IEA HPP ANNEX29 WS
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Field test of ground–coupled heat pump for cold climate region of Japan “First and Second demonstration project heat pump system in the Low Energy House”

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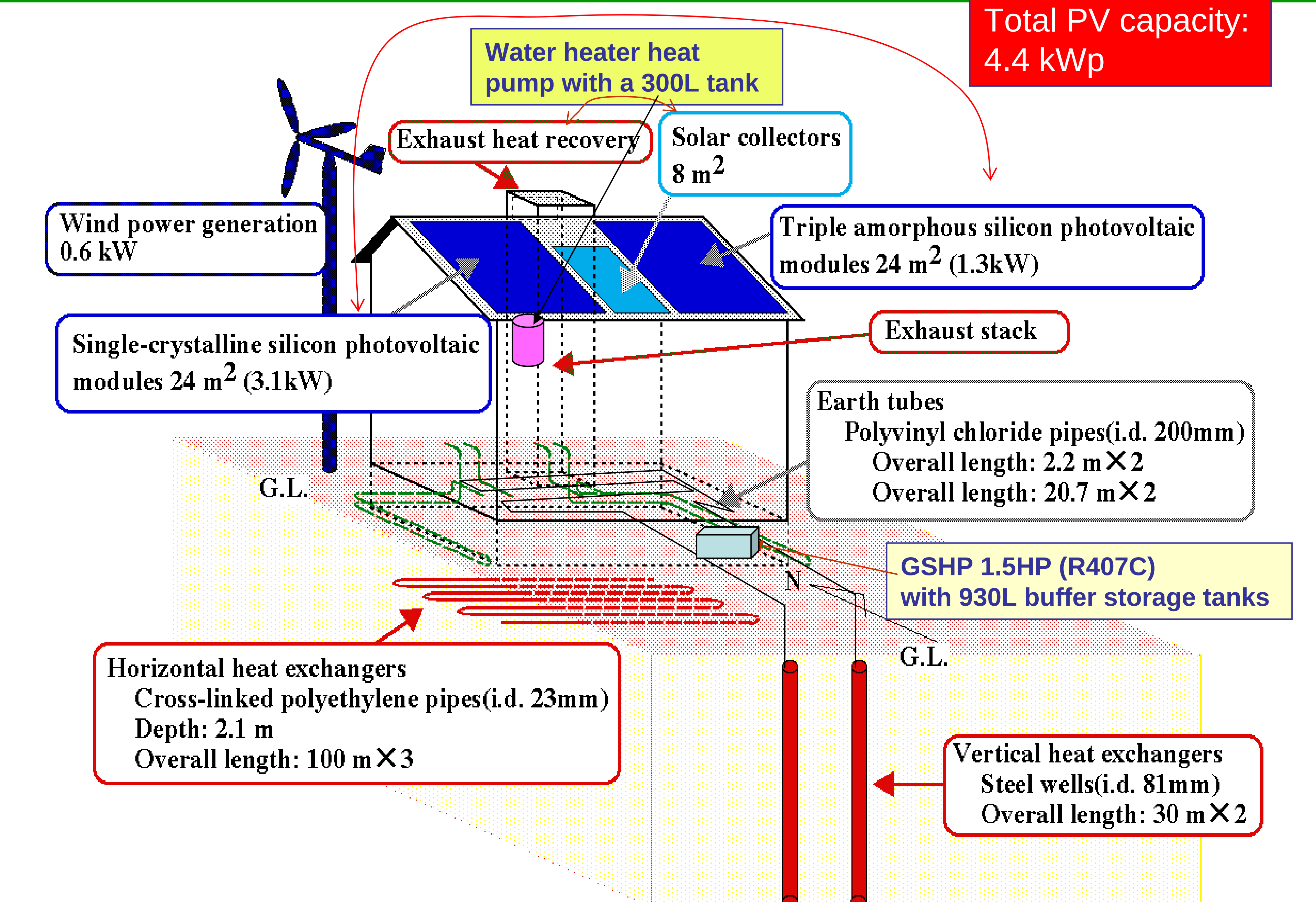
1. Hokkaido University's Low Energy Experimental House built in March, 1997

Outline of Hokkaido University's Low Energy Experimental House

Year of Completion	March,1997	
Method of construction	Insulation panel method	
Number of floors	two floors and semi-basement	
Total floor area	$192m^2$(incloud basement)	
Living room floor area	$46m^2$	
Insulation	outer wall	foam-polystyrene boad : 236mm
	loof	foam-polystyrene boad : 236mm
	basement	foam-polystyrene boad : 150mm (on the ground)
		foam-polystyrene boad : 100mm (under the ground)
	window	Low-E pair glass : overall heat transfer coeficient $1.38W/(m^2 \cdot K)$
Method of ventilation	Living room : stack ventilation+inhalation fan	
	Kitchen・rest room・bathroom : forcibly exhoust	
Method of heating	floor heating	
	radiation heating under window	
Heat loss coeficient	$0.97W/(m^2 \cdot K)$	

