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Annual Energy Consumption in an Actual Low Energy House in the Cold Region of Japan

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Background and today's topics

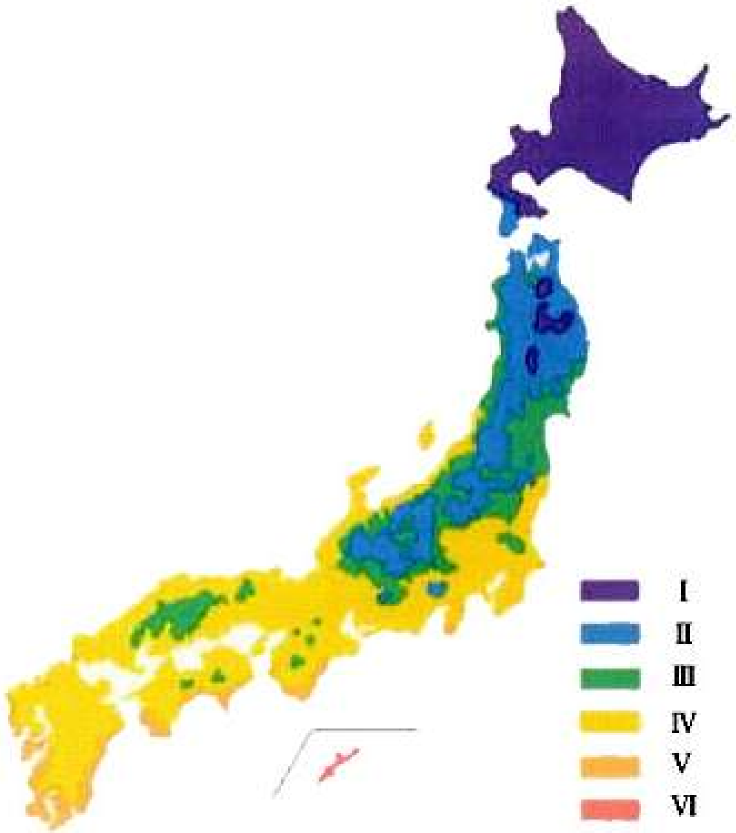
We have showed results* of a field test in a low energy house built in the cold region of Japan as a part of Task3 of the Annex32 from Japan.

In this presentation,

- we summarize the results* in terms of the seasonal heating performance and thermal environment.
- the annual electric balance is evaluated.
- further improvement is examined for the second field test as the best practice

*: All data here is from measurement
by Hokkaido University and Nissin Techno Incorporated

Next-Generation Energy Conservation Standard (for residences)



Source: *Institute for Building Environment and Enegy Conservation*

Main points

- Classify all the cities, towns and villages in Japan into 6 climatic zones
- Annual heating and cooling load [MJ/m²]

I	II	III	IV	V	VI
390	390	460	460	350	290

- Insulation:
  Heat loss coefficient (Q-value) [$W/m^2/K$]

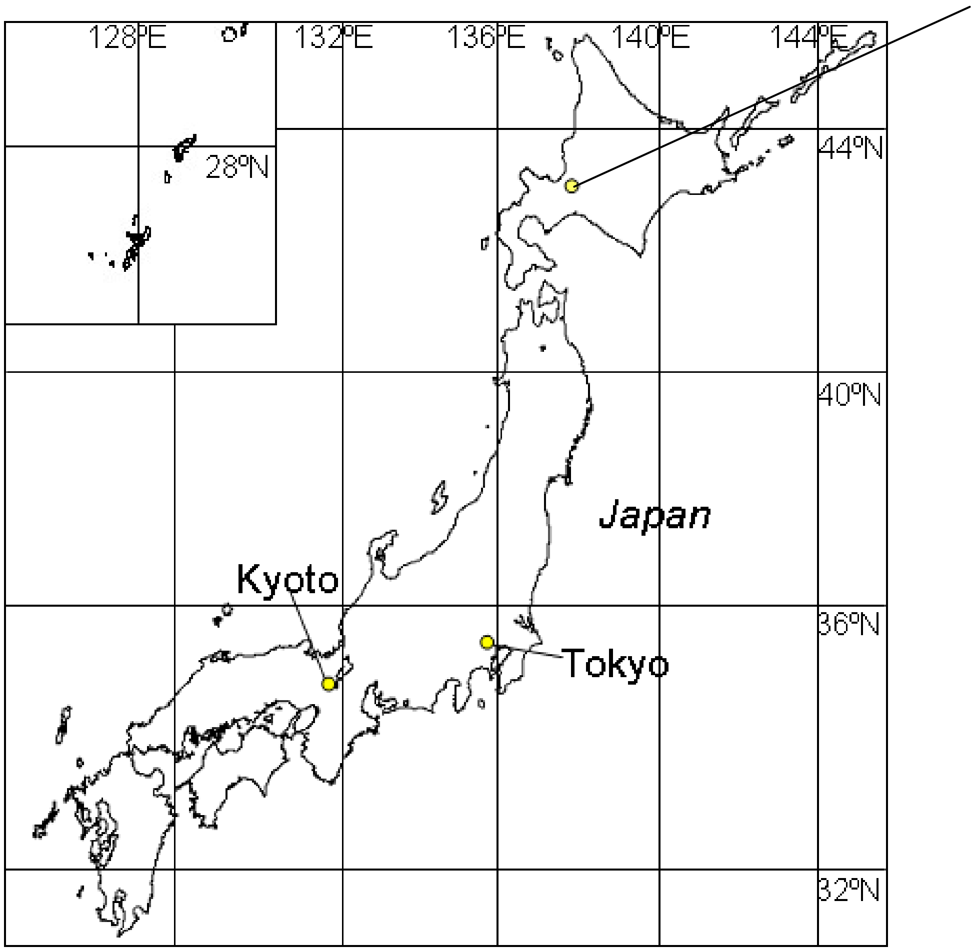
I	II	III	IV	V	VI
1.6	1.9	2.4	2.7	2.7	3.7

- Airtightness
  Equivalent clearance area (C-value) [cm^2/m^2]

I	II	III	IV	V	VI
2.0		5.0			

- Proper ventilation
  Basically more than 0.5 h^{-1}

Low energy house in *Naganuma*



Naganuma town

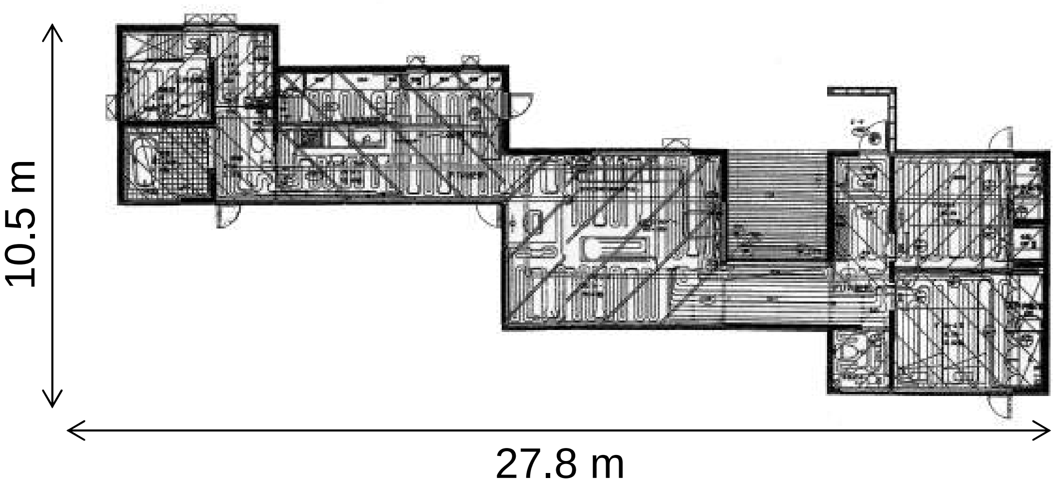
Location:

- Lat. 43º N, long. 141ºE
- 40 km southeast from Sapporo

Average temperature: 7.5°C

http://www.maoi-net.jp/index.htm

Building performance



General information

- 2 story and basement
- Habitant: 2 people
- Total floor area: 200 m^2
- Heating area: 178 m^2

Building envelope

- Floor slab: 300 mm
- Ceiling: 264 mm
- Outer wall: 198 mm
- Window area: 83 m^2 (63% facing south)
- Window: Low-E Triple filled with Argon gas (K value: 1.3 $W/m^2/K$)

