

4<sup>th</sup> Experts meeting and Workshop of IEA HPP Annex 32, Kyoto  
Dec.5<sup>th</sup>-7<sup>th</sup>, 2007

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

Sayaka Takeda-Kindaichi\*<sup>1</sup>

Katsunori Nagano\*<sup>2</sup>

Takao Katsura\*<sup>3</sup>

Shogo Hori\*<sup>2</sup>

Kazuo Shibata\*<sup>4</sup>

\*<sup>1</sup> *The University of Tokyo  
(Former post: Hokkaido University)*

\*<sup>2</sup> *Hokkaido University*

\*<sup>3</sup> *Fujiwara Environmental Science Institute Ltd.*

\*<sup>4</sup> *Nissin Techno Incorporated*

# 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

# Next-Generation Energy Conservation Standard (for residences)

## Main points

- Classify all the cities, towns and villages in Japan into 6 climatic zones
- Annual heating and cooling load [MJ/m<sup>2</sup>]

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

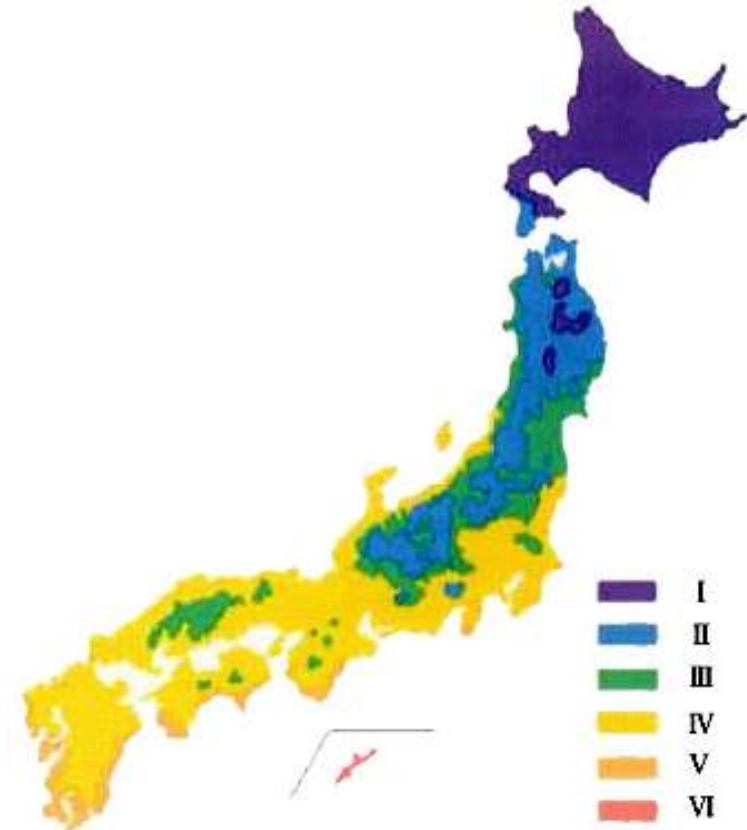
- Insulation:  
Heat loss coefficient (Q-value) [W/m<sup>2</sup>/K]

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<sup>2</sup>/m<sup>2</sup>]

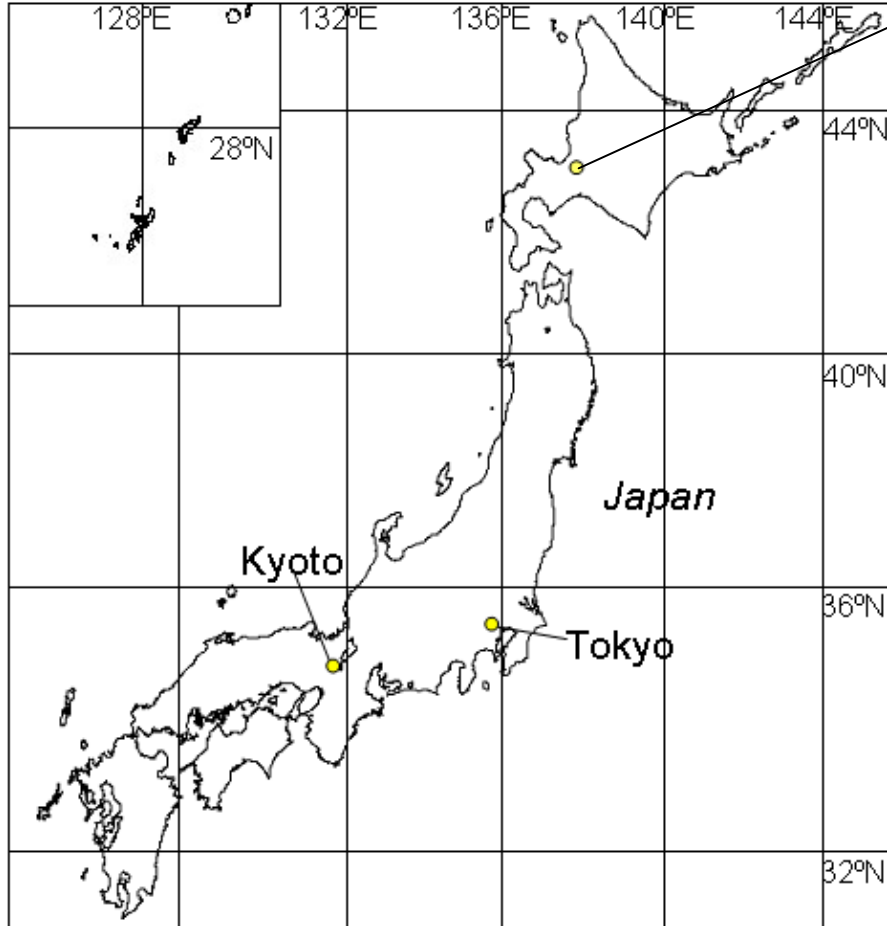
I	II	III	IV	V	VI
2.0		5.0			

- Proper ventilation  
Basically more than 0.5 h<sup>-1</sup>



Source: *Institute for Building Environment and Energy Conservation*

# Low energy house in *Naganuma*



Naganuma town

Location:

Lat. 43° N, long. 141°E

40 km southeast from Sapporo

Average temperature: 7.5°C



# Building performance



## General information

- ▣ 2 story and basement
- ▣ Habitant: 2 people
- ▣ Total floor area: 200 m<sup>2</sup>
- ▣ Heating area: 178 m<sup>2</sup>

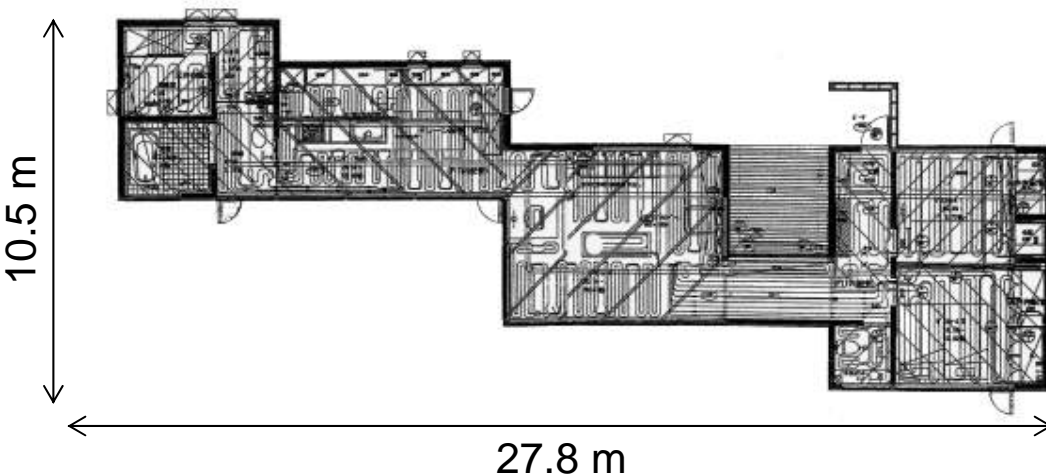
## Building envelope

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

## Insulation and airtightness

- ▣ Q value: 0.96 W/m<sup>2</sup>/K
- ▣ C value: 0.4 cm<sup>2</sup>/m<sup>2</sup>