Introduced active and passive techniques



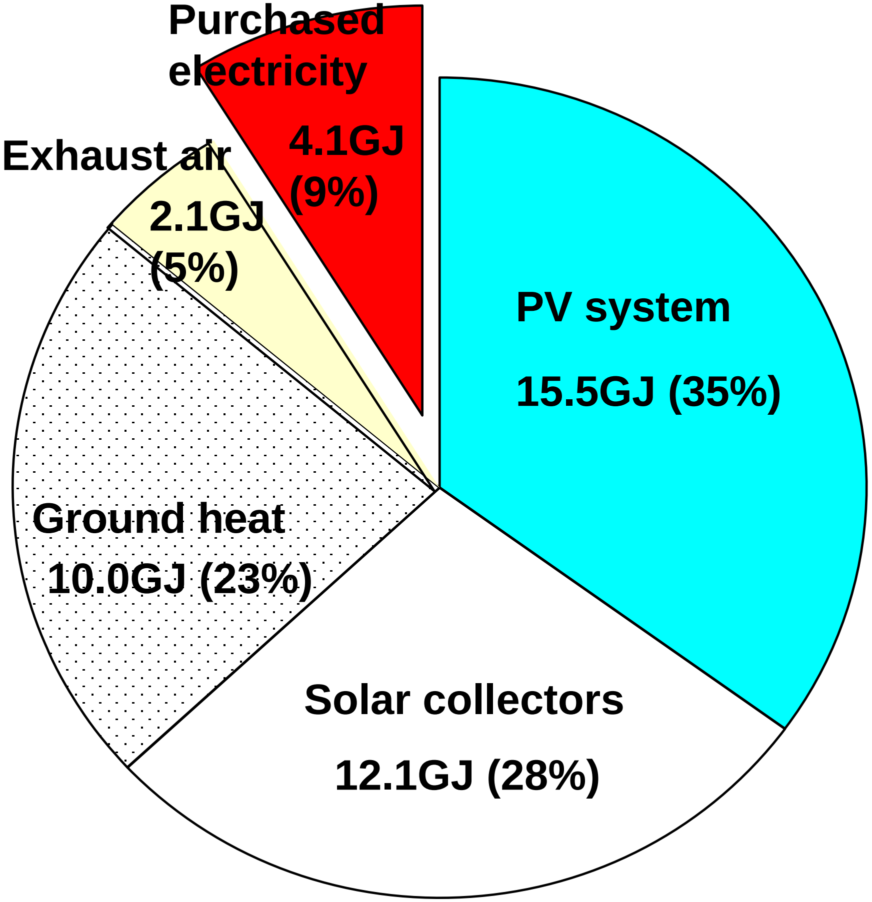
Actual COP of GSHP

COP=4.0, SCOP= 3.1

Table 3 Experimental results of heating operation
(Average daily values in Nov. 5, '97 – Apr. 30,'98)

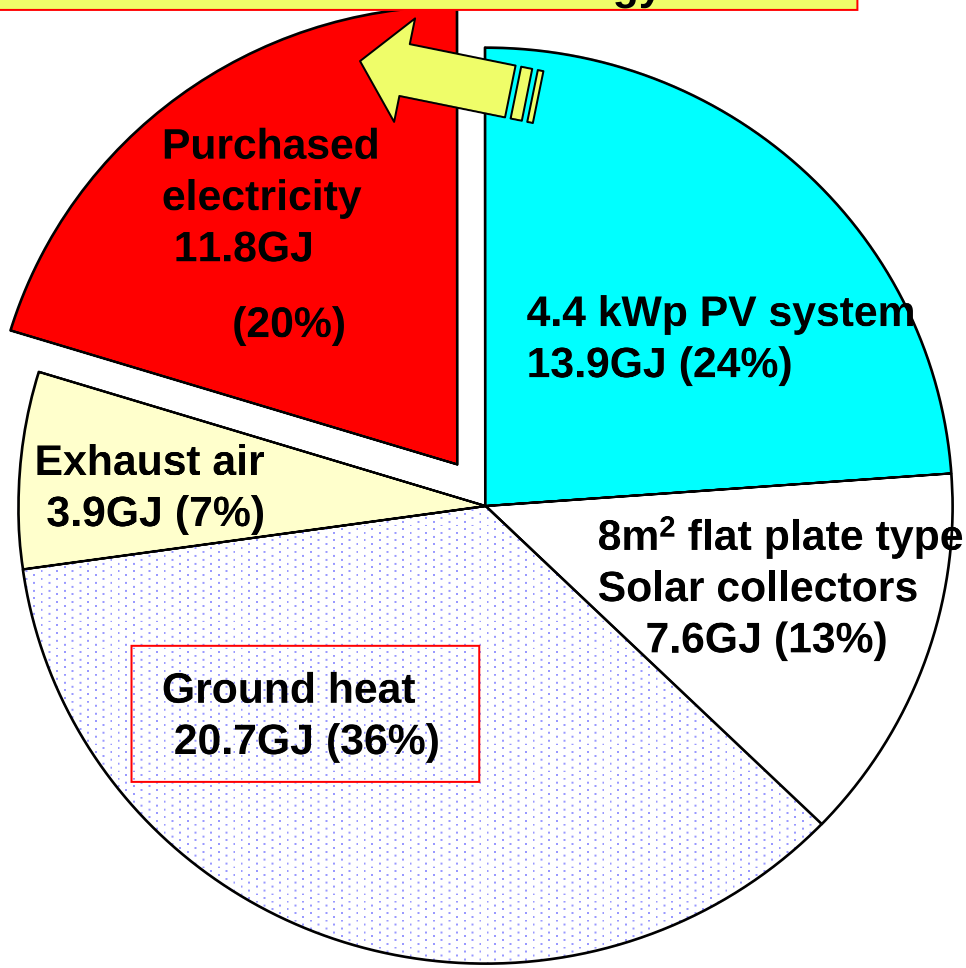
Operation time	12.5 [h/d]
Outdoor air temperature	1.5 [℃]
Room temperature	18.6 [℃]
Relative humidity	0.21 [%(RH)]
Brine Temp.	40.8 [℃]
Heat extraction rate	40.8 [W/m]
C.O.P.	4.0
S.C.O.P.	3.1

Estimated and actual energy sources



Total : 43.8 GJ/year

When total PV system of 8.2 kWp is introduced, this low house becomes “Net Zero Nergy House”



Total: 57.7GJ/year

2. First best practice GSHP for a low energy house

- Dec. 2005,
- Two habitants (Adults)
- Total floor area: 200m^2
- Thick concrete slab floor
- Heat loss coefficient (Q value) : 0.96 W/m^2/K
- Window area: 83 m^2 (64 m2 is faced to south)
- Window performance: Low-E Triple Argon gas filled (K value<1.3 W/m^2/K)

Concept of this Low Energy House

Building physics
- High thermal insulation, and high air tightened
- Passive solar techniques (Big windows and large thermal mass)