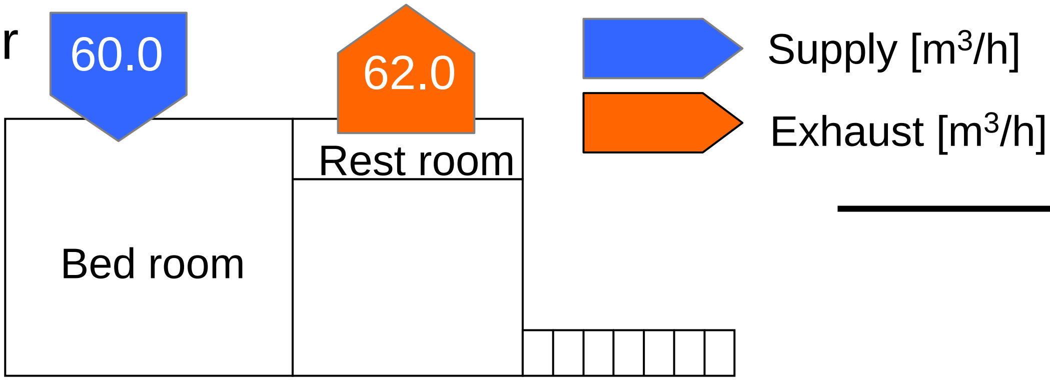
Insulation and airtightness

- Q value: 0.96 $W/m^2/K$
- C value: 0.4 cm^2/m^2

Satisfy the standard values

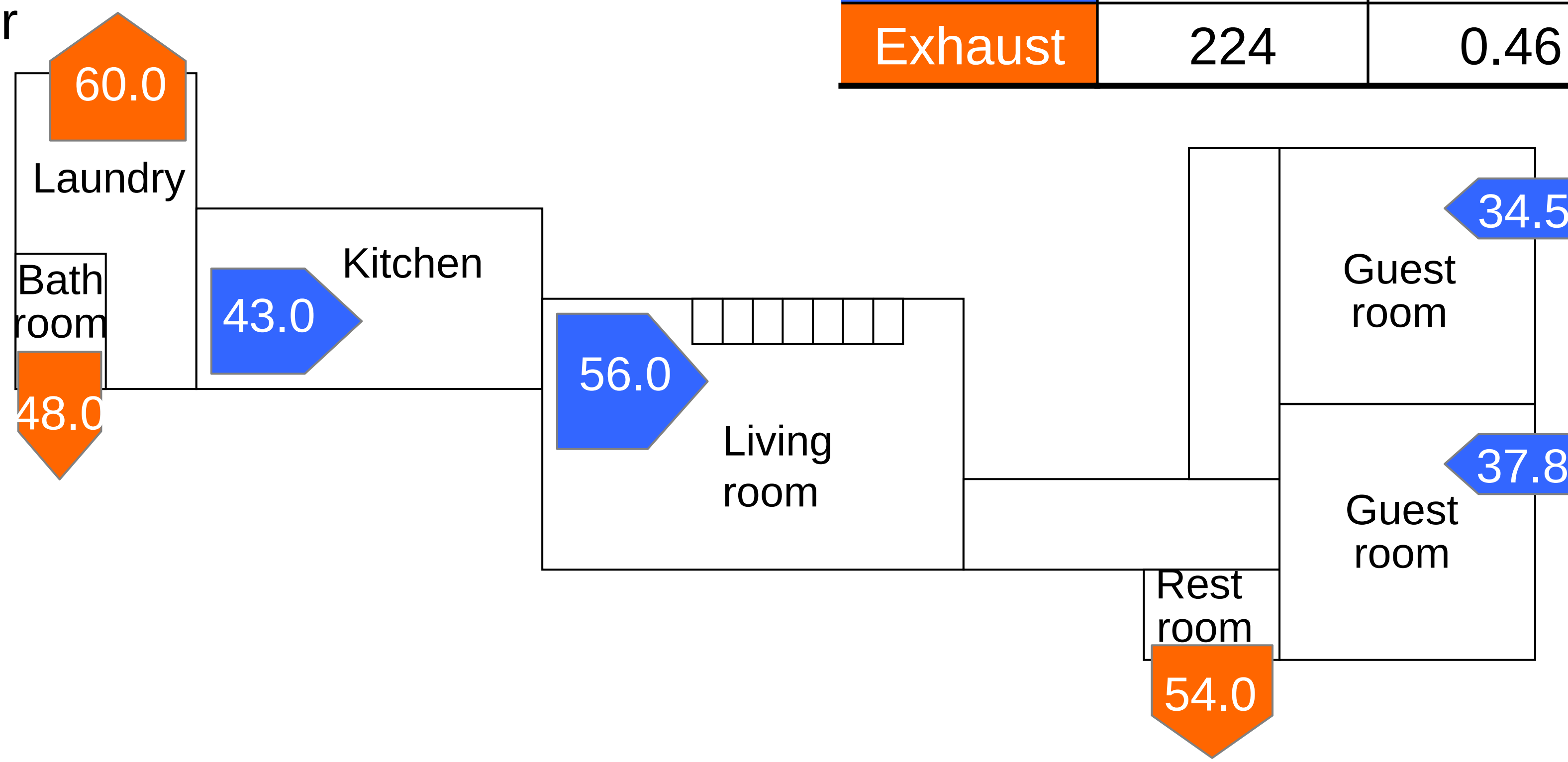
Ventilation rate

2nd floor



	Air flow volume $[m^3/h]$	Ventilation rate [1/h]
Supply	231	0.47
Exhaust	224	0.46

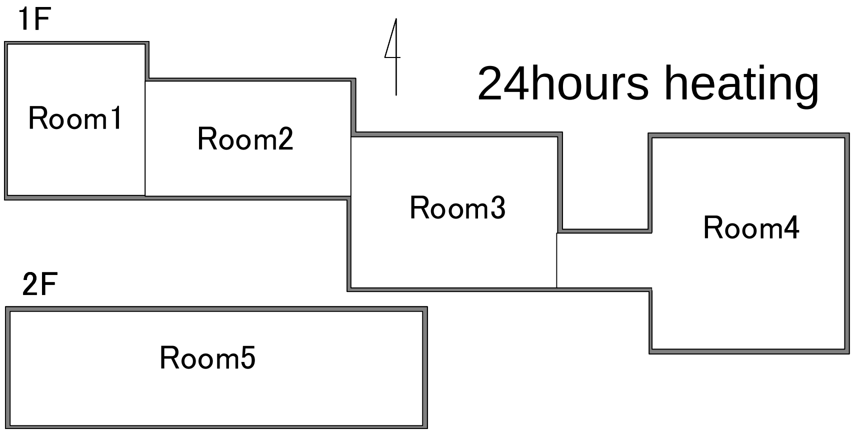
1st floor

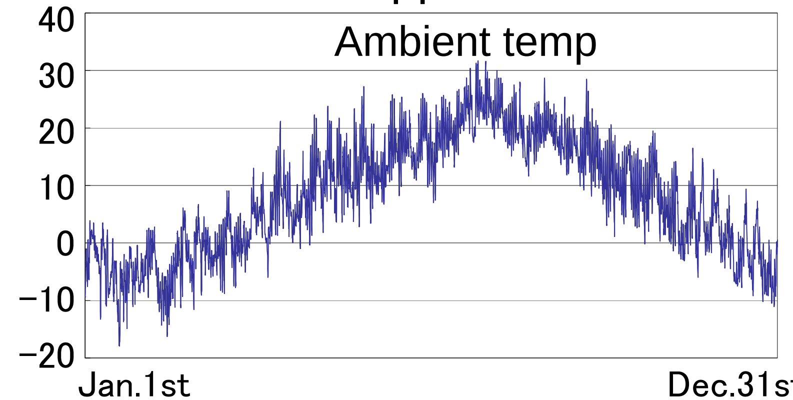


How much is the heating load?

