Floor heating (40/30°C)	Floor heating (40/30°C)	Floor heating (40/30°C)	Supply air heating + El. floor heating in bathroom
Hot water storage tank capacity	180L 300L (with solar thermal)	200L 300L (with solar thermal)	205L 300L (with solar thermal)	290L 300L (with solar thermal)
Cooling	Free cooling with boreholes	Free cooling with horizontal ground loop	Free cooling with horizontal ground loop	The main heating system in a cooling mode + air to air heat pump in a bedroom
Solar thermal system / area	Flat plate 12m²	Flat plate 12m²	Flat plate 12m²	Flat plate 12m²
PV area	18m² (typical) 36m² (large)	18m² (typical) 36m² (large)	18m² (typical) 36m² (large)	18m² (typical) 36m² (large)
Lighting	Standard (11W/m²) LED 4.8 W/m²)	Standard (11W/m²)	Standard (11W/m²)	Standard (11W/m²)

New apartment building

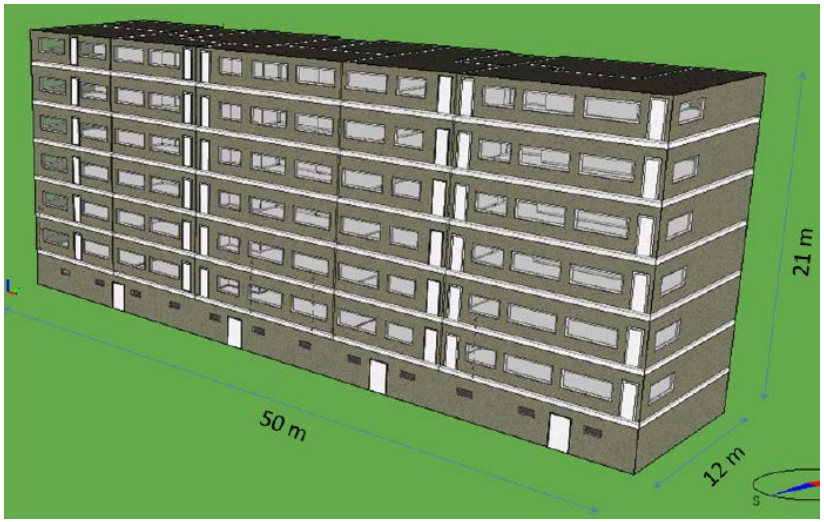
- Net heated floor area 3098m²
- U-values, W/m²K
  - Ext wall: 0.17
  - Roof: 0.09
  - Base floor: 0.16
  - Windows: 1.0
- Air tightness q_{50} = 1.4 m³/m²h
- Mec. supply and exhaust ventilation system (HR 75%)
- Supply and exhaust air flow rate 0.5 dm³/s,m²

System concepts for the new apartment building

	CONCEPT		
	1: GSHP	**2: AWHP**	**3: DH**
Main heating system	**Ground source heat pump**	**Air to water heat pump**	**District heating**
Heating power and COP	61 kW COP: 3.6 (0/45°C)	64 kW COP: 4.2 (+7/35°C)	-
Backup heating	Electricity	Electricity	-
Heat distribution system	Low temperature radiators (45/35 °C)	Low temperature radiators (45/35 °C)	Low temperature radiators (45/35 °C)
Hot water storage tank capacity	2500L	2500L	2500L (with solar thermal)
Cooling system	Free cooling with boreholes	Mechanical water chiller system	Mechanical water chiller system
Cool distribution system	Ventilation supply air (10/15°C)	Ventilation supply air (10/15°C)	Ventilation supply air (10/15°C)
Solar thermal system / area	Flat plate 78m²	Flat plate 78m²	Flat plate 78m²
PV area	66m² (typical) 200m² (large)	66m² (typical) 200m² (large)	66m² (typical) 200m² (large)
Lighting	Standard (11W/m²) LED (4.8 W/m²)	Standard level (11W/m²)	Standard level(11W/m²)

1960s apartment building

- Year of construction 1960
- Net heated floor area 3698m²
- U-values, W/m²K
  - Ext wall: 0.6
  - Roof: 0.34
  - Base floor: 0.4
  - Windows: 2.5
- Air tightness q_{50} = 6 m³/m²h
- Mec. exhaust ventilation system
- Supply and exhaust air flow rate 0.4 dm³/s,m²