DHW
- Air source CO2 heat pump water heater

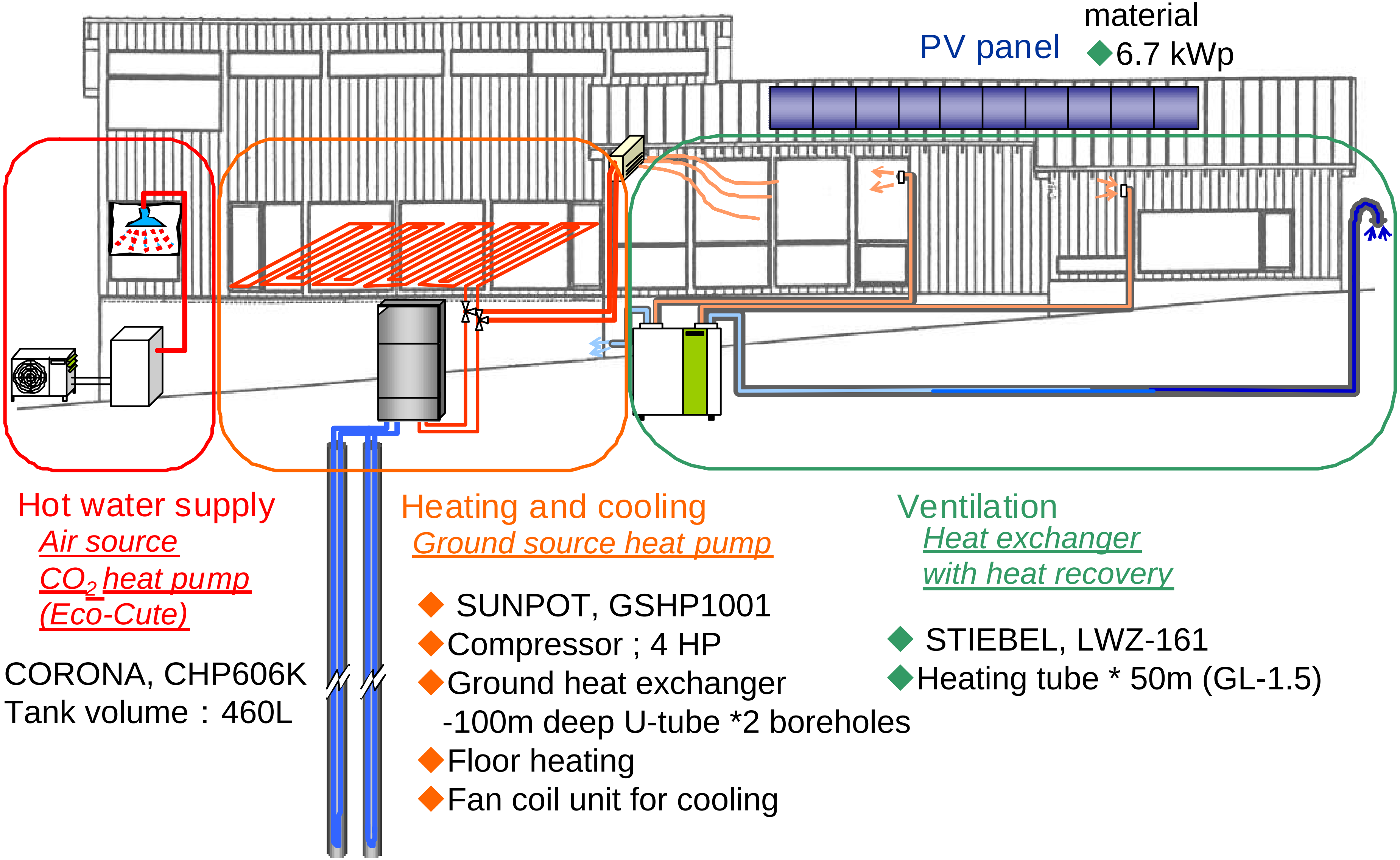
Heating and cooling
- GSHP + floor heating (+ fan coil units)

Ventilation
- 50 m Heating tube + High efficient heat recovery ventilation unit

Electric power generation
- 6.79kWp of solar PV integrated with the roof material

Applied active contents

PV panel
- Integrated in roof material
- 6.7 kWp



Hot water supply

Air source CO_2 heat pump (Eco-Cute)

- CORONA, CHP606K
- Tank volume：460L

Heating and cooling

Ground source heat pump

- SUNPOT, GSHP1001
- Compressor ; 4 HP
- Ground heat exchanger
  -100m deep U-tube *2 boreholes
- Floor heating
- Fan coil unit for cooling

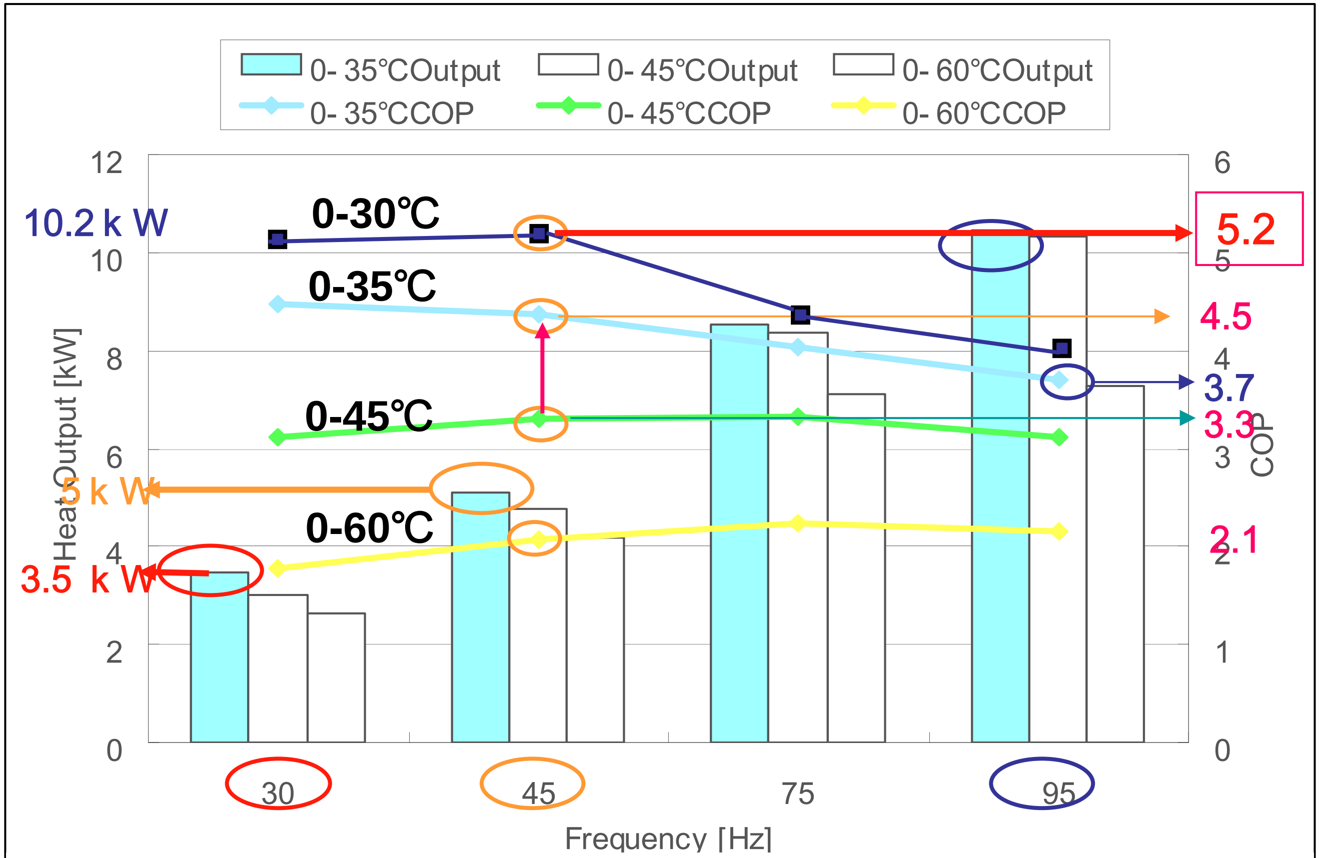
Ventilation

Heat exchanger with heat recovery

- STIEBEL, LWZ-161
- Heating tube * 50m (GL-1.5)