**Satisfy the standard values**



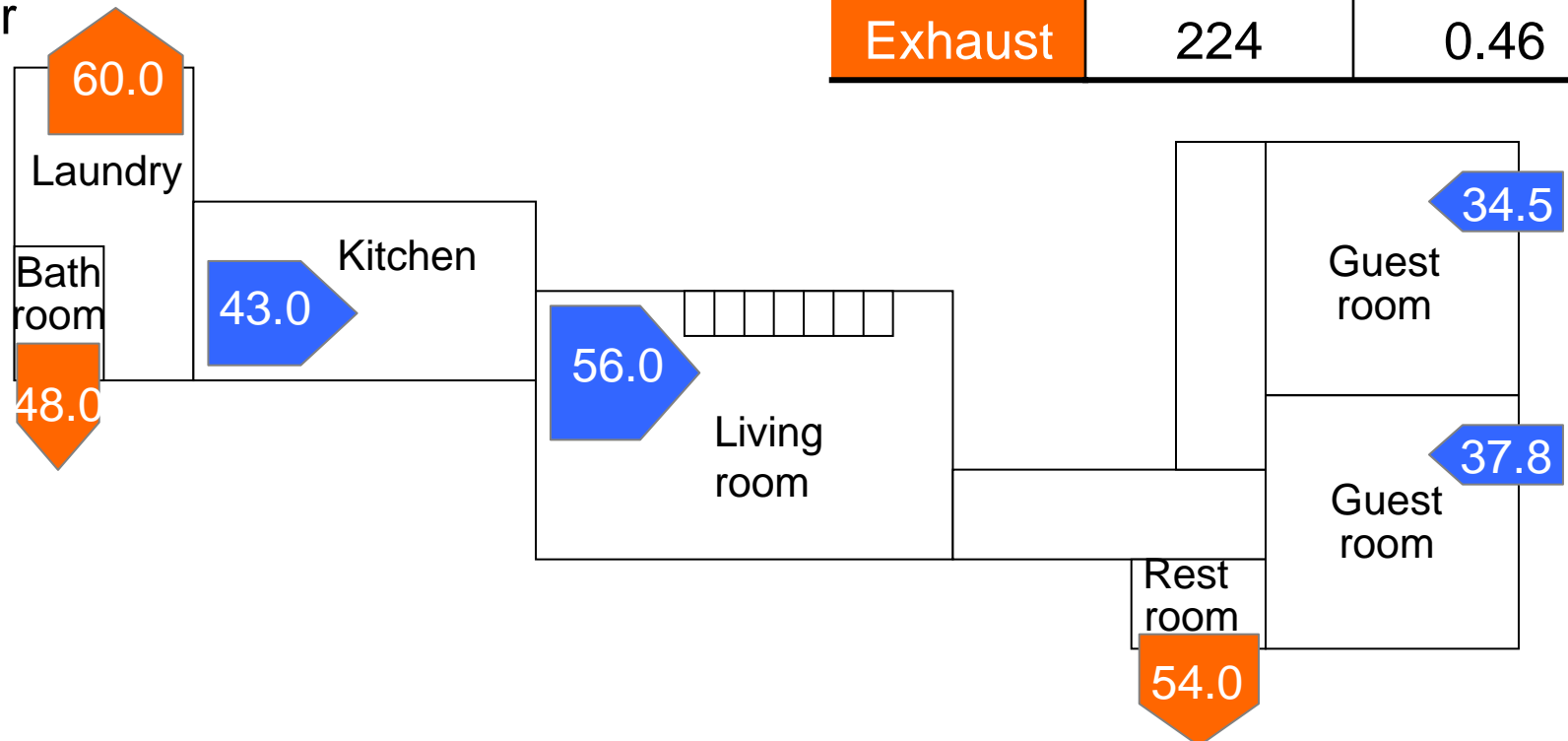
# Ventilation rate

2<sup>nd</sup> floor



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

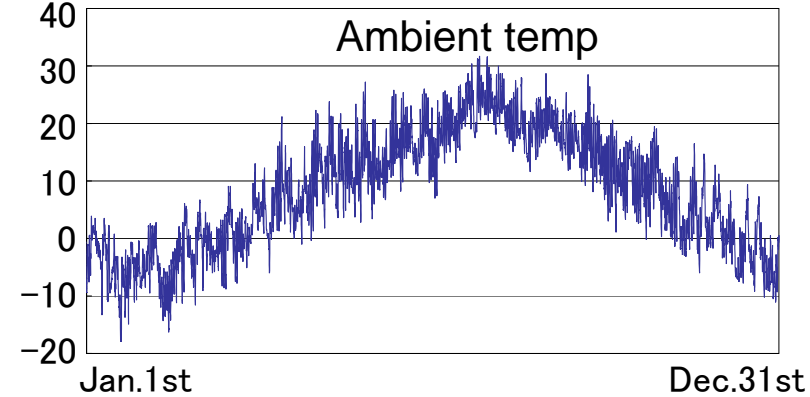
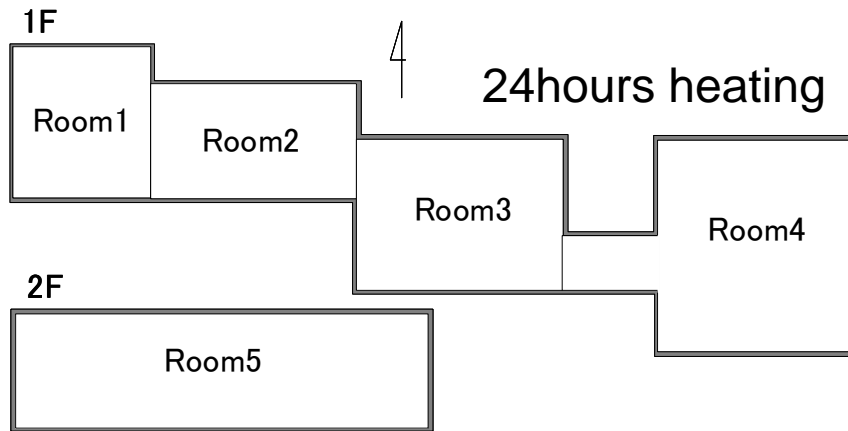
1<sup>st</sup> floor