System concepts for the 1960s apartment building

	CONCEPT			
	1: DH	**2: EAHP**	**3: GSHP**	**4: AWHP**
Main heating system	**District heating**	**Exhaust air heat pump**	**Ground source heat pump**	**Air to water heat pump**
Heating power and COP	-	39kW COP: 3.7 (0/45°C) (min. temp. of extract air +5°C)	156kW COP: 3.7 (0/45°C)	128 kW COP: 4.2 (+7/35°C)
Backup heating	-	District heating	District heating	District heating
Heat distribution system	Original radiators (80/50 °C)	Low temperature radiators (45/35 °C)	Low temperature radiators (45/35 °C)	Low temperature radiators (45/35 °C)
Hot water storage tank capacity	2500L (with solar thermal)	2500L	2500L	2500L
Cooling	-	-	-	-
Solar thermal system / area	Flat plate 90m²	Flat plate 90m²	Flat plate 90m²	Flat plate 90m²
PV area	66m² (typical) 200m² (large)	66m² (typical) 200m² (large)	66m² (typical) 200m² (large)	66m² (typical) 200m² (large)
Lighting	Original (11W/m²)	Original (11W/m²)	Original (11W/m²)	Original (11W/m²) LED 4.8 W/m²)

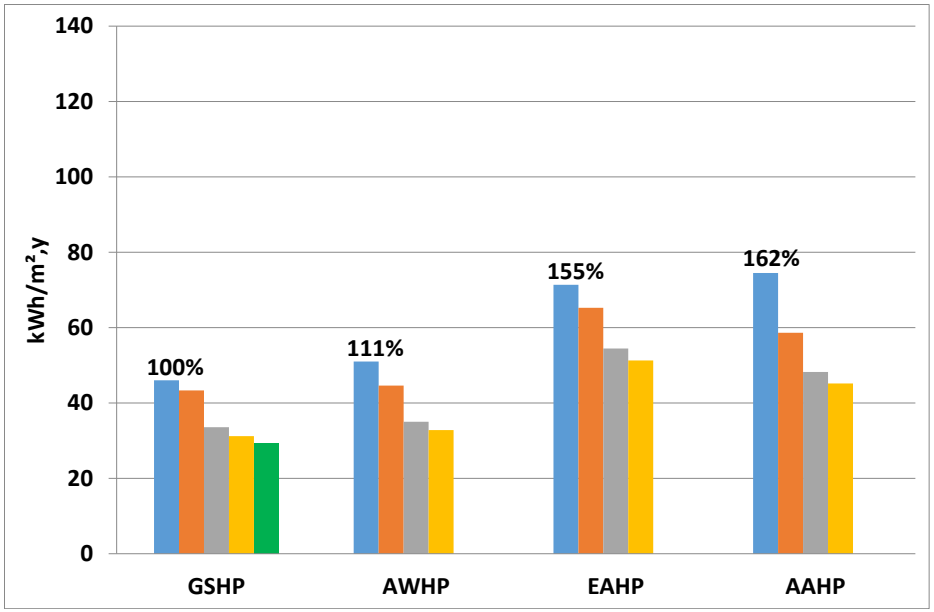
Finnish energy performance value of buidings: E-number

$$E = \frac{\sum_i \left(E_{DE,i} \cdot f_{DE,i} \right)}{A_{net}}$$

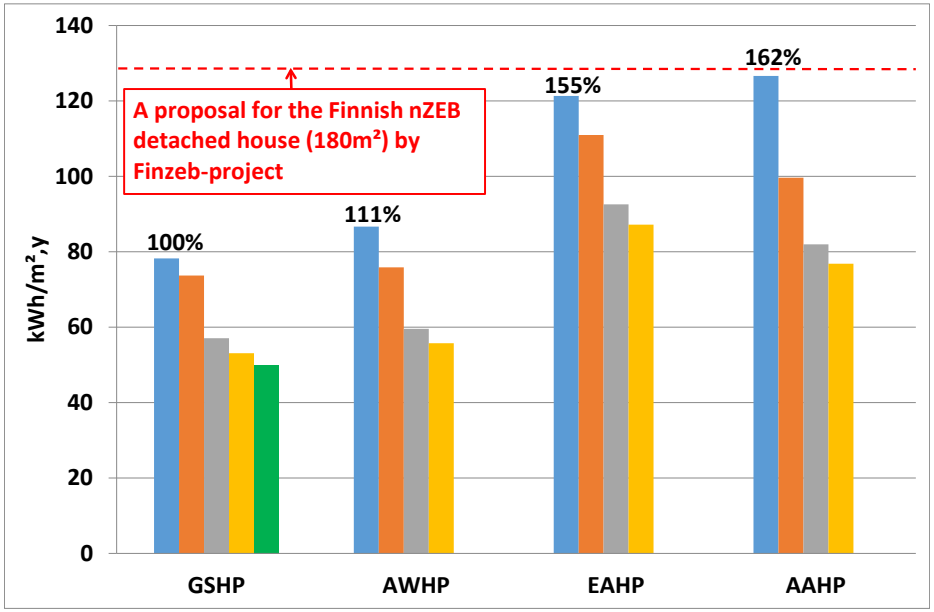
- $E_{DE,i}$ = Total delivered energy of building, kWh
- $f_{DE,i}$ = Weighing factor of energy form i
  - 0.7 for district heating,
  - 1.7 for electricity,
  - 1.0 for fossil fuels,
  - 0.5 for renewable fuels,
  - 0.4 for district cooling
- A_{net} = heated net floor area of the building, m^2