Calculation by SMASH

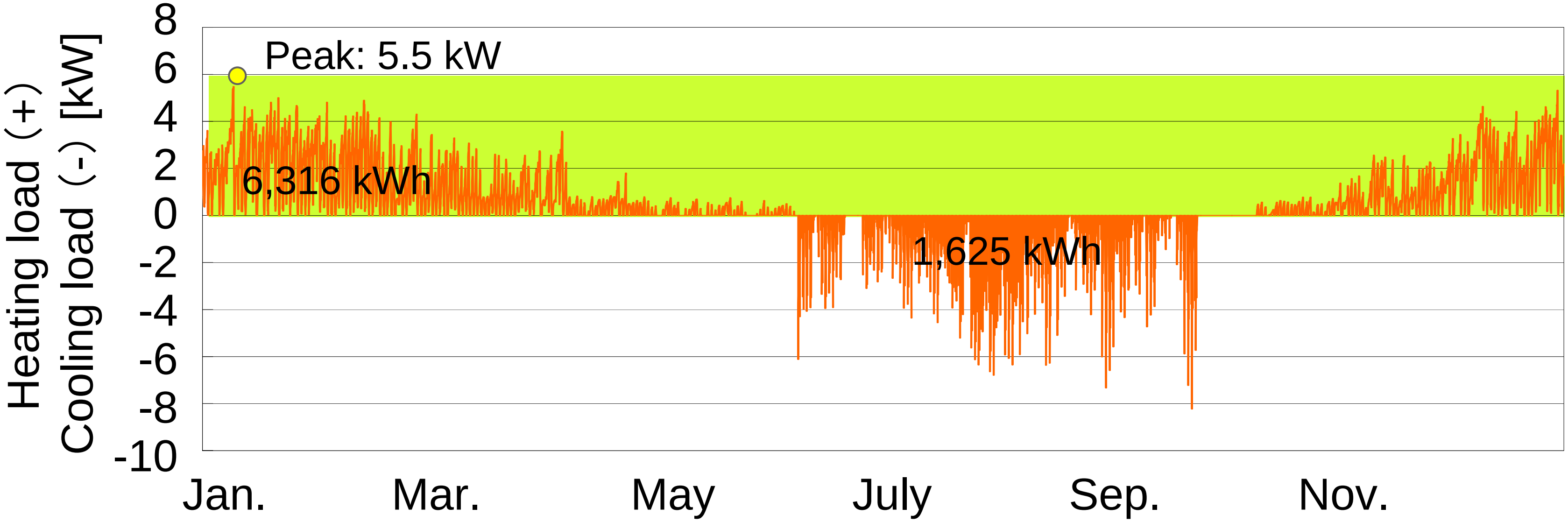
* Weather condition: Sapporo

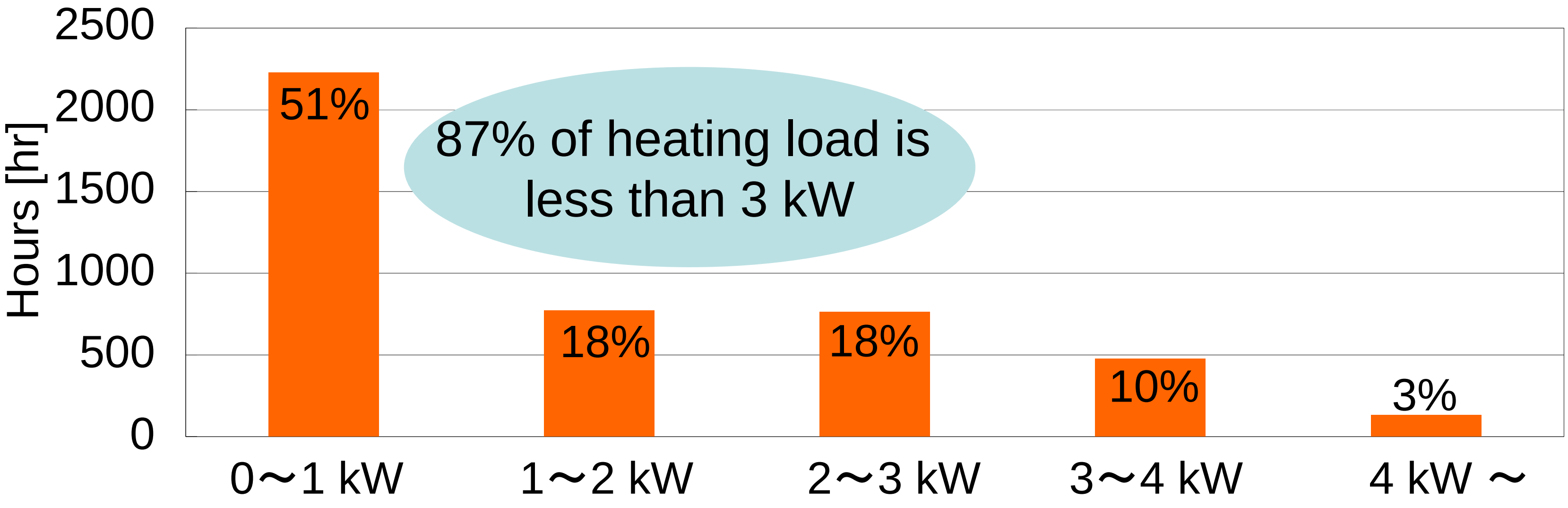




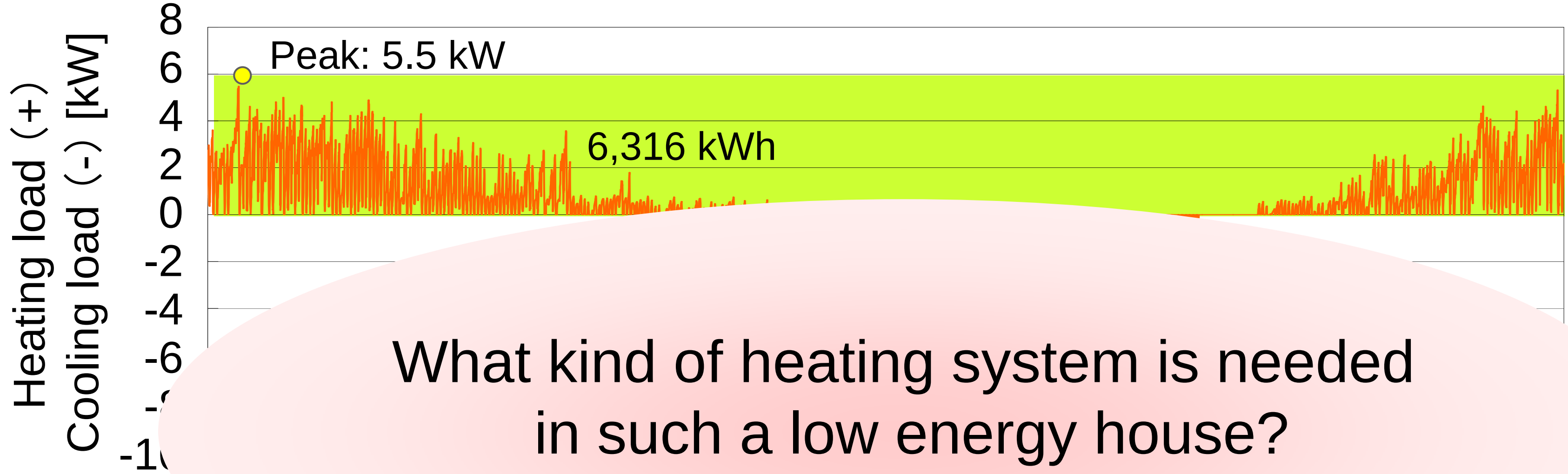
		Room1	Room2	Room3	Room4	Room5	Total
Floor area [m^2]		22.8	25.9	34.2	49.3	46.2	178.4
Ceiling area [m^2]		5.5	0.0	31.1	49.3	46.2	132.1
Outer wall area [m^2]	E	2.7	3.8	11.2	22.6	6.6	46.9
	W	10.4	0.0	5.3	15.8	6.5	38.0
	S	4.1	2.4	3.2	18.4	26.4	54.5
	N	9.1	14.8	19.7	25.9	24.5	94.0
	Total	26.3	21.0	39.4	82.7	64.0	233.4
Window area [m^2]	E	0.0	1.6	2.0	0.0	2.6	6.2
	W	0.7	0.0	8.1	0.0	0.0	8.8
	S	6.1	12.6	17.9	5.4	10.6	52.6
	N	0.9	0.7	2.5	8.0	1.4	13.5
	Total	7.7	14.9	30.5	13.4	14.6	81.1
Air volume [m^3]		50.4	57.7	120.9	149.8	108.2	487.0