# How much is the heating load?

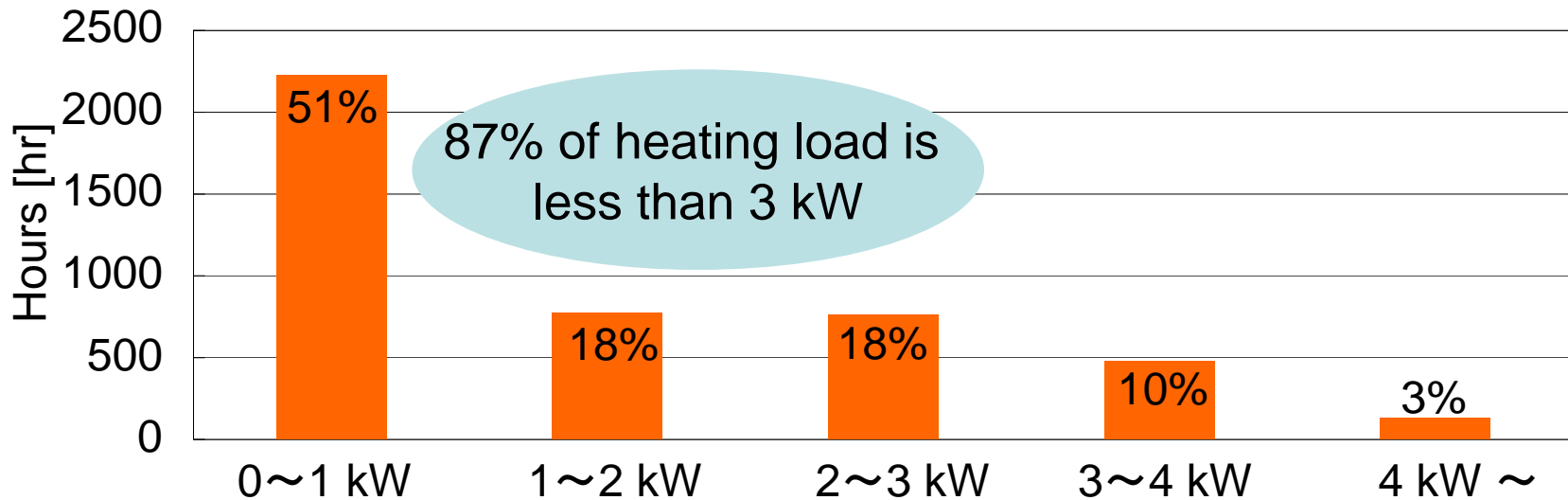
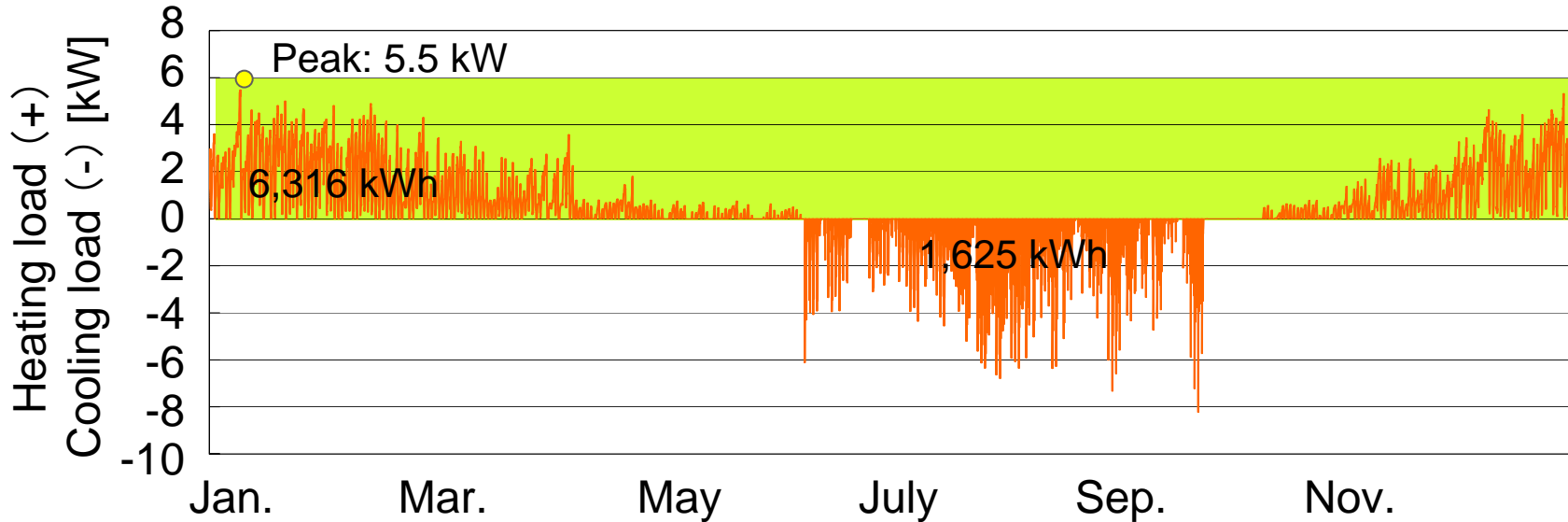
Calculation by SMASH

\* Weather condition: Sapporo

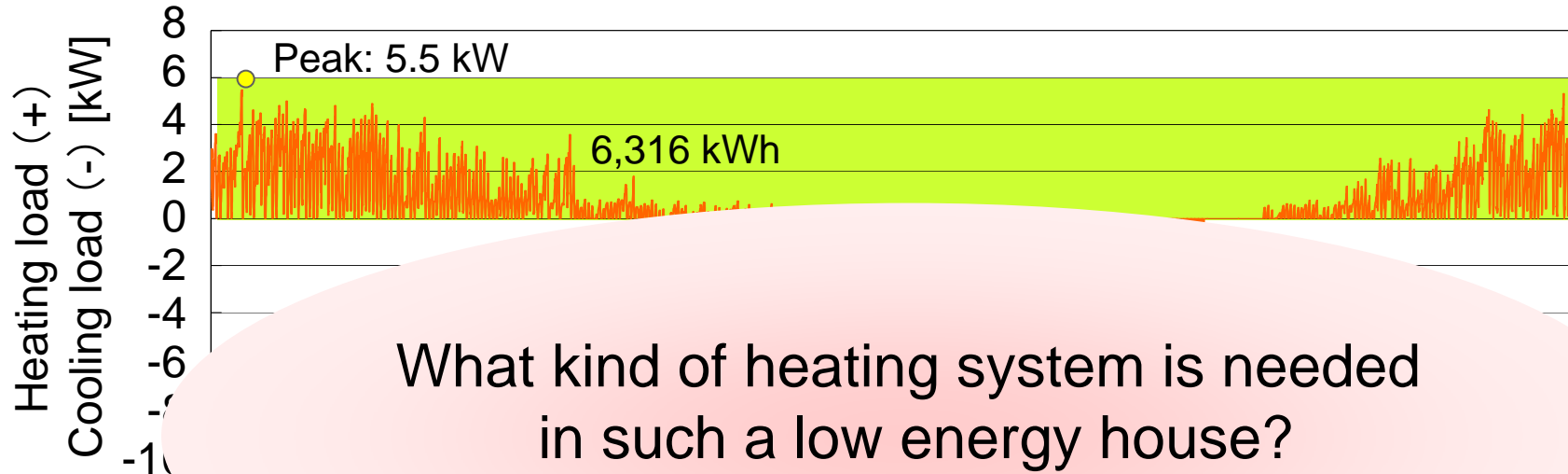


		Room1	Room2	Room3	Room4	Room5	Total
Floor area [m <sup>2</sup> ]		22.8	25.9	34.2	49.3	46.2	178.4
Ceiling area [m <sup>2</sup> ]		5.5	0.0	31.1	49.3	46.2	132.1
Outer wall area [m <sup>2</sup> ]	E	2.7	3.8	11.2	22.6	6.6	46.9
	W	10.4	0.0	5.3	15.8	6.5	38.0
	S	4.1	2.4	3.2	18.4	26.4	54.5
	N	9.1	14.8	19.7	25.9	24.5	94.0
	Total	26.3	21.0	39.4	82.7	64.0	233.4
Window area [m <sup>2</sup> ]	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 <sup>3</sup> ]		50.4	57.7	120.9	149.8	108.2	487.0