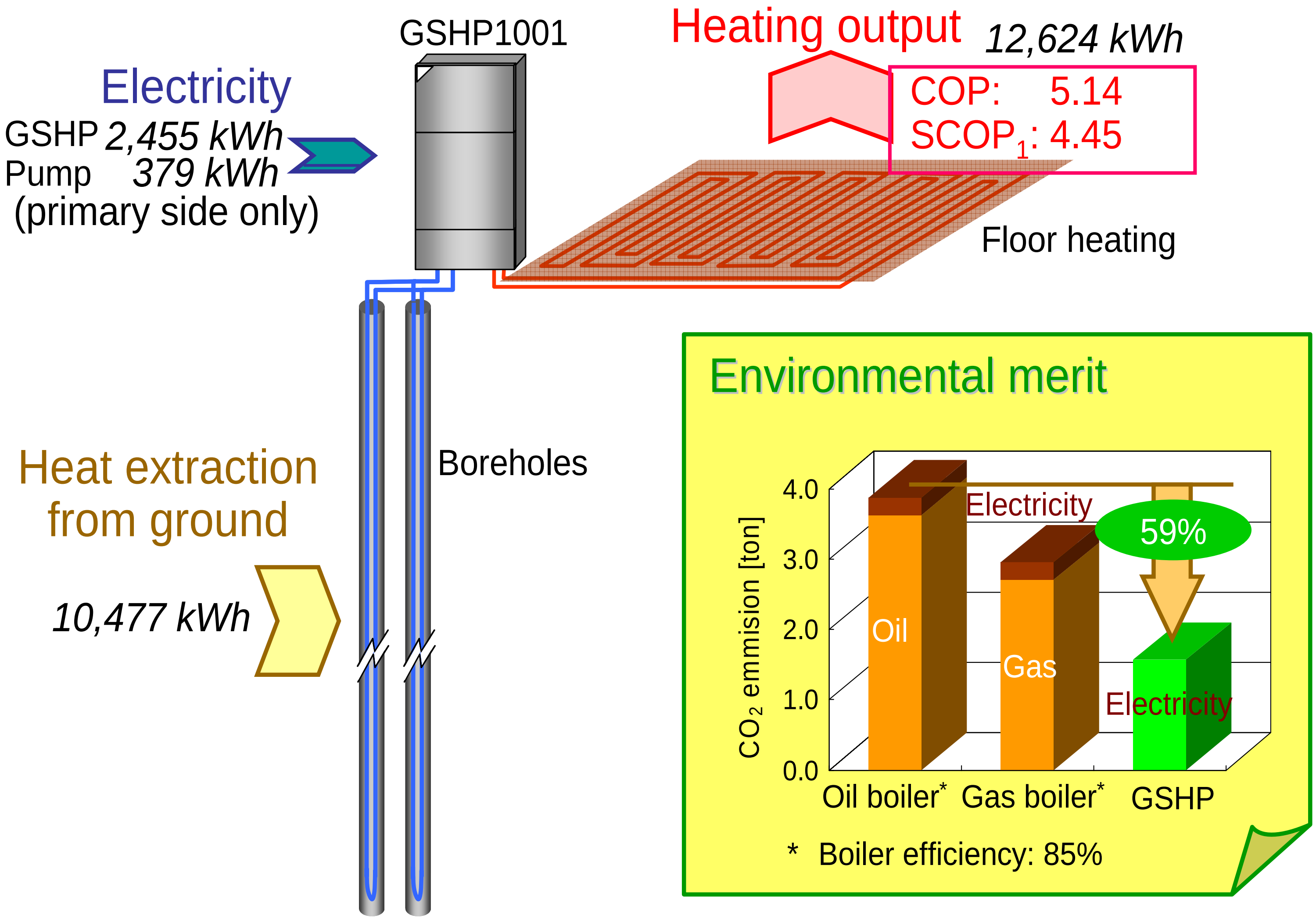
GSHP unit for heating and cooling capacity of 10 kW, "GSHP-1001" from April, 2007 by SUNPOT Co ltd cooperated with Nagano lab.

- **Heating and cooling (Max. output 10 kW)**
- **Inverter controlled twin rotary compressor (3.5 kW – 10kW)**
- **DC brushless circulation pumps are included**
- **Outside installation is available**



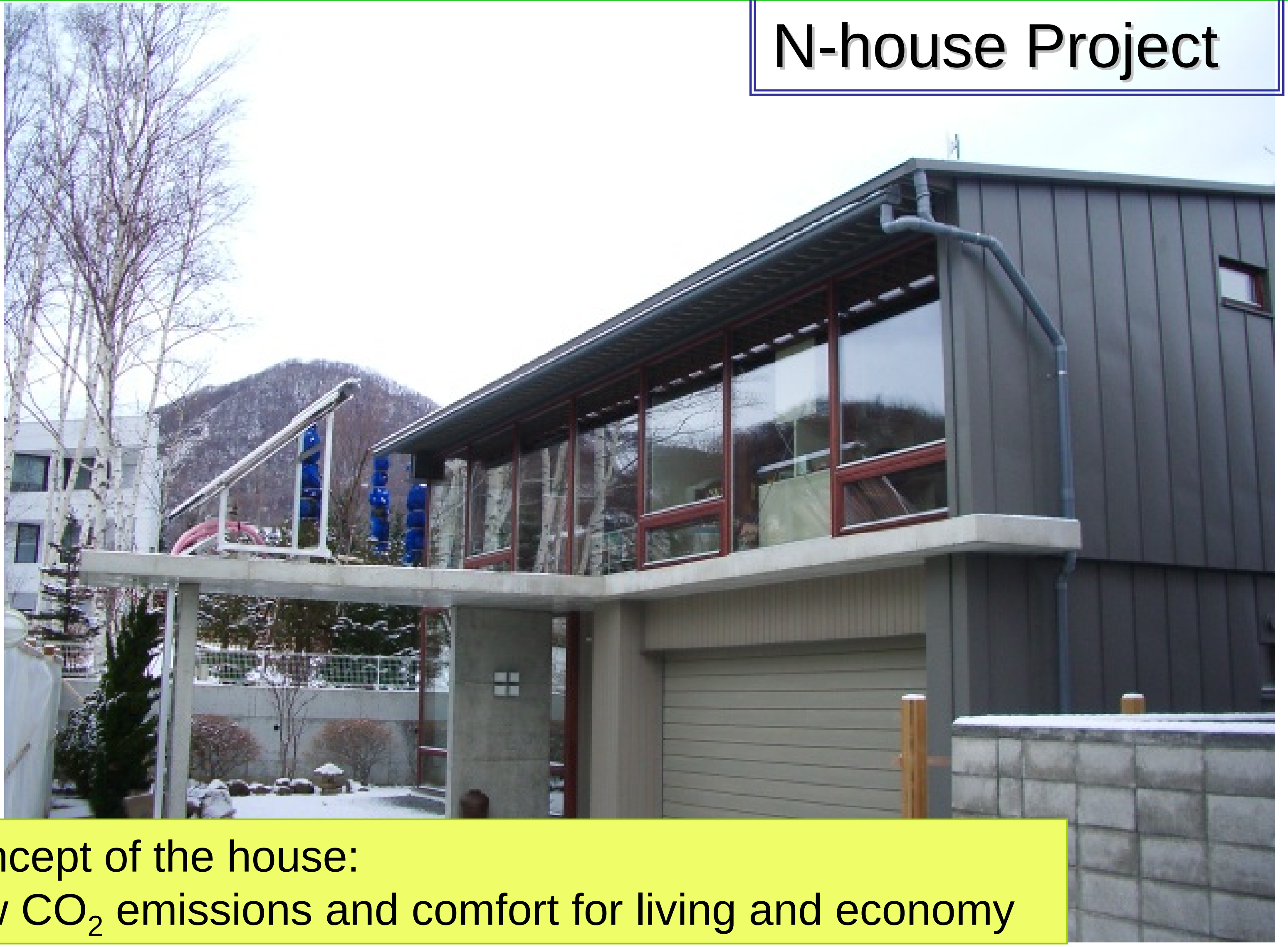
Frequency of power supply to a compressor