Calculated heating/cooling load

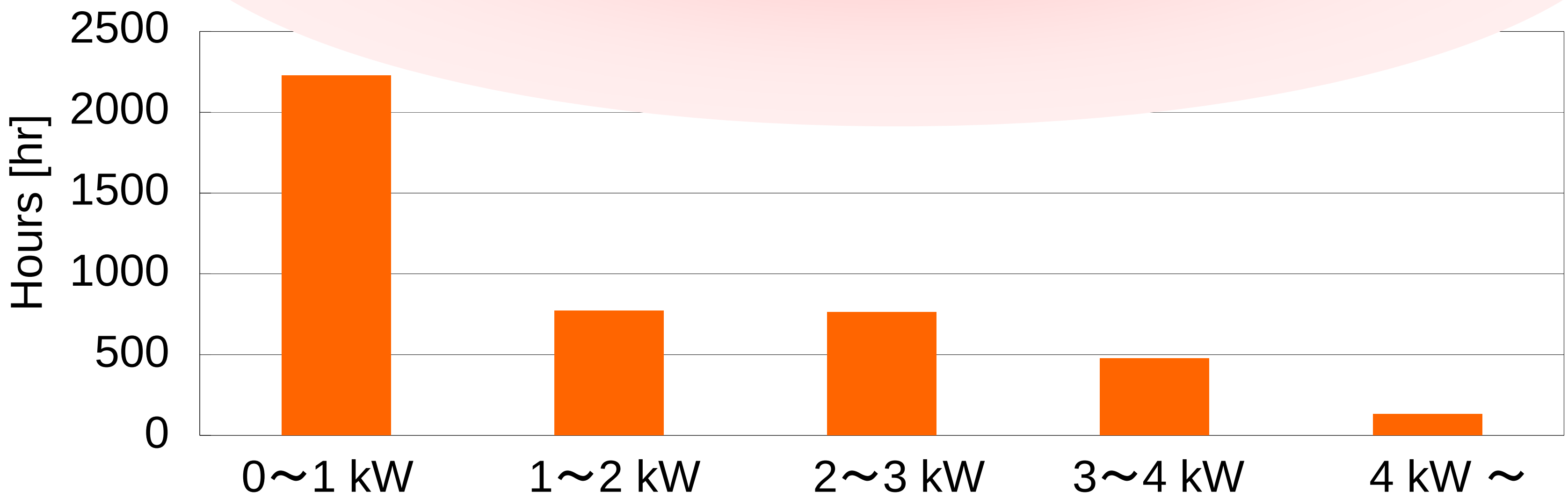




Calculated heating/cooling load

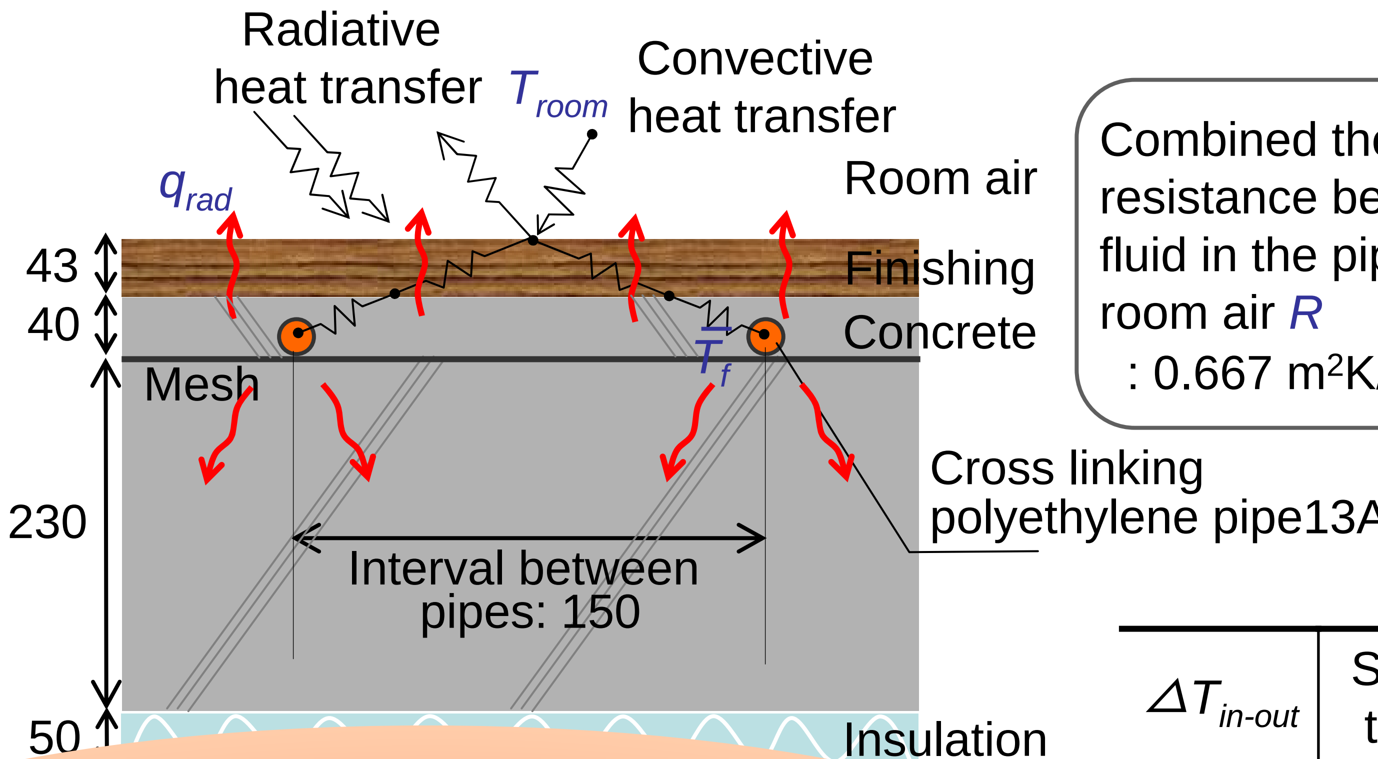


What kind of heating system is needed
in such a low energy house?
High temperature heat source is still needed?



What degree of supply temperature is needed ?

Floor construction and the thermal resistance



Combined thermal resistance between fluid in the pipe and room air R
: 0.667 m²K/W

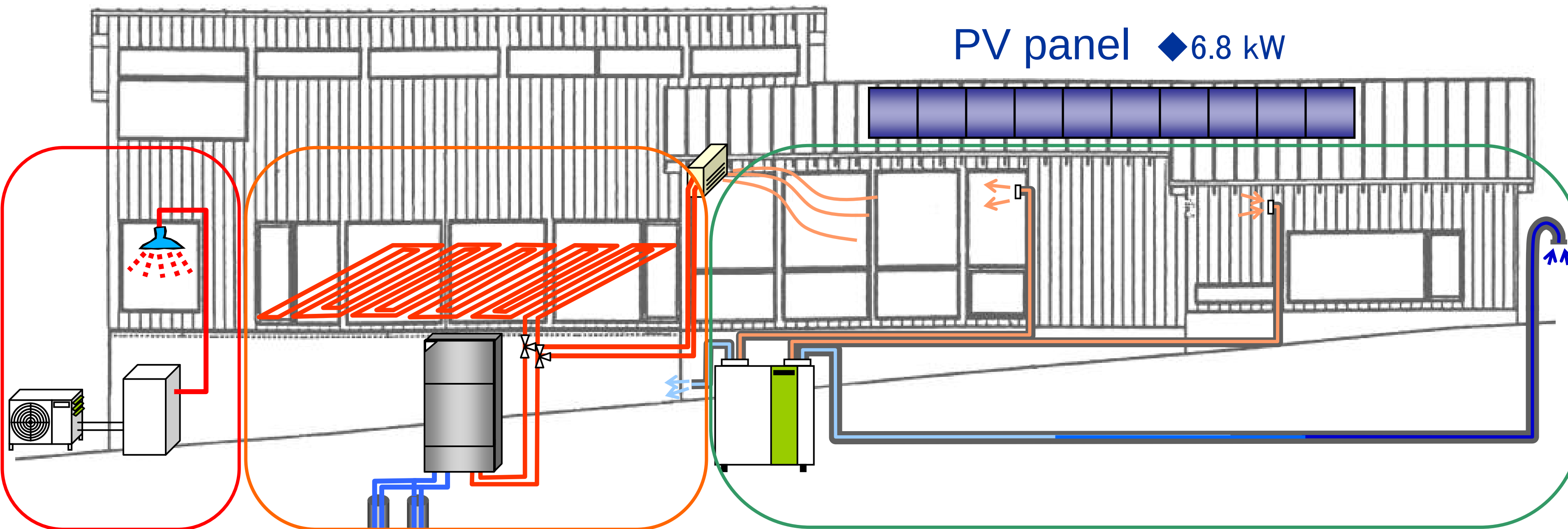
$\Delta T_{in\text{-}out}$	Supply temp.
2	34.5
4	35.5
6	36.5

We can use lower supply temperature
especially in such a floor heating system.
In the case, heat pump would be a suitable heat source.