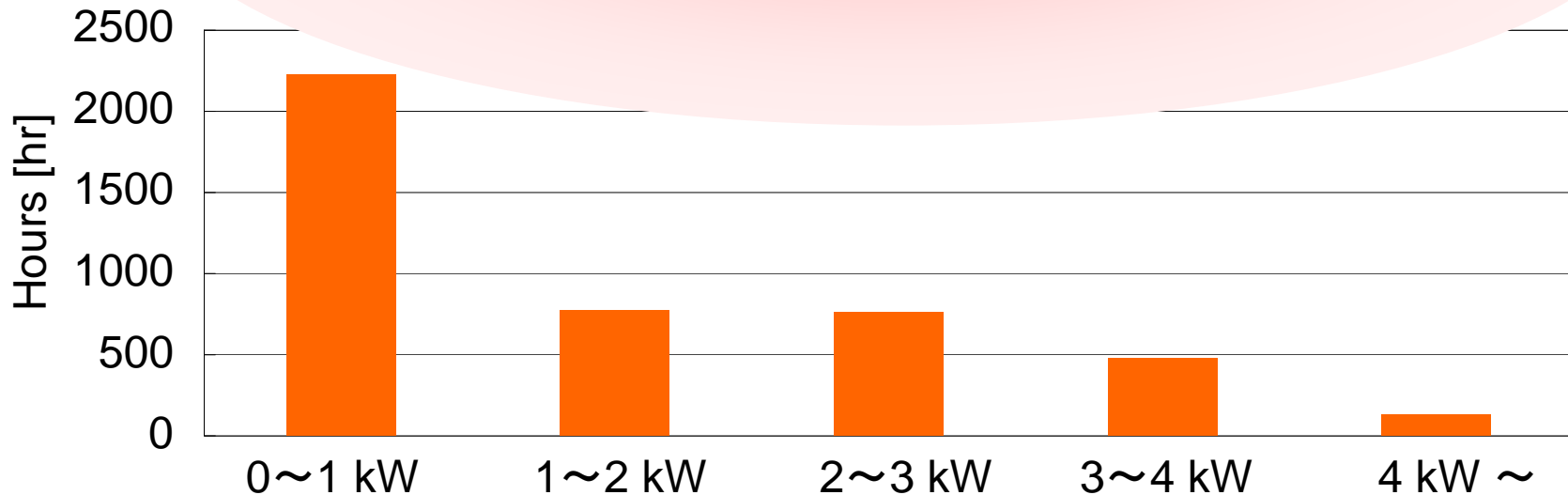
# Calculated heating/cooling load



# Calculated heating/cooling load

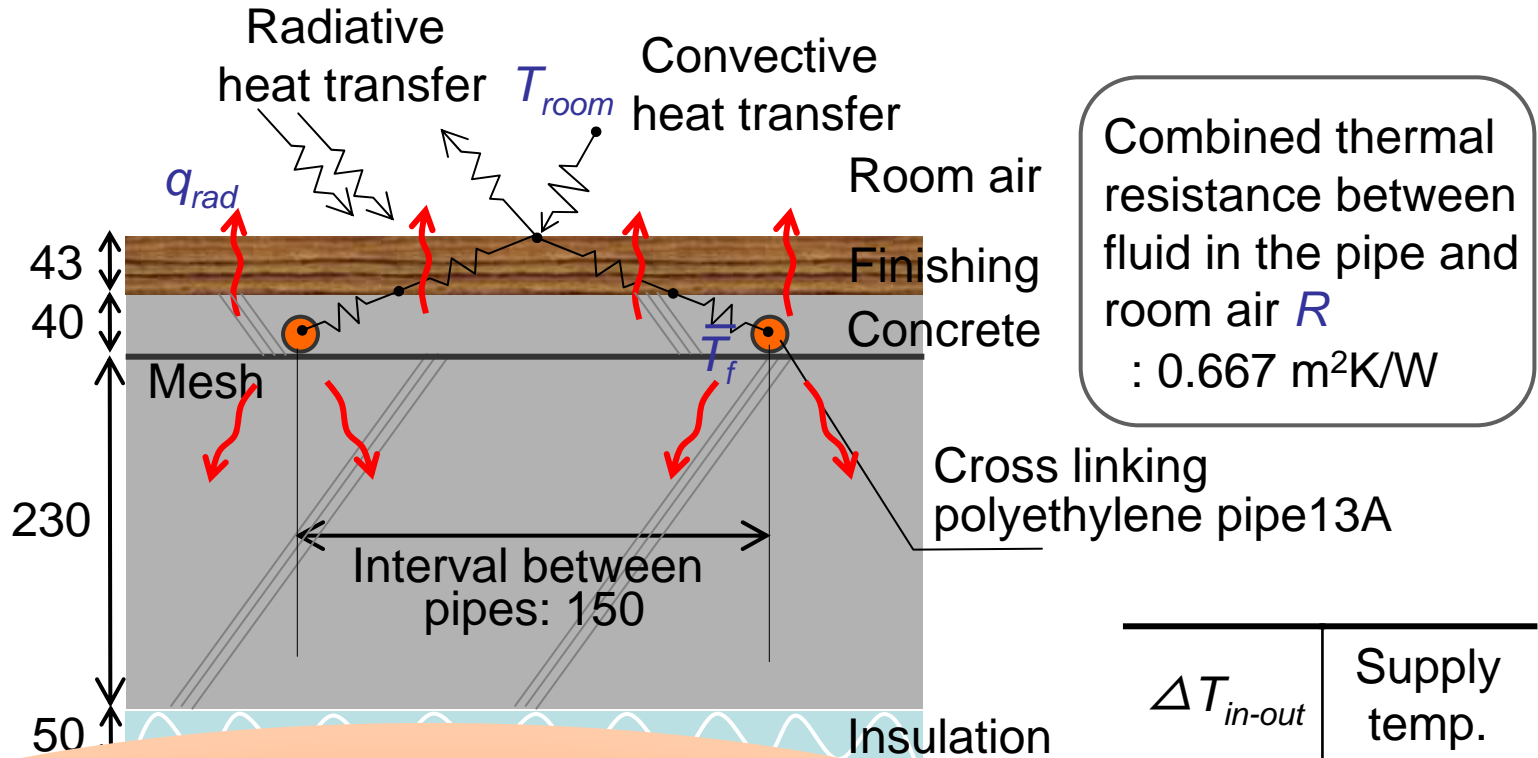


What kind of heating system is needed  
in such a low energy house?  
High temperature heat source is still needed?



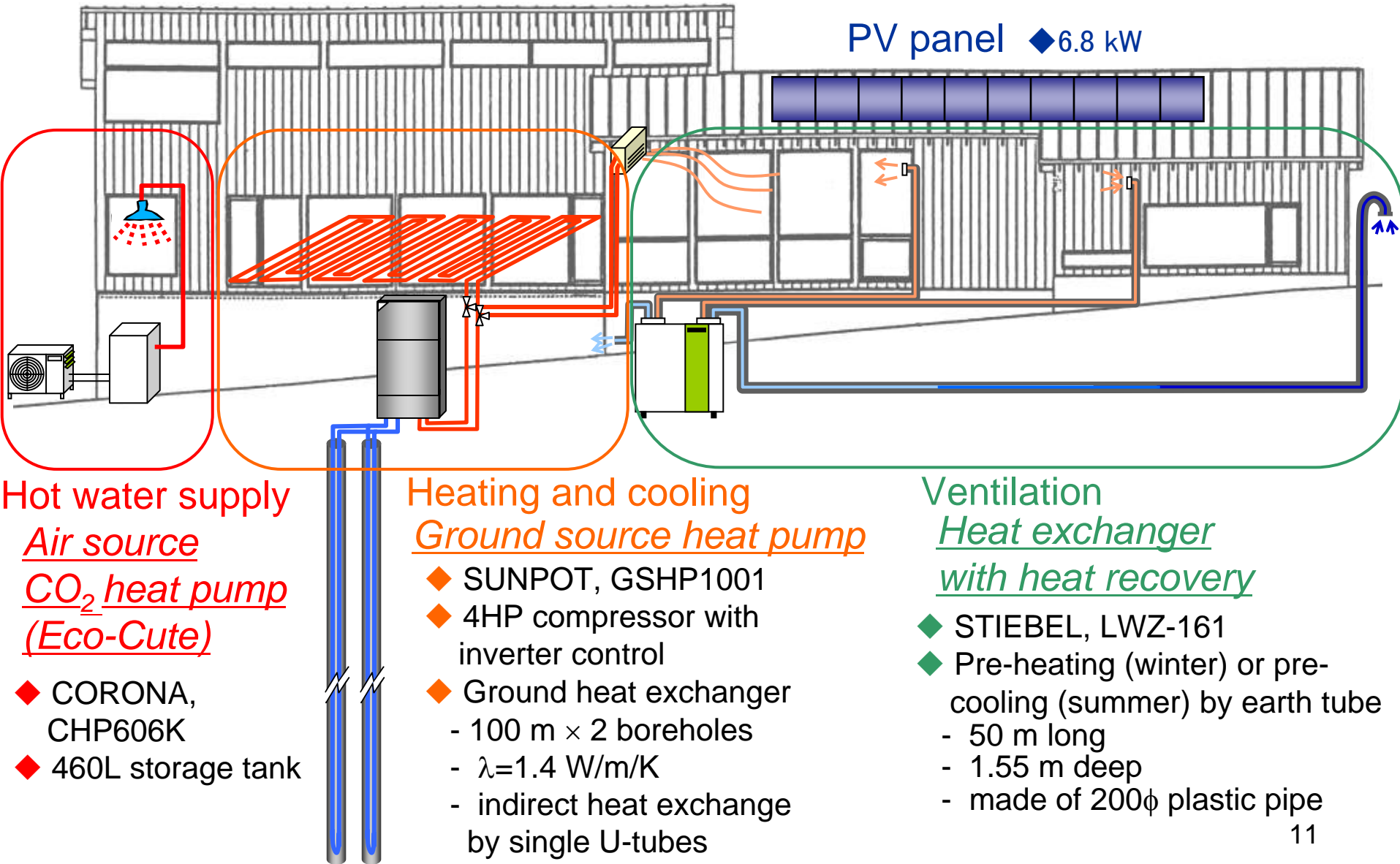
# What degree of supply temperature is needed ?