Detached house
Delivered energy and E-number

- Total delivered energy:



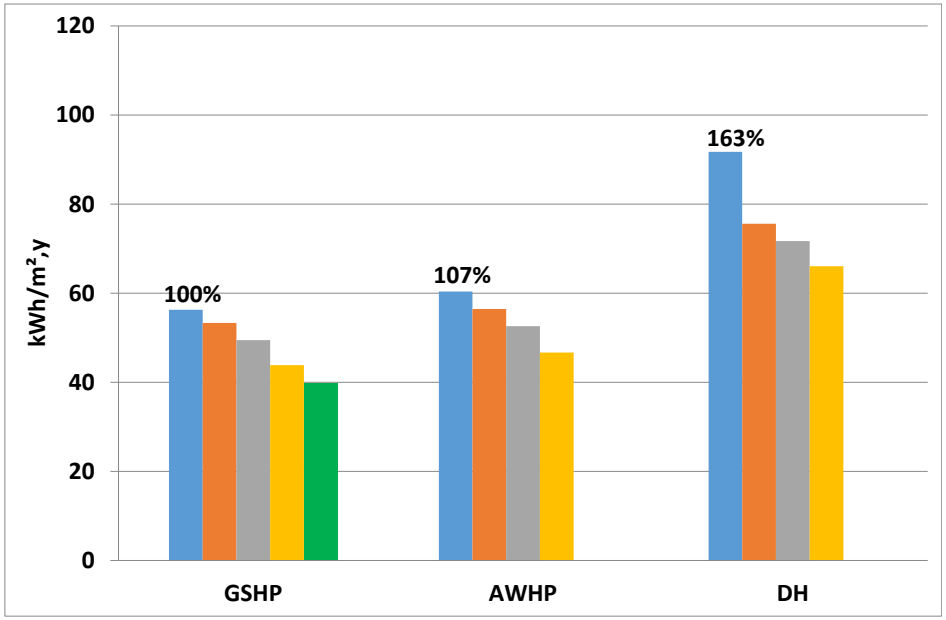
- E-number:

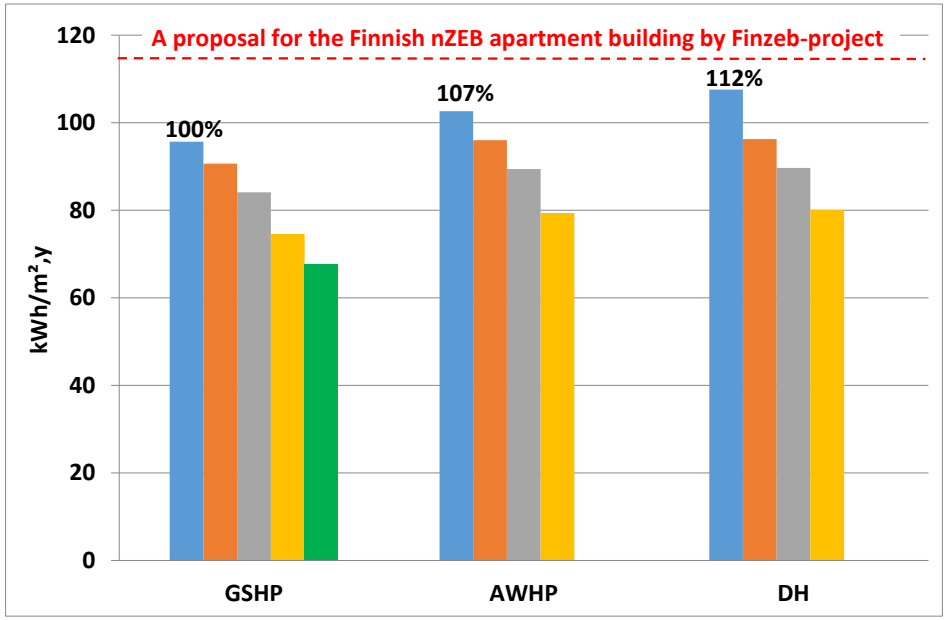


No Solar Systems ST(12m²) ST(12m²)+PV(18m²) ST(12m²)+PV(36m²) ST(12m²)+PV(36m²)+LED

New apartment building
Delivered energy and E-number

- Total delivered energy:
- E-number:

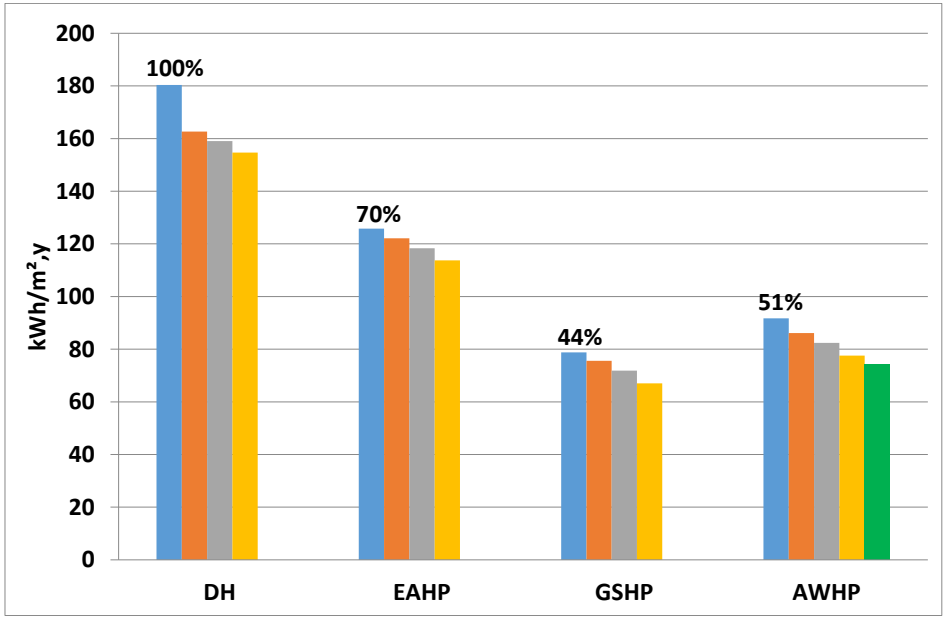




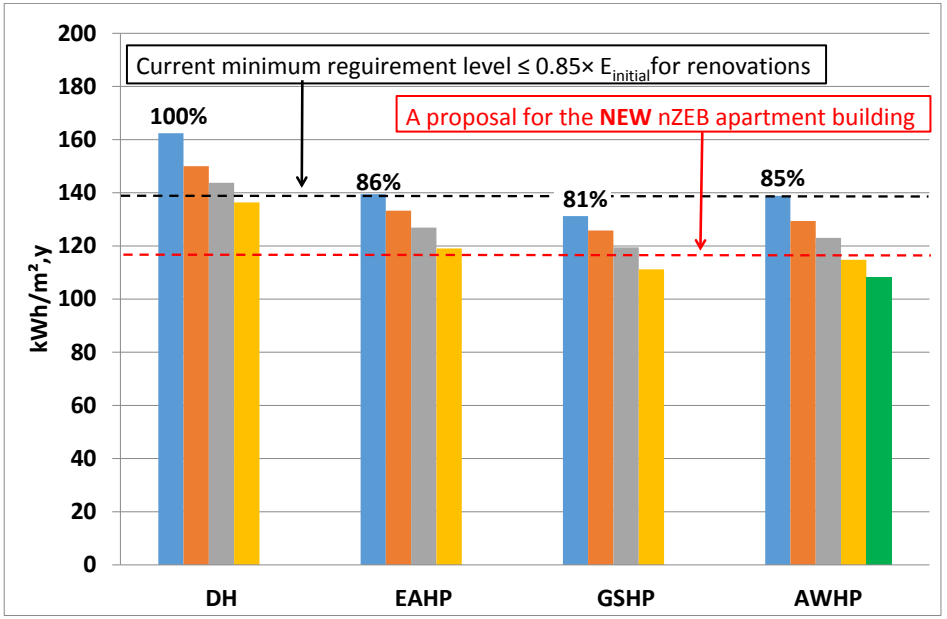
No Solar Systems ST(78m²) ST(78m²)+PV(66m²) ST(78m²)+PV(200m²) ST(78m²)+PV(200m²)+LED

1960s apartment building
Delivered energy and E-number

- Total delivered energy:



- E-number:



No Solar Systems ST(90m²) ST(90m²)+PV(66m²) ST(90m²)+PV(200m²) ST(90m²)+PV(200m²)+LED

Conclusions

- All the studied concepts of new buildings fulfill the suggested Finnish nZEB levels.
- Delivered energy consumption is significantly lower with the studied heat pump solutions compared to district heating.
- GSHP and AWHP are the most efficient solutions to save delivered energy among the studied solutions.
- The heat pumps seems to be exellent solutions for new nZEBs and for renovations