He

[kW] [°C] [°C] [m²] 0.667 [m²K/W]

Active design measures for energy savings



Hot water supply

Air source CO_2 heat pump (Eco-Cute)

- CORONA, CHP606K
- 460L storage tank

Heating and cooling

Ground source heat pump

- SUNPOT, GSHP1001
- 4HP compressor with inverter control
- Ground heat exchanger
  - 100 m × 2 boreholes
  - λ=1.4 W/m/K
  - indirect heat exchange by single U-tubes
- Floor heating or FCU

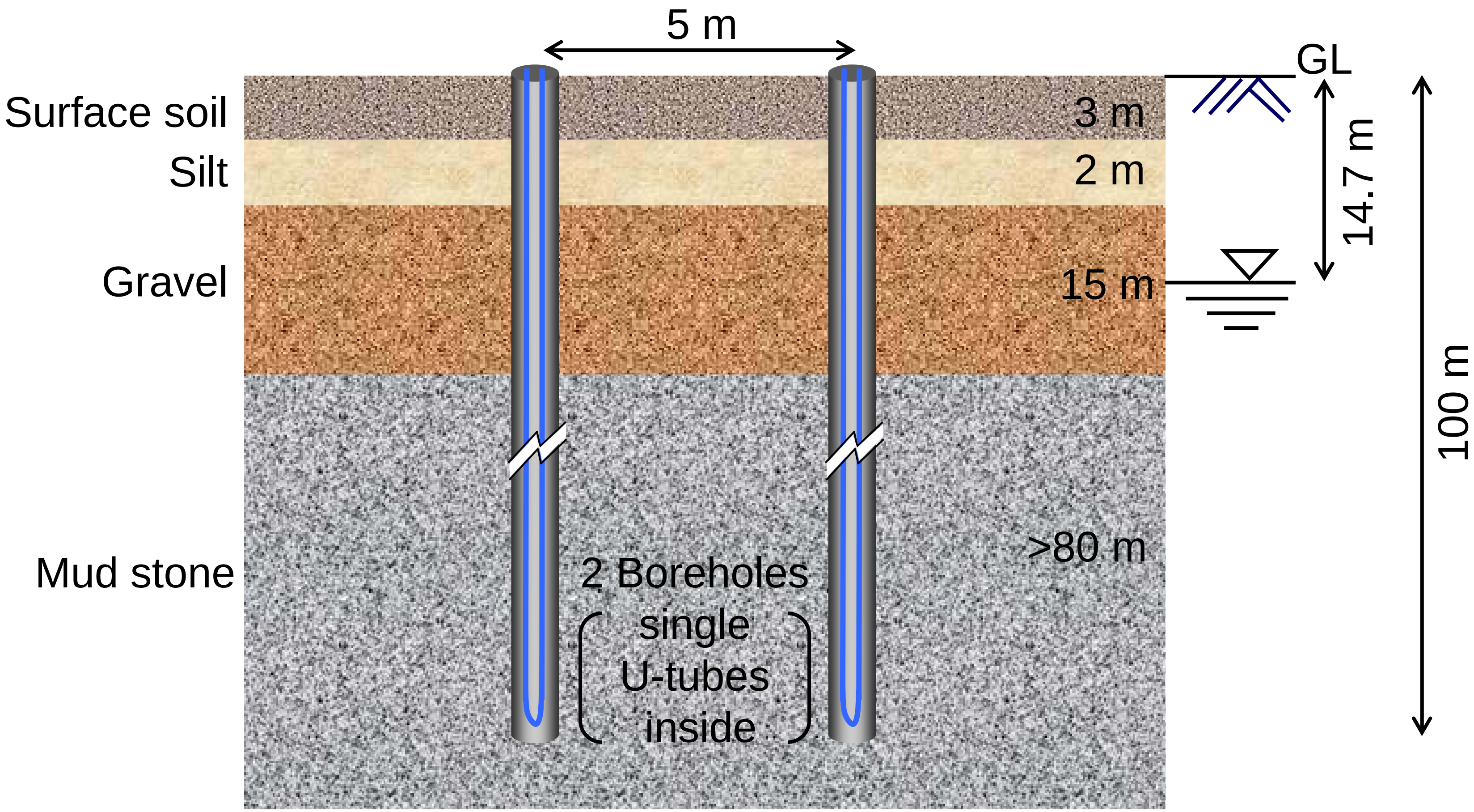
Ventilation

Heat exchanger with heat recovery

- STIEBEL, LWZ-161
- Pre-heating (winter) or pre-cooling (summer) by earth tube
  - 50 m long
  - 1.55 m deep
  - made of 200ϕ plastic pipe

GSHP system - *Geological condition -*

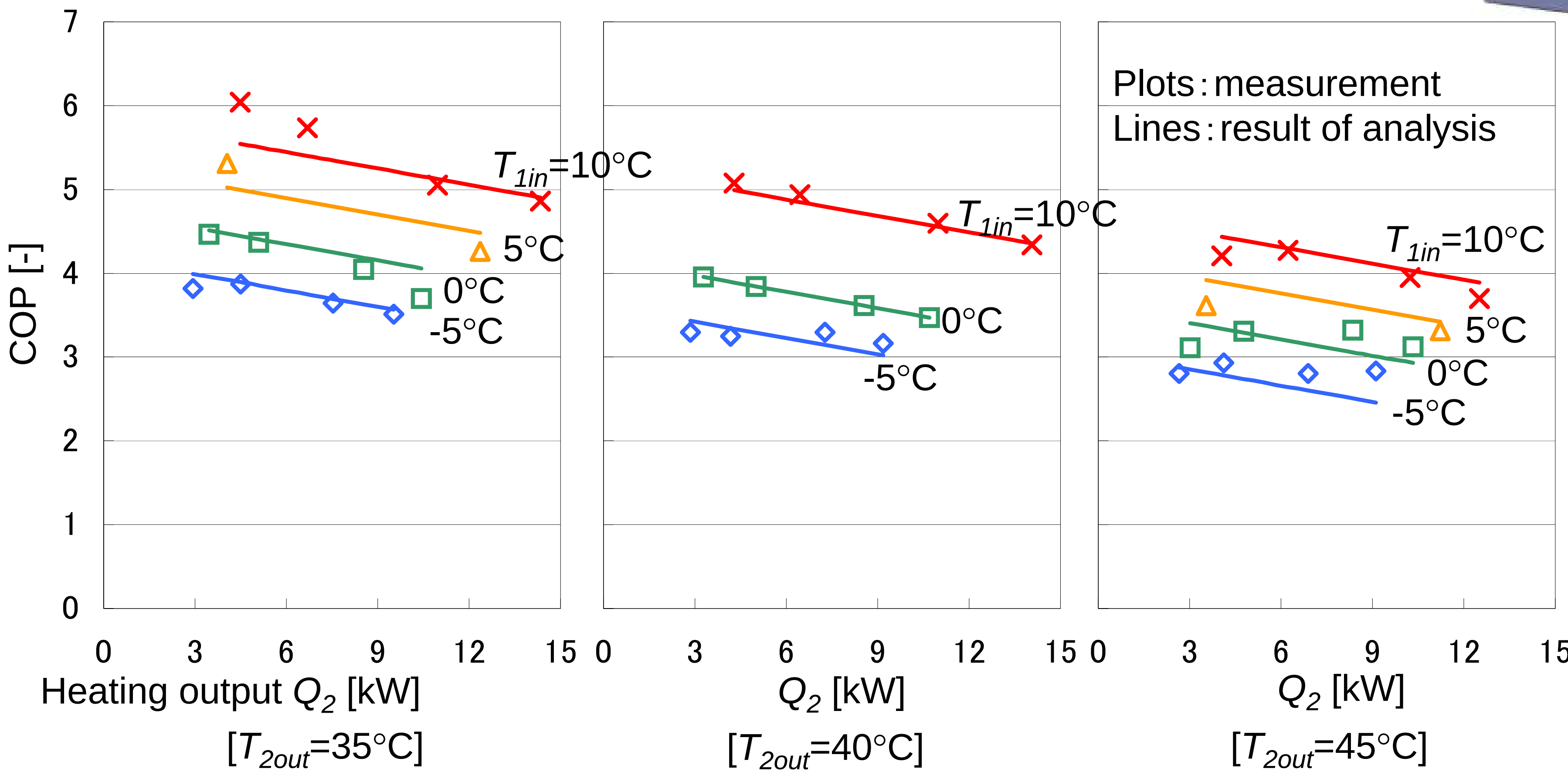
Effective thermal conductivity: 1.4 W/m/K
(from a thermal response test)