## Floor construction and the thermal resistance



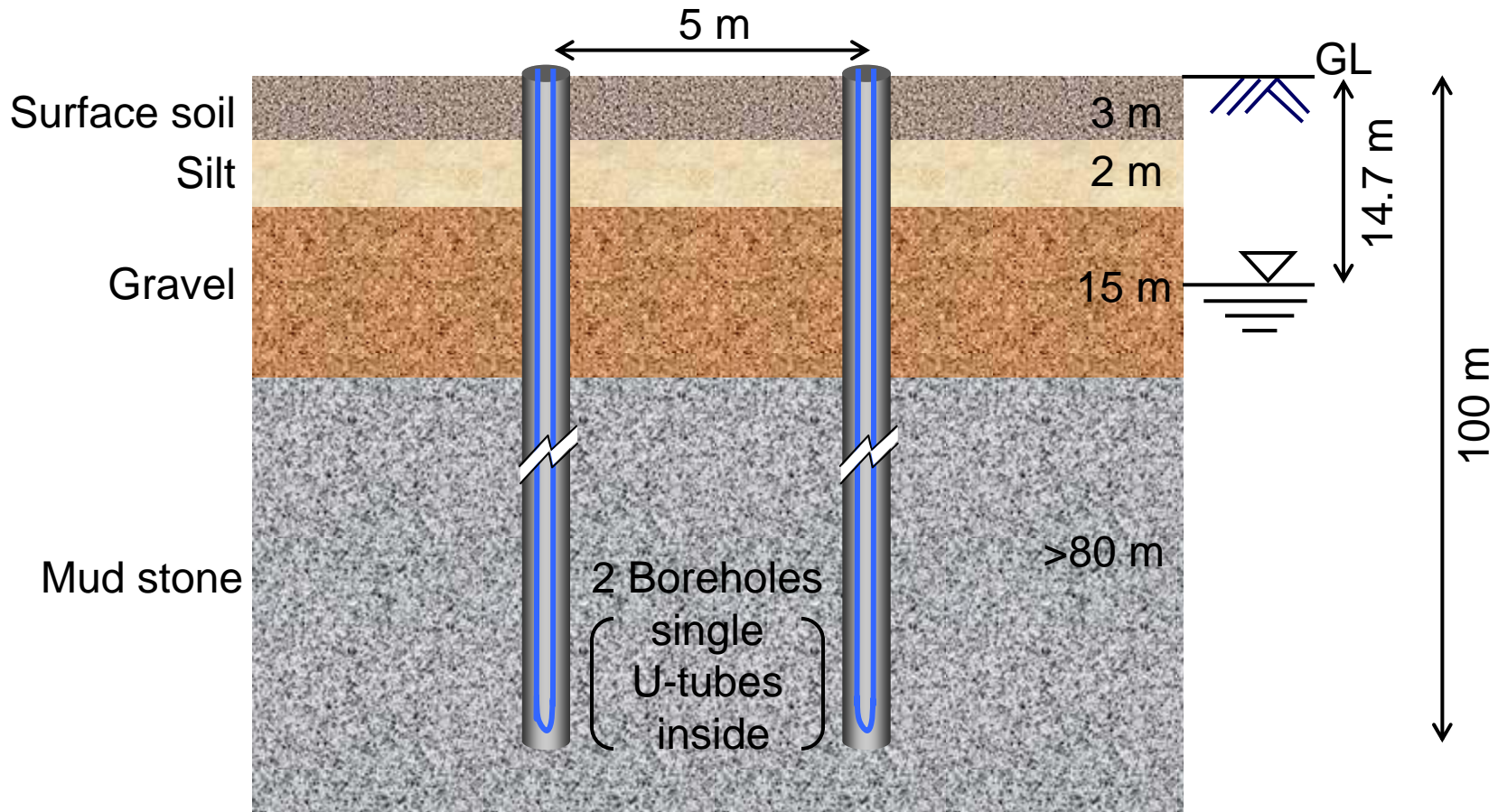
We can use lower supply temperature especially in such a floor heating system. In the case, heat pump would be a suitable heat source.