Seasonal heat balance and performance of the GSHP system (Nov. 2006 – May. 2007)



3. The second demonstration project
Urban Low Energy House integrated with HPs in cold region of Japan

N-house Project



Concept of the house:
Low CO_2 emissions and comfort for living and economy

Outline of the Low energy house

- Living from 19th of November, 2007
- Monitoring from 1st January, 2008

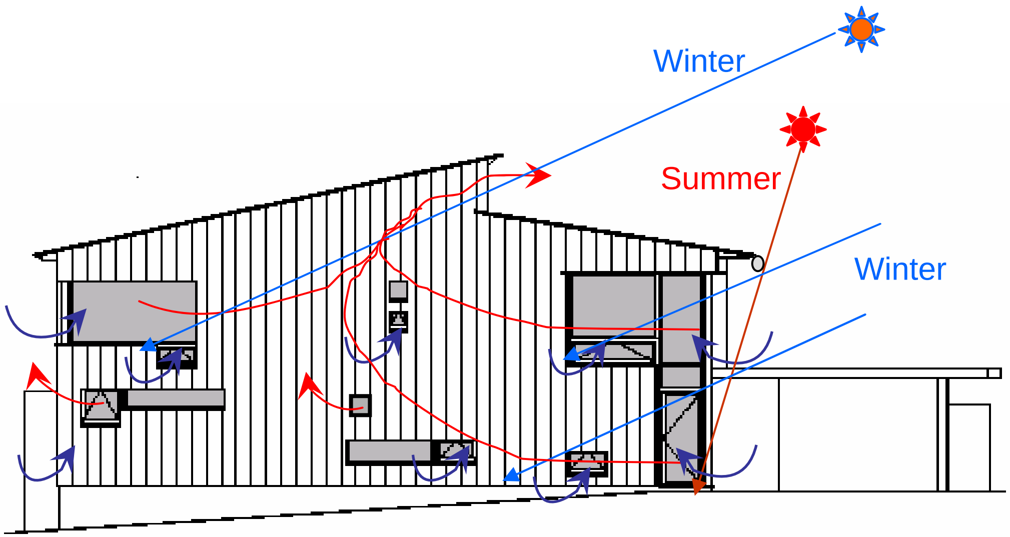
- Overall heat loss coefficient (Q value) : 0.94 $W/m^2/K$
- Total living floor area: 200 m^2
- Construction method: reinforced-concrete (1st floor and concrete slab and inner wall of 2nd floor)+ Wooden construction (outside wall of 2nd floor and roofs)
- Four heat pumps:
  - –One for Heating (Max. output 10 kWX1)
  - –One for Water heater (Max. output 4.5 kWX1)
  - –Two for Snow melting (6.2 kWX2)
- GSHP floor heating system with thermal energy storage in thermal mass of concrete slab during night time
- Free cooling for floor and fan coil units
- Earth tube + Humidity control chamber + Heat recovery ventilation system
- GSHP water heater assisted by a evacuated solar collector
- 3 kW PV system with roof snow melting
- GSHP snow melting system for the pavement

Passive Solar House

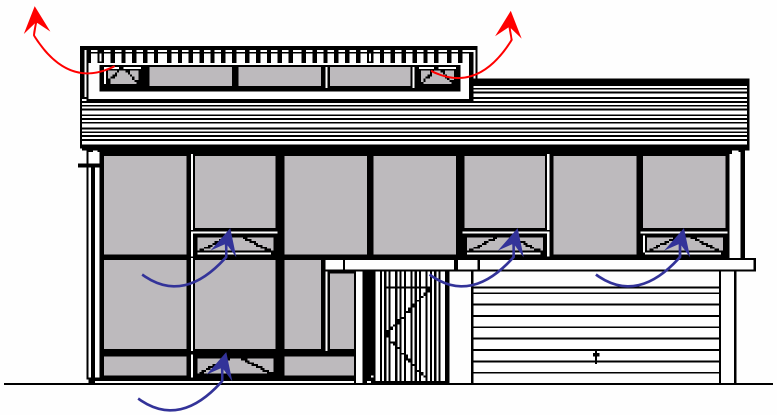
Southern glazing curtain wall construction

Entrance hall and conservatory

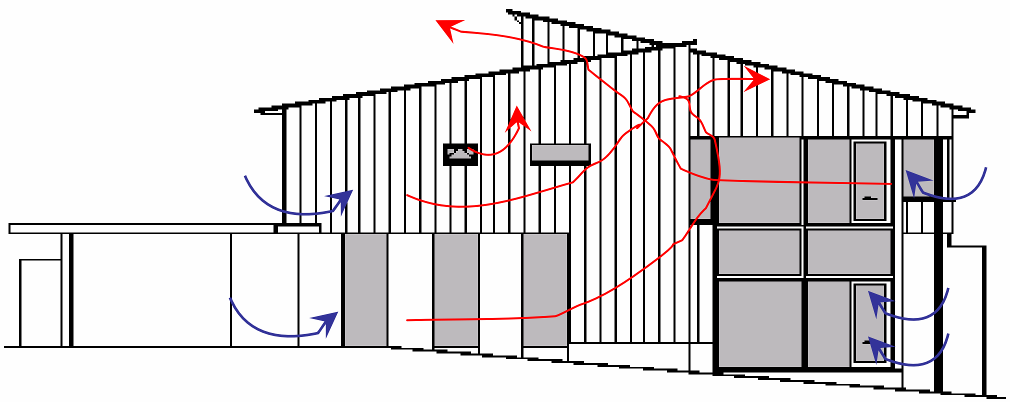
Elevations and natural ventilation passes