GSHP system *-Performance of heat pump -*

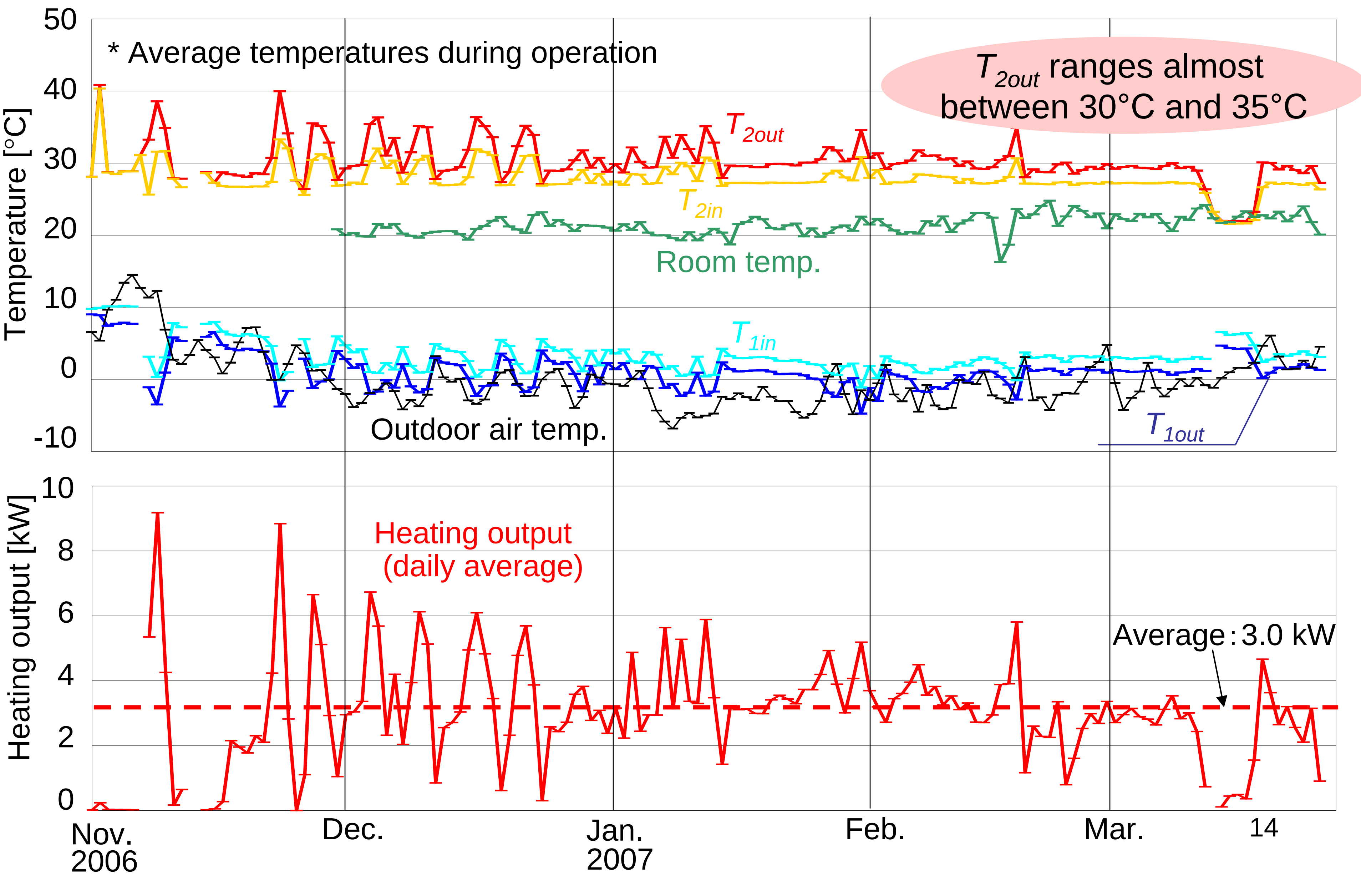
COP function obtained by multi-regression analysis:

$$COP = -\ 0.0650\ Q_2 + 0.1101\ T_{1in} - 0.1135\ T_{2out}$$



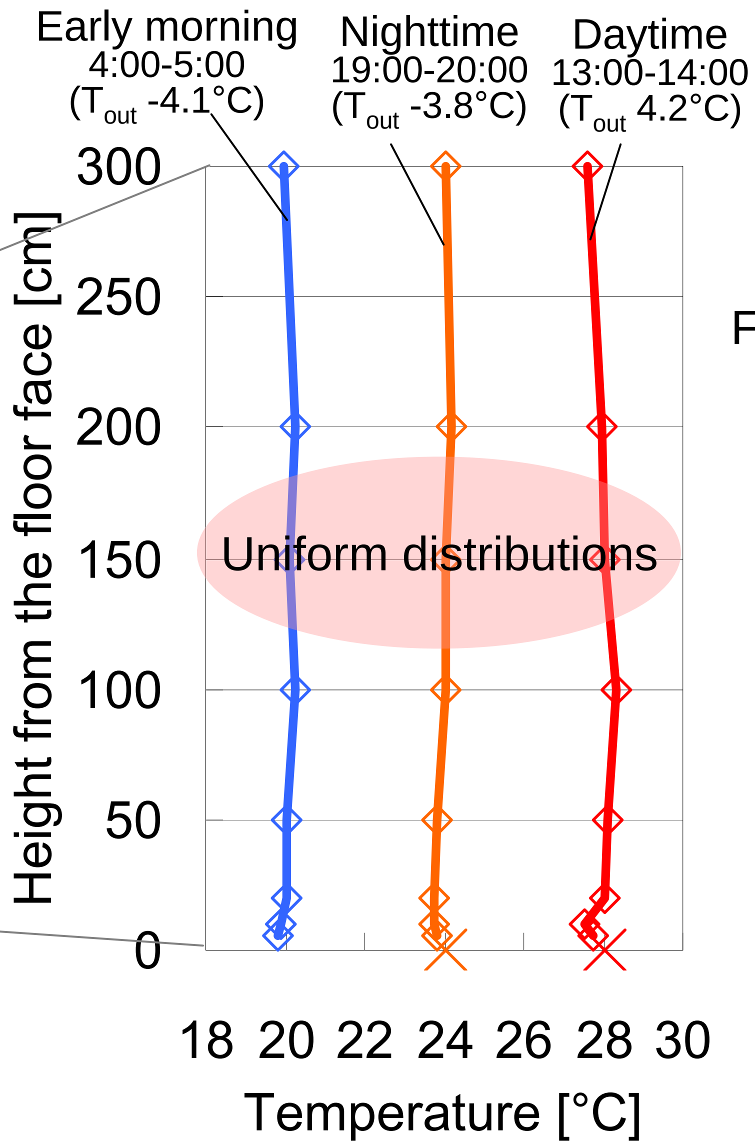
Control: The heat pump provides a constant supply temperature T_{2out}.
T_{2out} can be set by the user depending on the heating load.