# Active design measures for energy savings



# GSHP system - Geological condition -

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

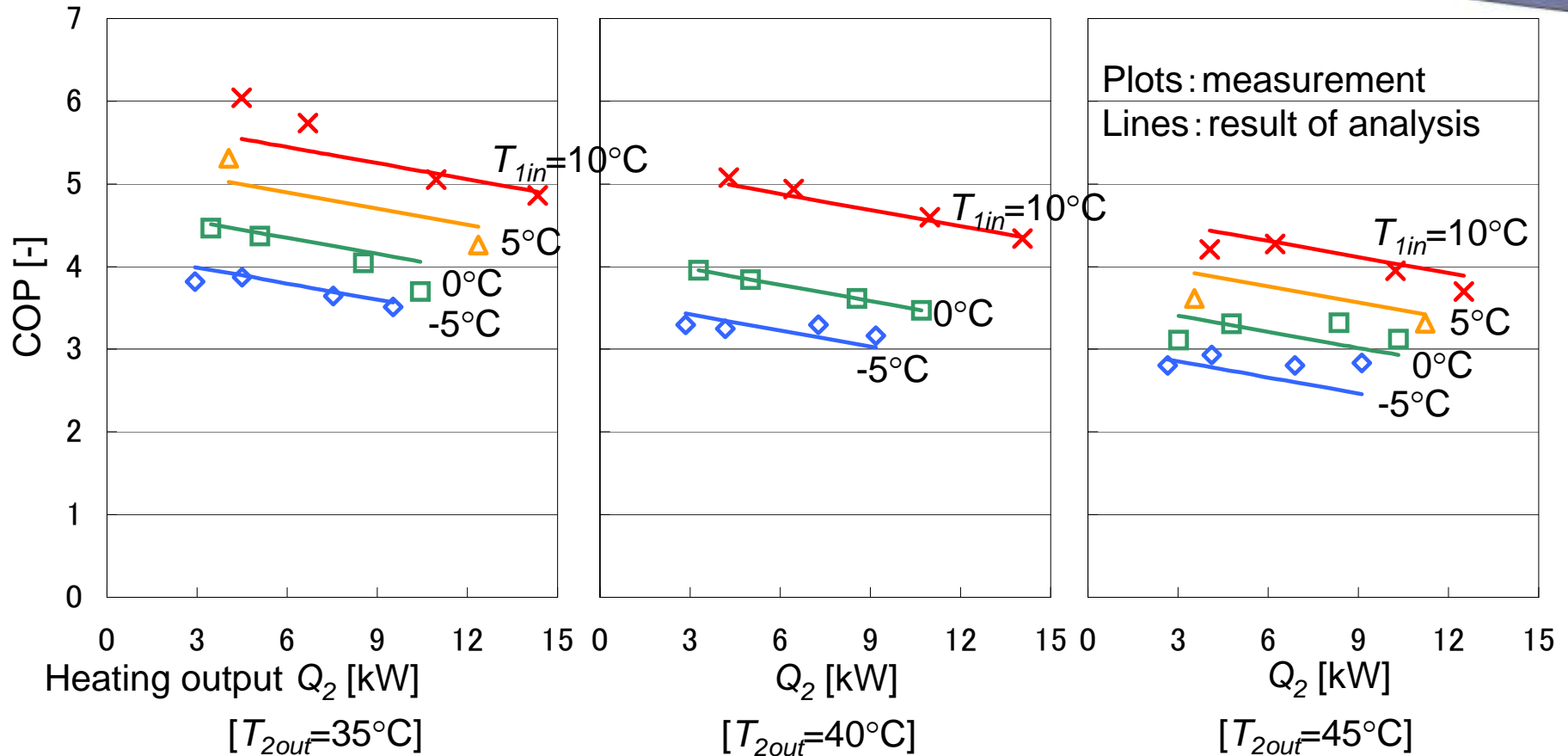


# GSHP system -Performance of heat pump -



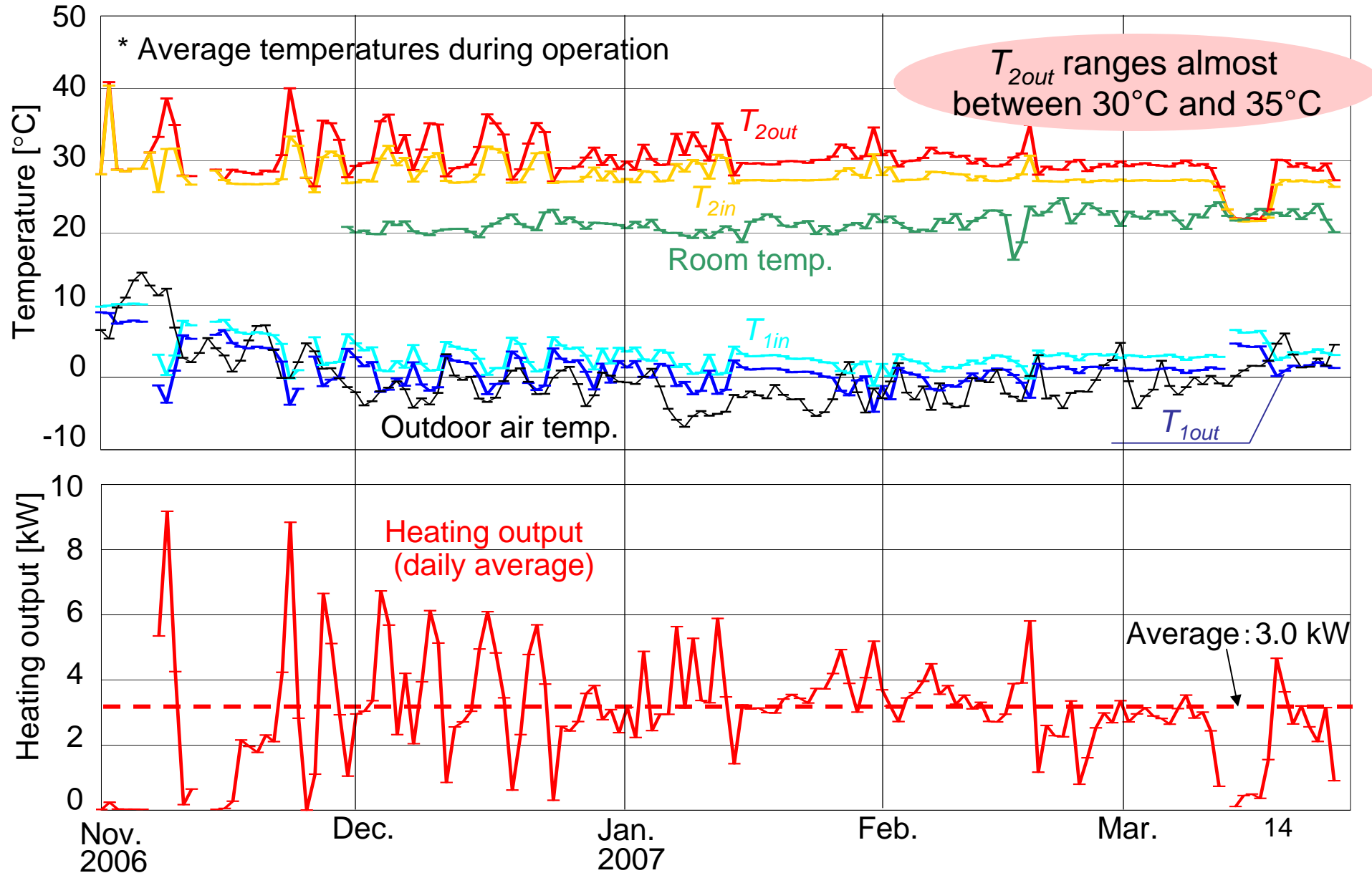
COP function obtained by multi-regression analysis:

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



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

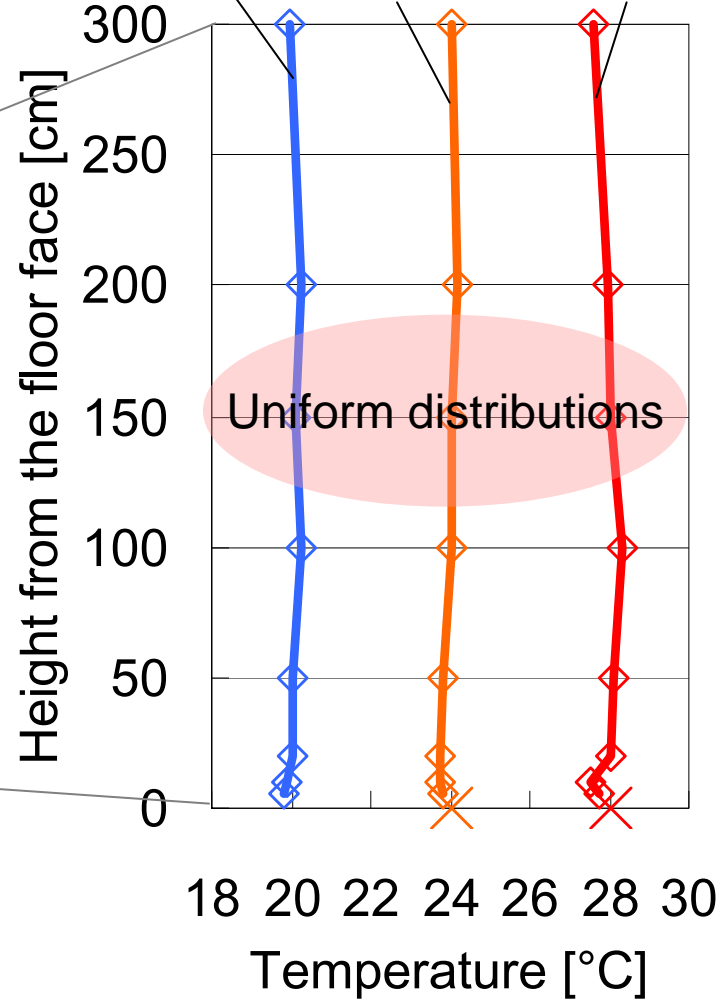
Jan.17,2007



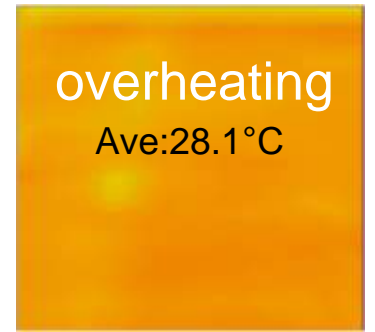
Early morning  
4:00-5:00  
( $T_{out} -4.1^{\circ}C$ )