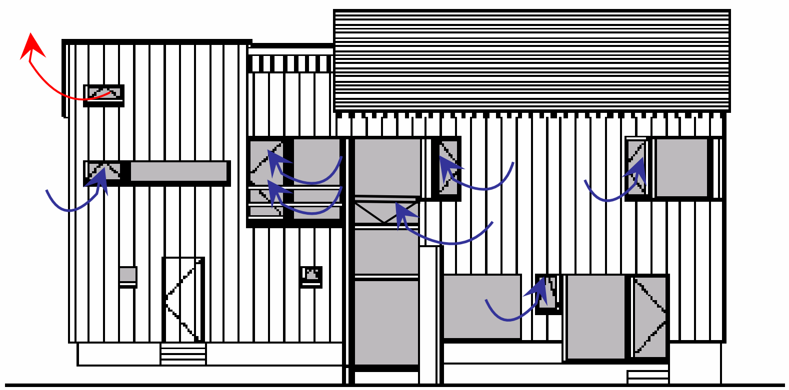
西立面図



南立面図

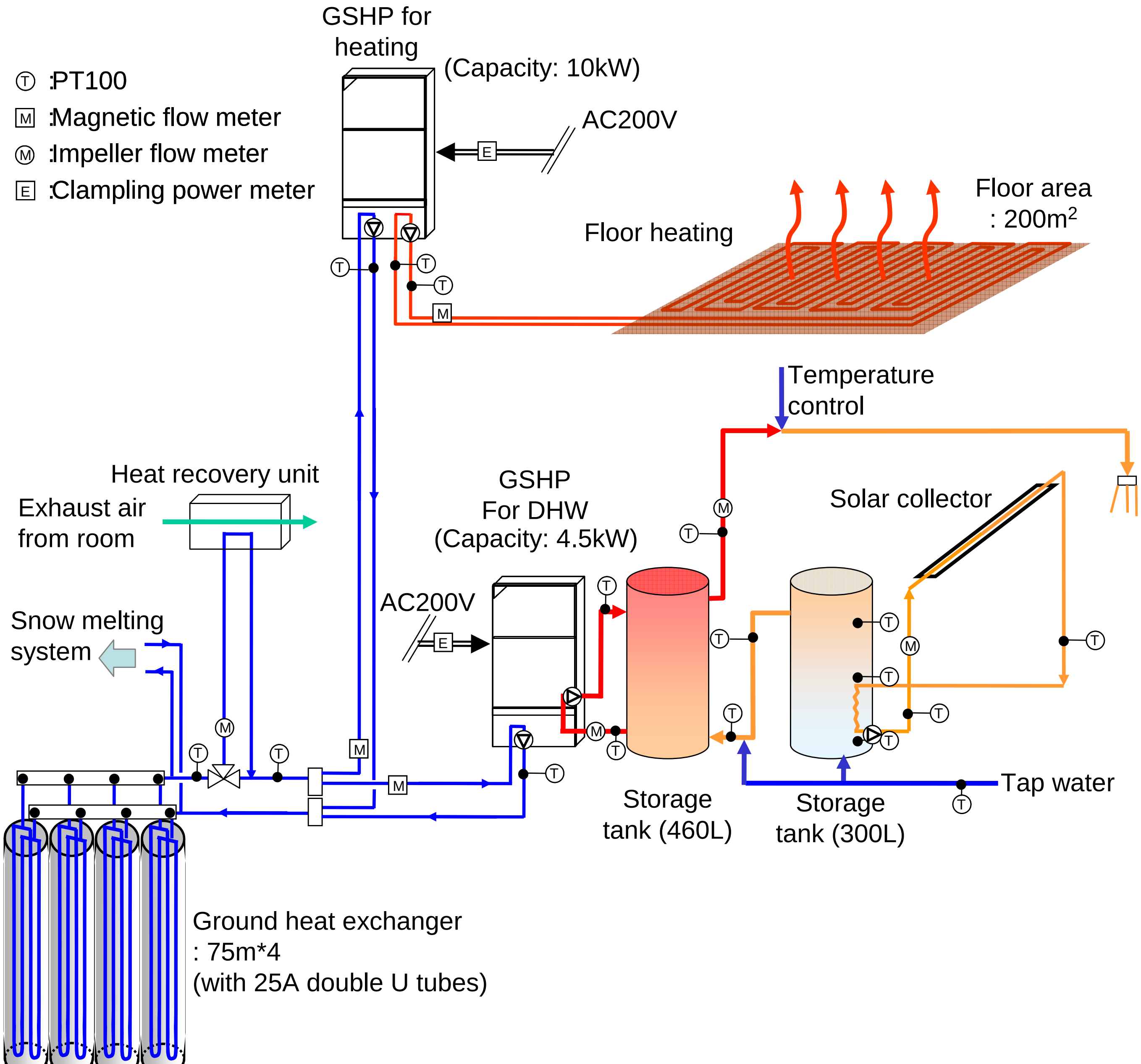


東立面図



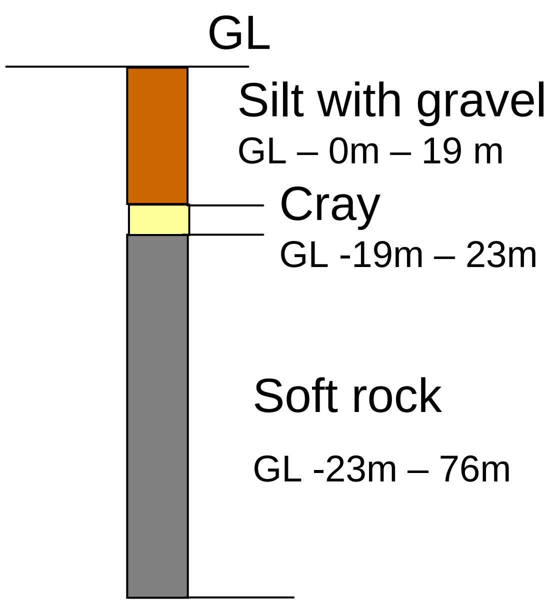
北立面図

System configuration of the GSHP Heating, cooling and DHW system



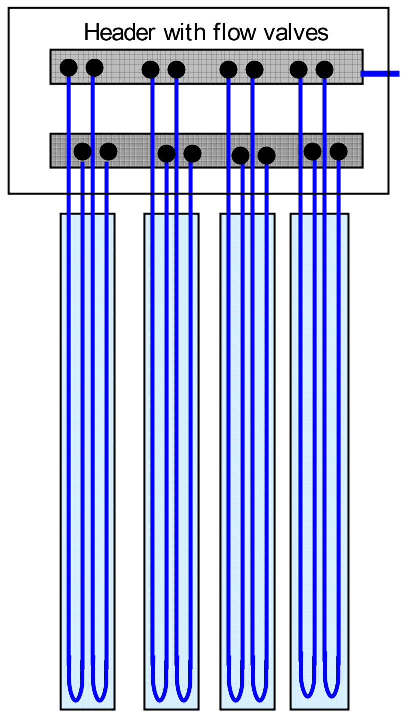
Geological conditions and Ground heat exchanger