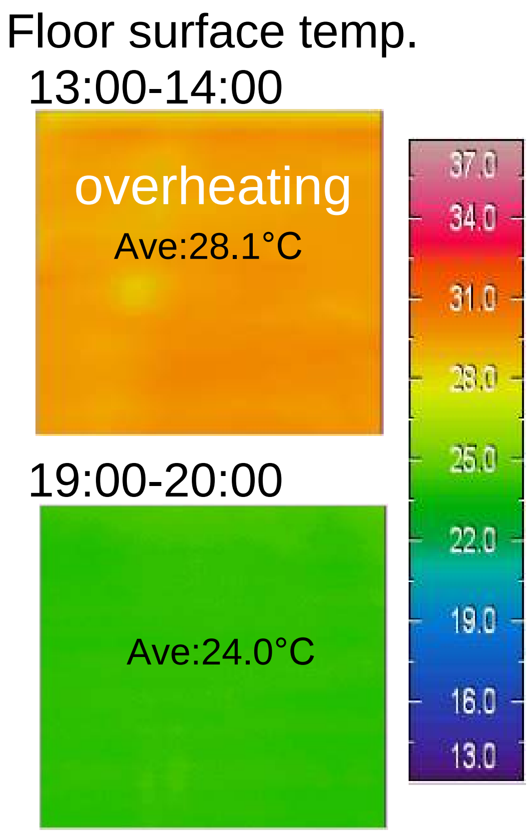
Temperature and heating output (season)