Nighttime  
19:00-20:00  
( $T_{out} -3.8^{\circ}C$ )

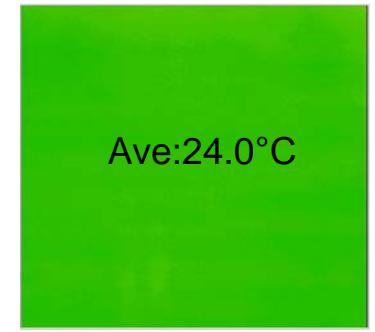
Daytime  
13:00-14:00  
( $T_{out} 4.2^{\circ}C$ )



Floor surface temp.  
13:00-14:00



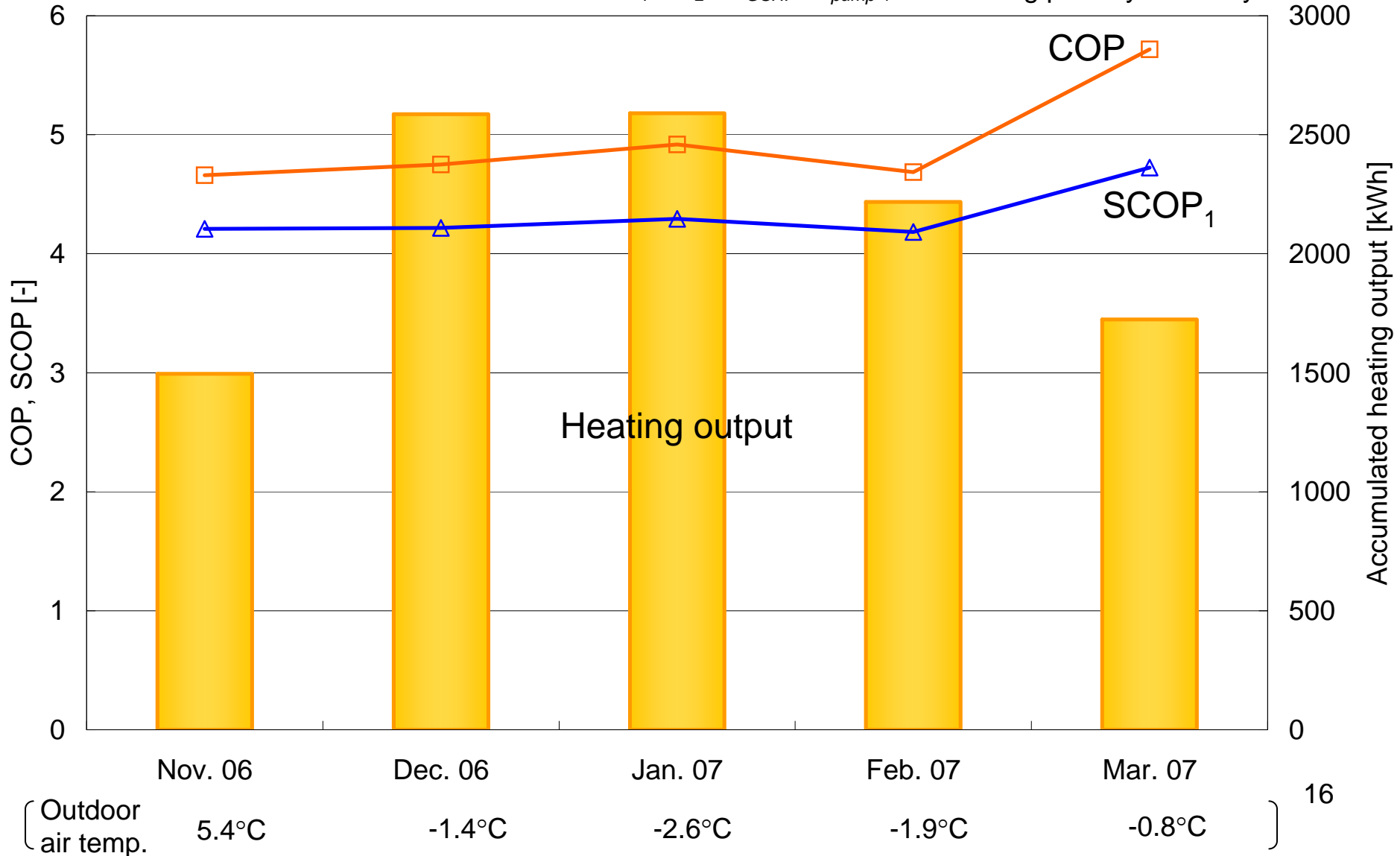
19:00-20:00



# Seasonal performance of GSHP

$$\text{COP} = Q_2 / E_{\text{GSHP}}$$

$$\text{SCOP}_1 = Q_2 / (E_{\text{GSHP}} + E_{\text{pump-1}}) \text{ : including primary side only}$$



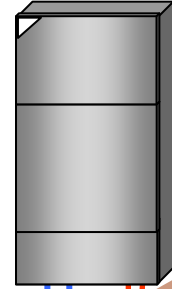
# Seasonal heat balance of GSHP system

Nov.'06. – May'07

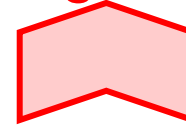
Electricity

GSHP 2,455 kWh  
Pump 379 kWh  
(primary side only)