Central area of Sapporo city (+50 m SL)



Geological Condition

Effective thermal conductivity is 2.5 W/m/K

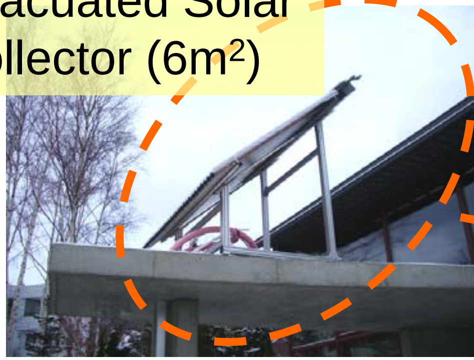


Ground Temperature at 75m deep is 11.8 ^{o}C

4 vertical boreholes (75m deep * 4 boreholes (Double-U tubes)) are connected to 4 heat pumps of total heat output of 26 kW

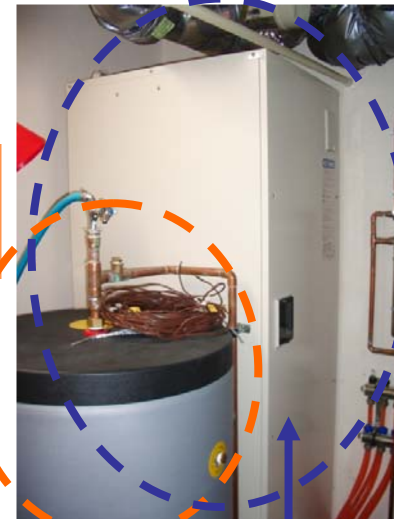
GSHP Water heater assisted by solar Collector

Evacuated Solar Collector (6m²)



Daytime

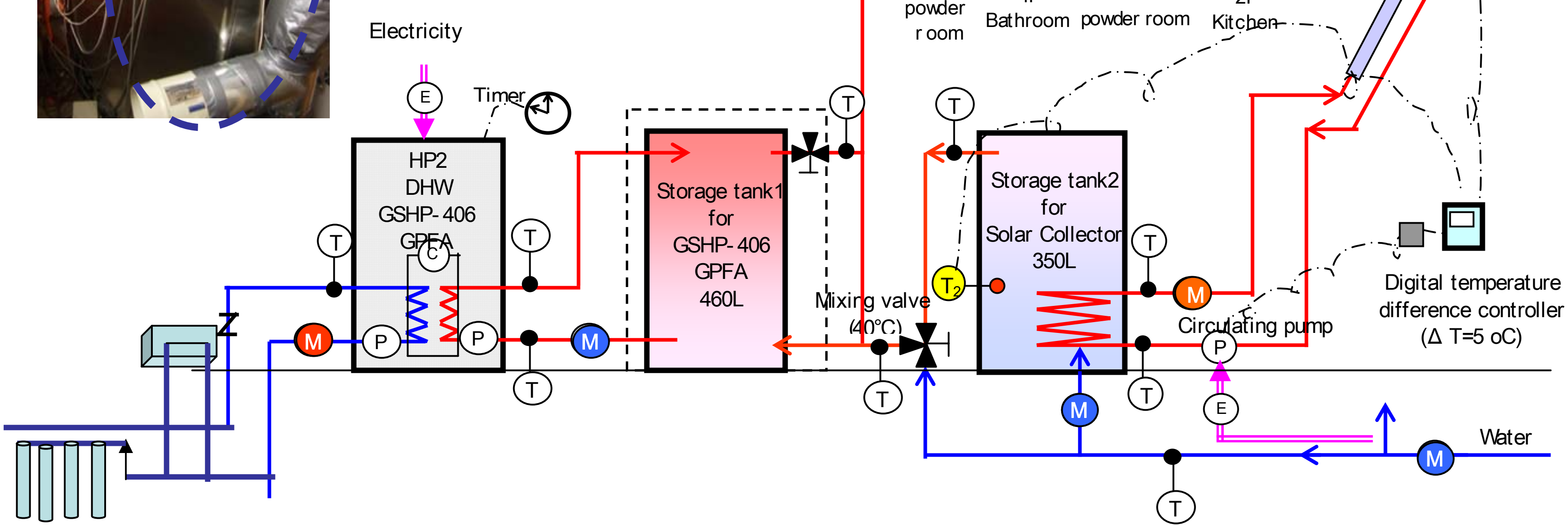
Storage tank 1
V=350 L



Storage tank 2
V=460L
Stored temp. = 65 °C

Nighttime
1:00AM -7:00AM (6hrs)