Vertical temperature variations

Jan.17,2007

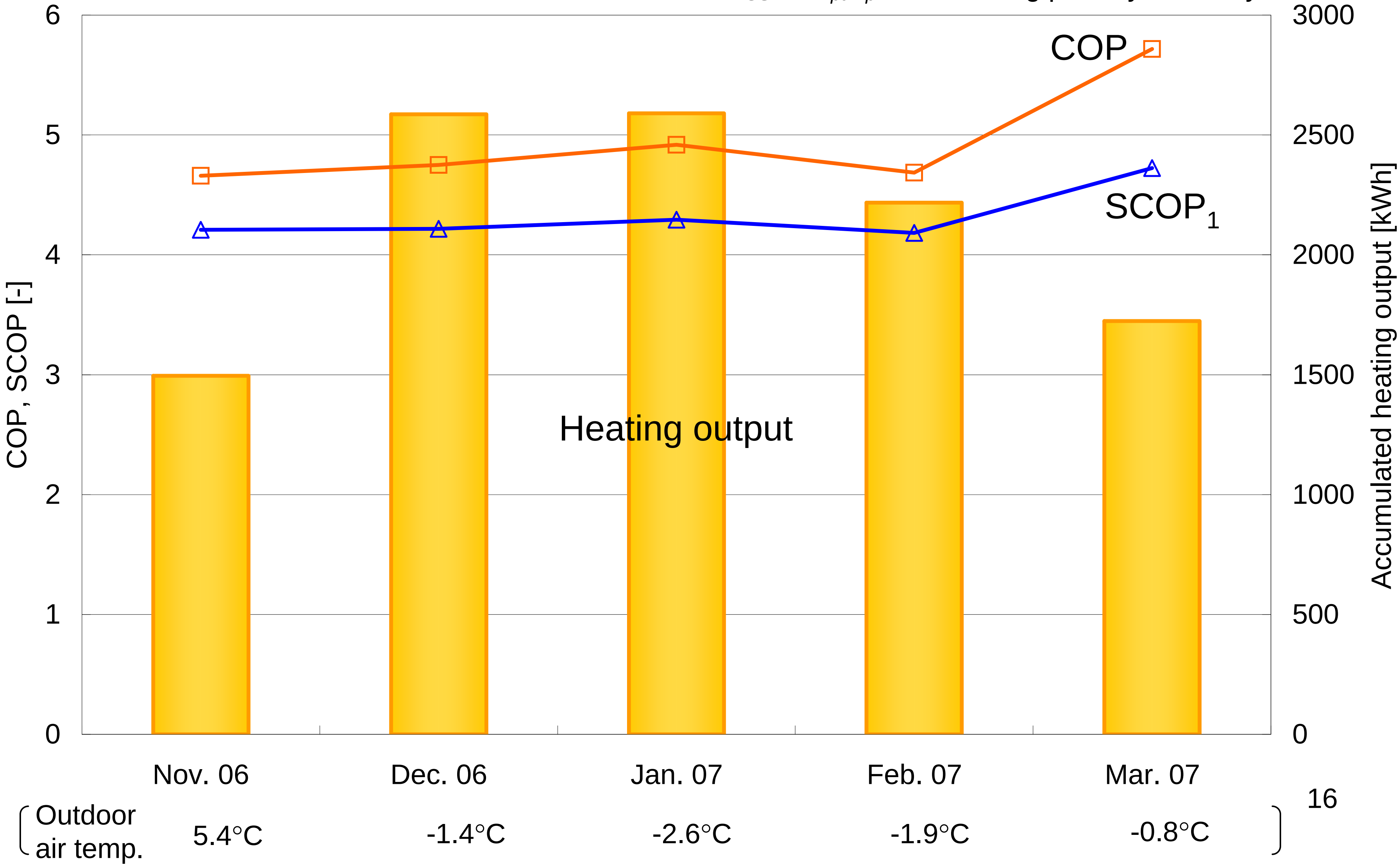




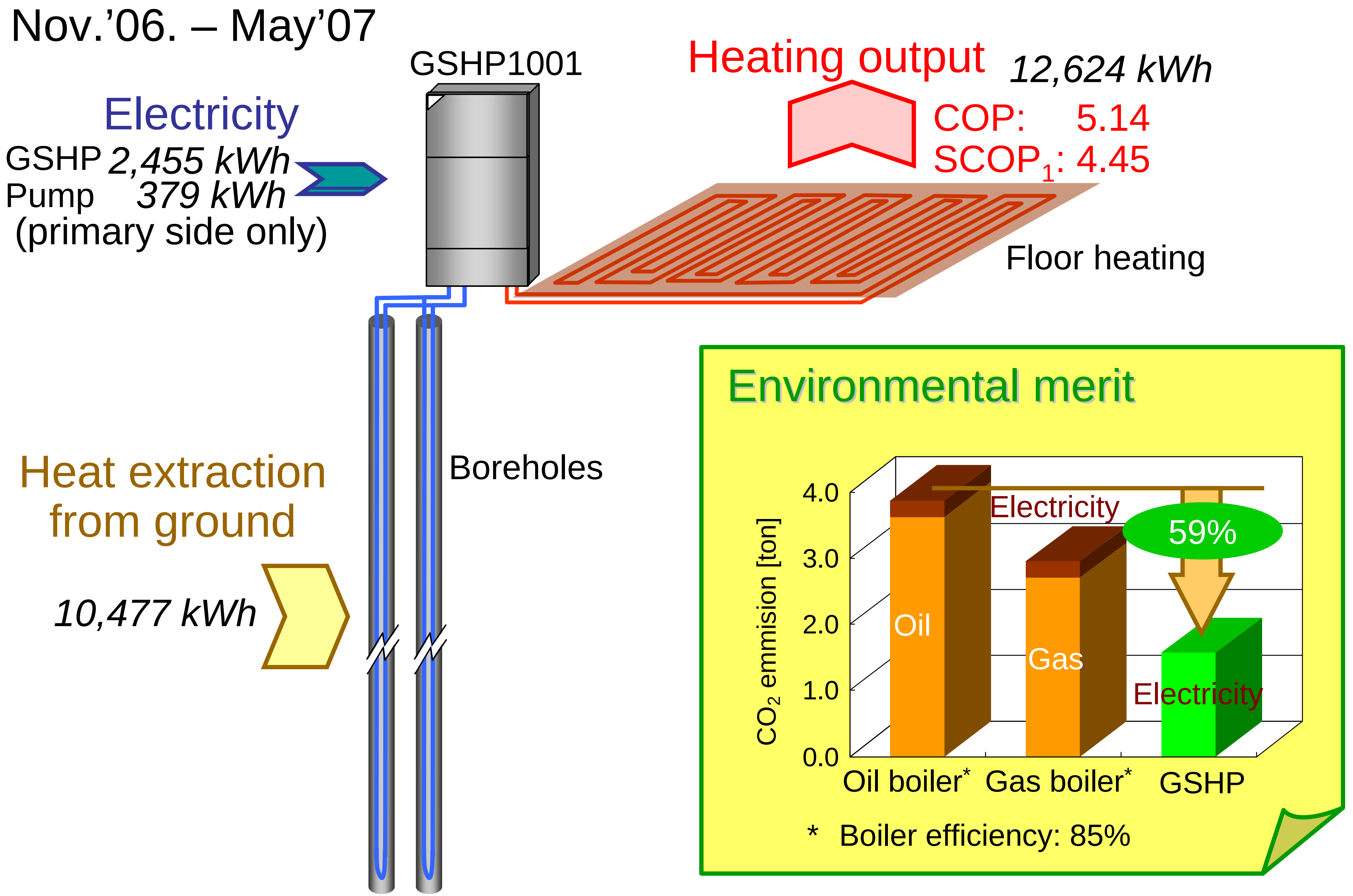
Seasonal performance of GSHP

$COP = Q_2 / E_{GSHP}$

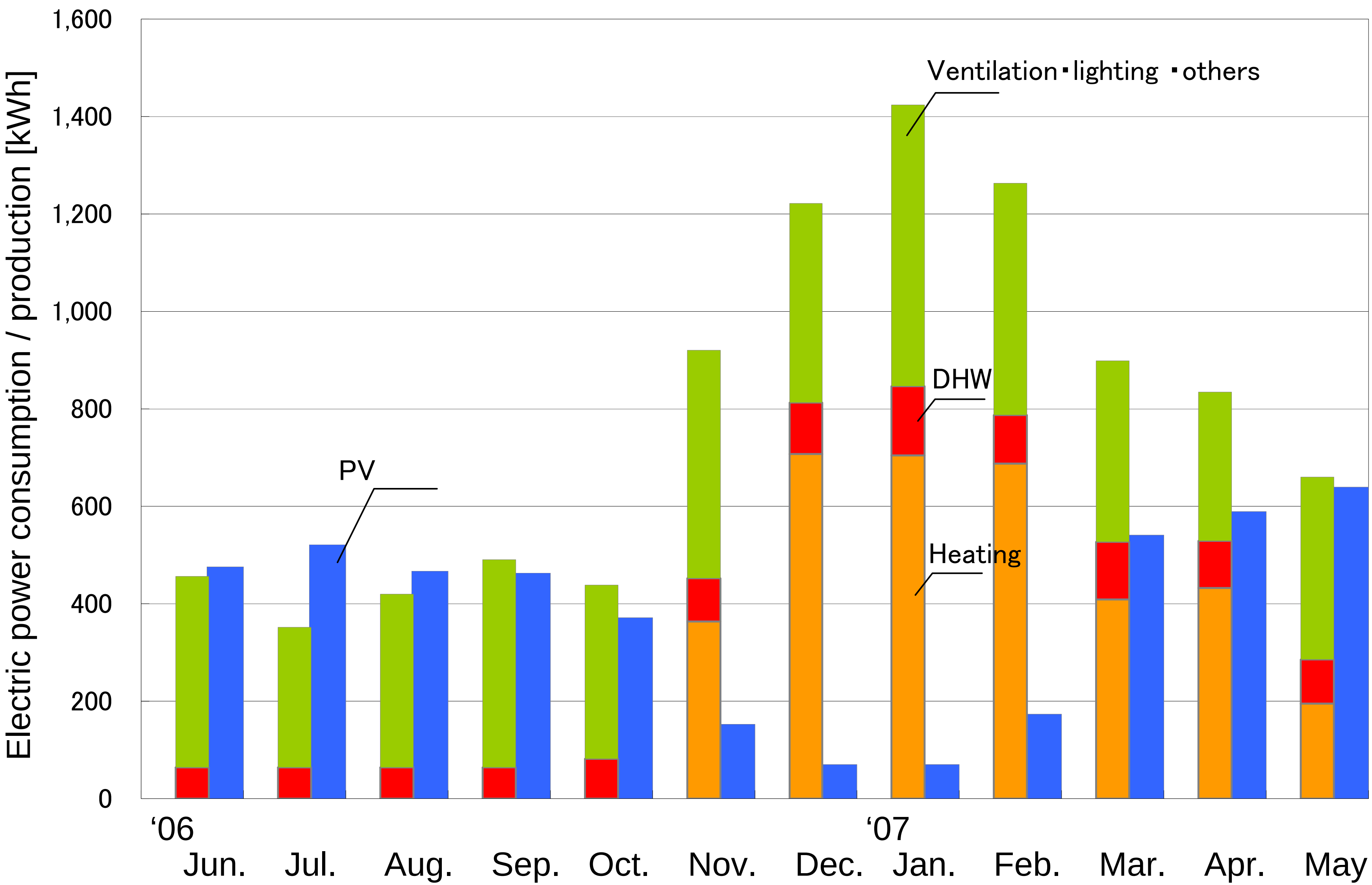
$SCOP_1 = Q_2 / (E_{GSHP} + E_{pump\text{-}1})$: including primary side only



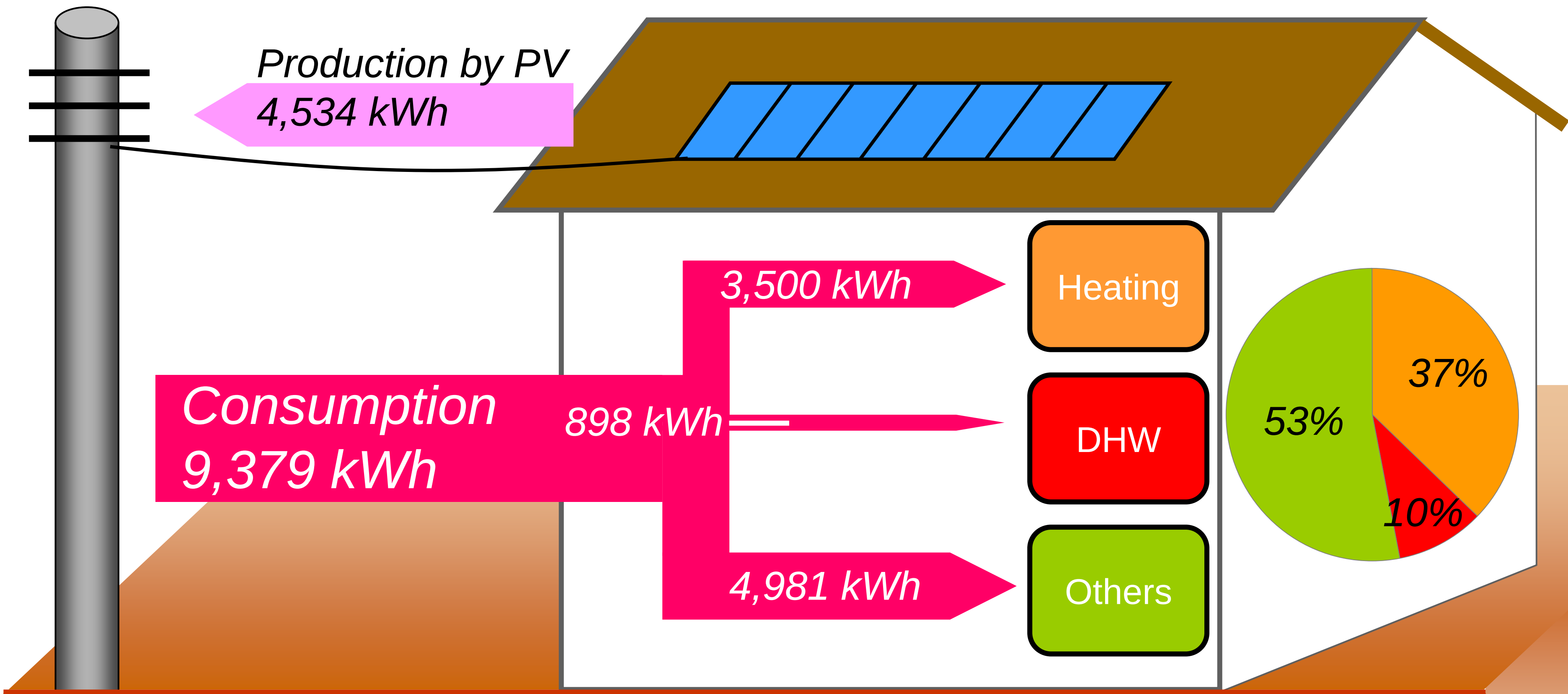
Seasonal heat balance of GSHP system



Monthly power consumption and production



Annual energy balance



Real consumption
4,845 kWh
(24 kWh/m^2)
= 236 MJ/m^2 (primary energy)

Energy self-sufficiency rate
48%

$$\left(\frac{production}{consumption} \times 100\,[\%] \right)$$

Summary

- From a seasonal measurement of GSHP system in an actual low energy house in the cold region of Japan, the system provides the satisfied heating performance with a low supply temperature around 30°C. High values of COP and SCOP are observed and then the reduction of CO_2 emission is estimated to be around 58% compared to conventional systems.
- Room temperature is kept uniformly in the room space all day. Overshooting during the daytime would be improved by heat storage to an additional storage media.

Summary

- Annual electric balance in the low energy house

Consumption	: 9,379 kWh
Production	: 4,534 kWh
Real consumption	: 4,845 kWh
	(24 kWh/m^2)

Totally, 48% of electric power demand can be covered by the PV system.

For the 2nd field testing

- Evaluation of an integrated heat pump system in a well-designed low energy house
- Optimization of floor heating by GSHP
  - ✓ 24hours operation or intermittent operation?
  - ✓ Control of supply water temperature
- Measures to prevent overshooting
- Pre-cooling (and passive dehumidification) effects in a ventilation system using earth tube

  (Preheating effect to avoid defrost working has been already confirmed.)
- Exhaust heat recovery of ventilation air
- Improvement of PV performance in winter