GSHP1001



Heating output 12,624 kWh



COP: 5.14  
SCOP<sub>1</sub>: 4.45

Floor heating

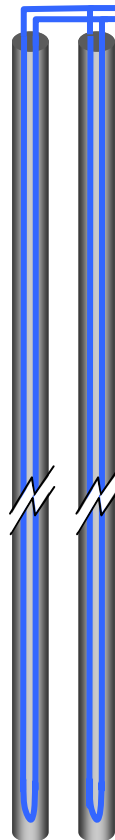


Heat extraction  
from ground

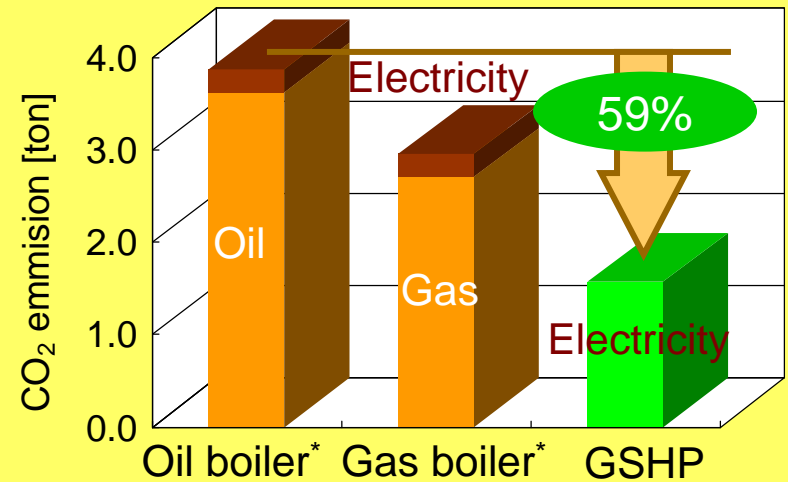
10,477 kWh



Boreholes

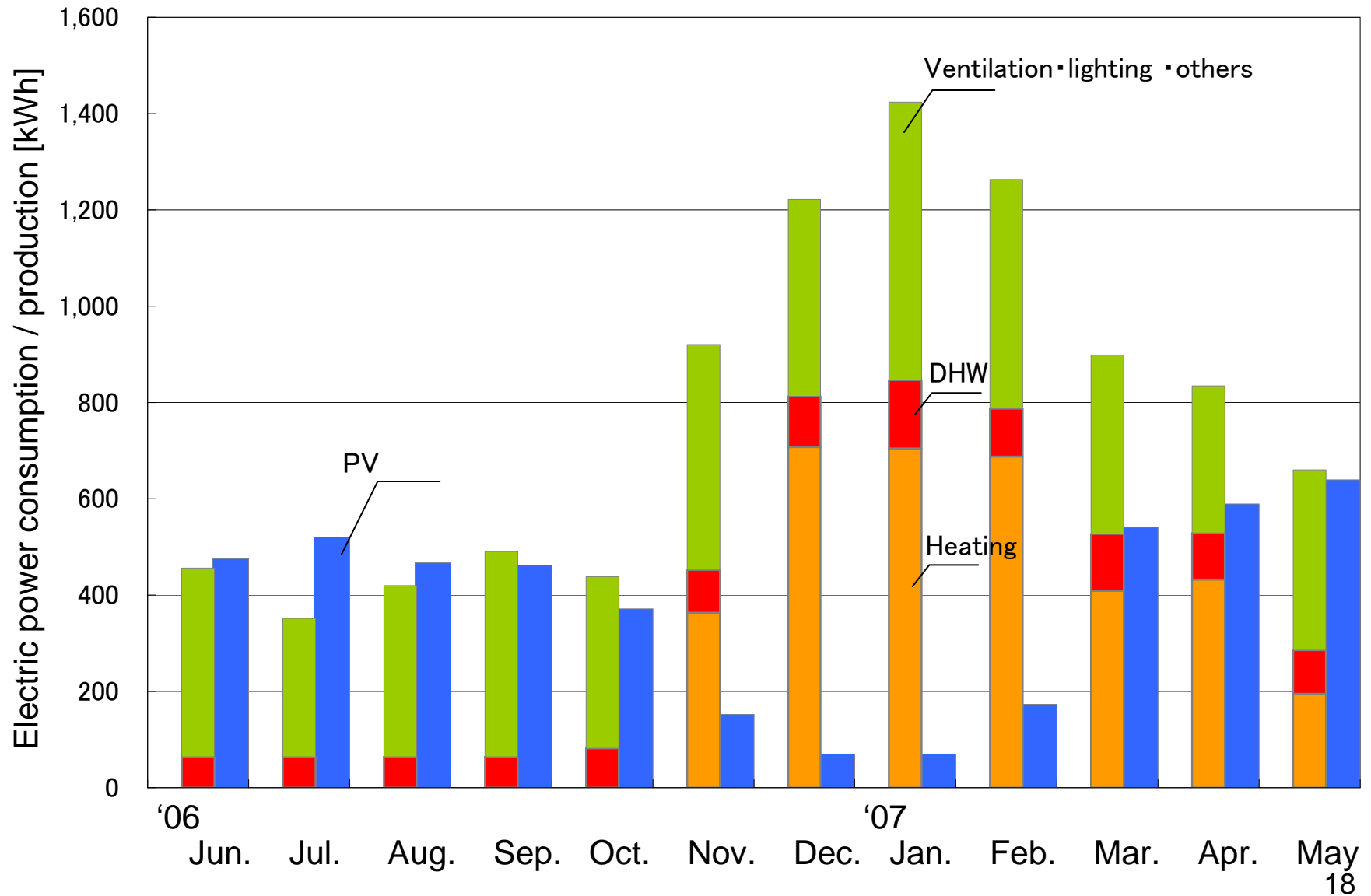


## Environmental merit

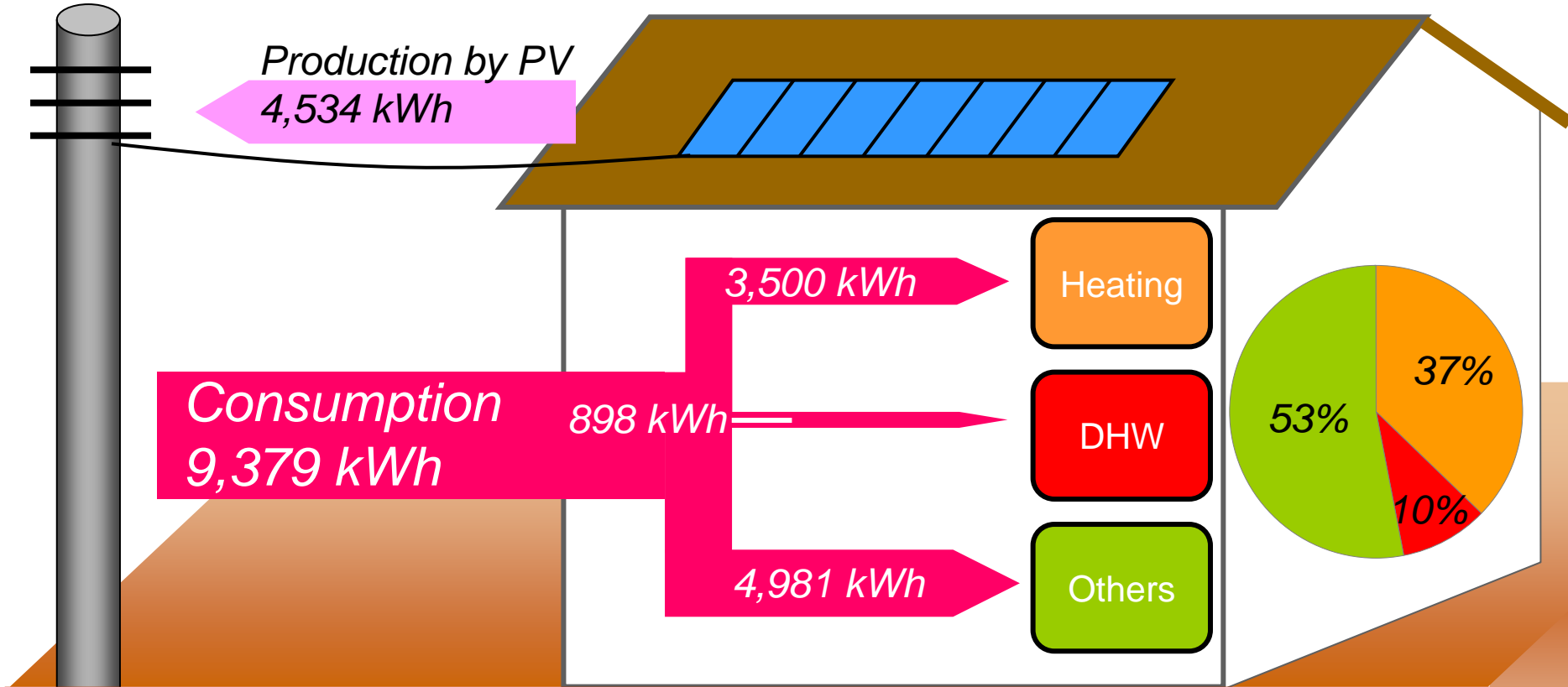


\* Boiler efficiency: 85%

# Monthly power consumption and production



# Annual energy balance



Real consumption  
4,845 kWh  
(24 kWh/m<sup>2</sup>)

= 236 MJ/m<sup>2</sup> (primary energy)

Energy self-sufficiency rate

48%

$$\left[ \frac{\text{production}}{\text{consumption}} \times 100 [\%] \right]$$

# 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<sub>2</sub> 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<sup>2</sup>)

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

# For the 2<sup>nd</sup> 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