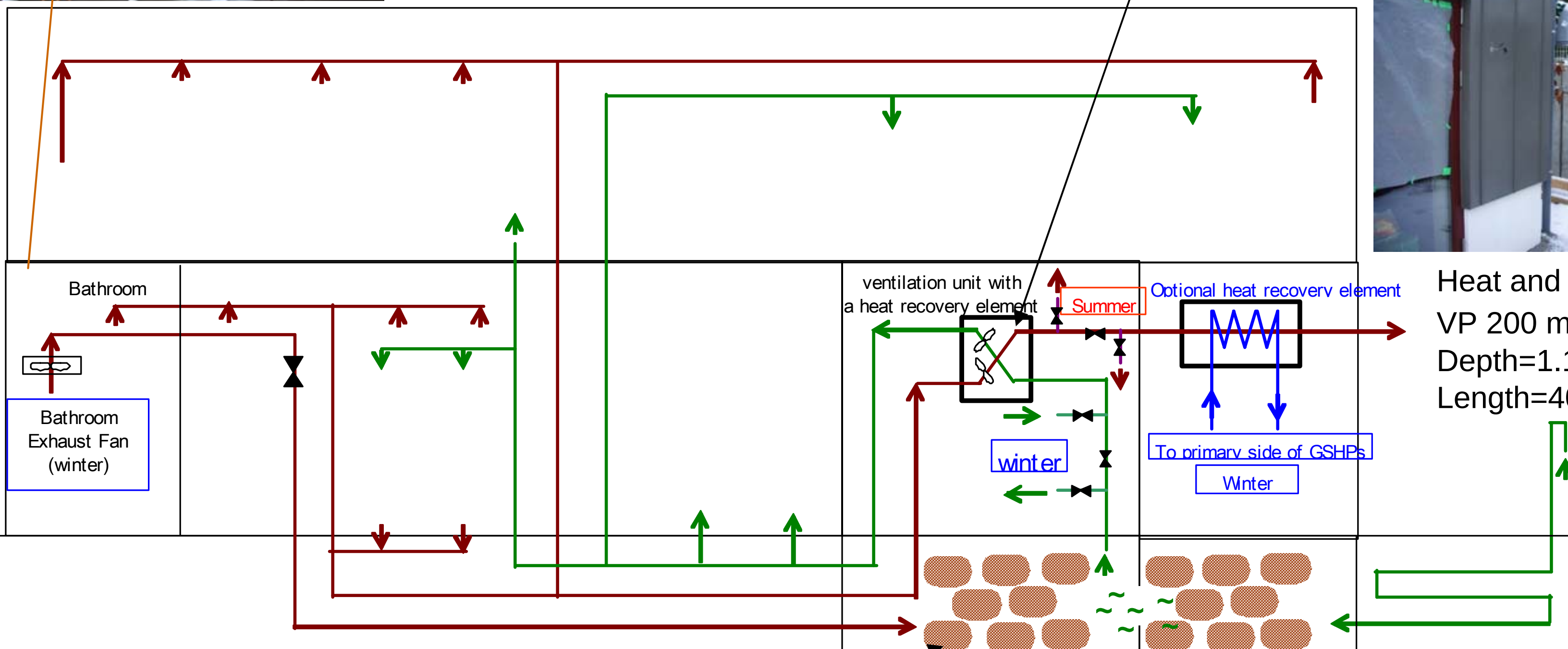
Heat output is 4.5 kW



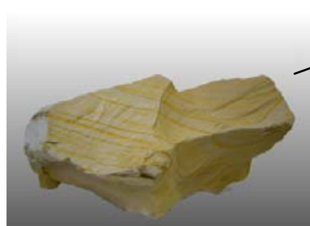
Ventilation system

Plastering wall by powder of Wakkanai Siliceous Shale

ventilation unit with a heat recovery element



Heat and cool tube
VP 200 mm ϕ
Depth=1.1m,
Length=40m



Nano-porous rocks for passive humidity control:
Wakkanai Siliceous Shale Stone 10 kg/bag * 150 bags

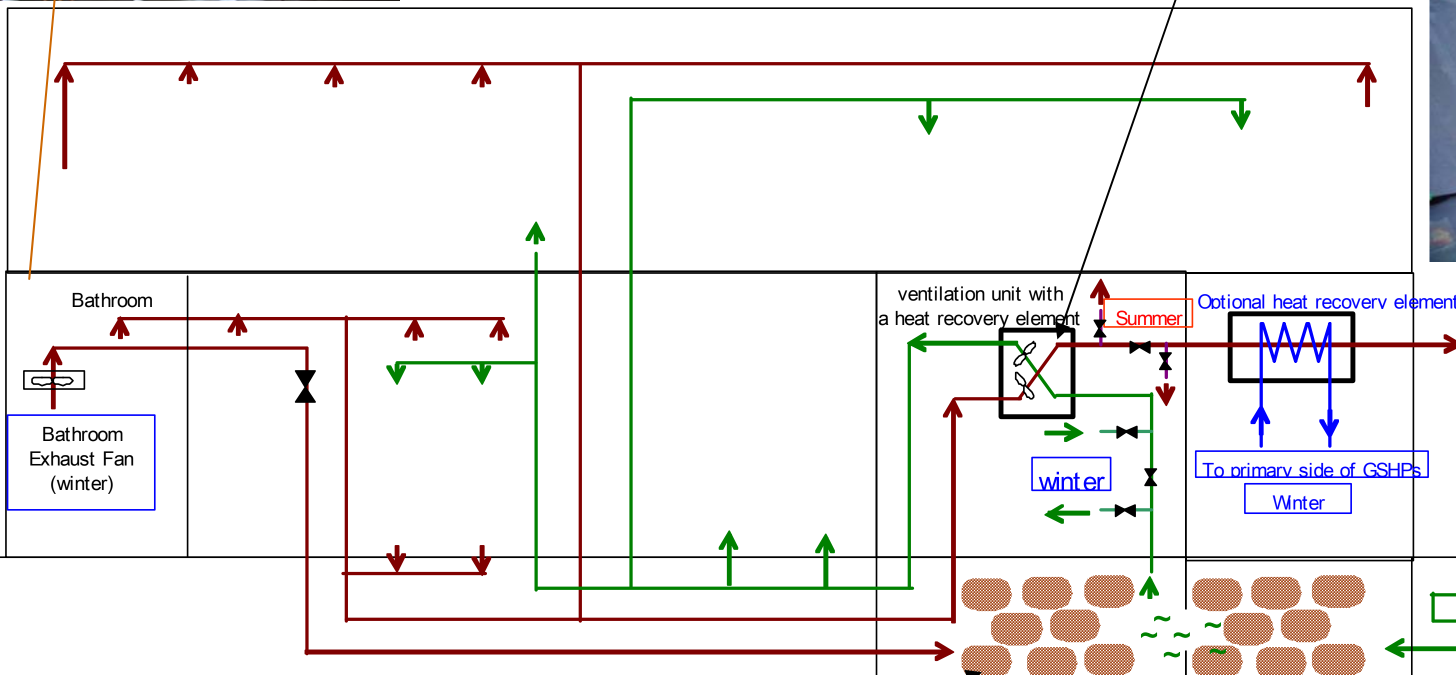
Automatic FF type wooden pellet stove made by SUNPOT Co.ltd.

Polly crystalline PV system wit roof snow melting function (Capacity; 3.0 kWp)

Ventilation system with passive humidity control

Plastering wall by powder of Wakkanai Siliceous Shale

ventilation unit with a heat recovery element



Heat and cool tube
VP 200 mm ϕ
Depth=1.1m,
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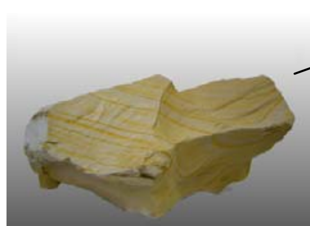
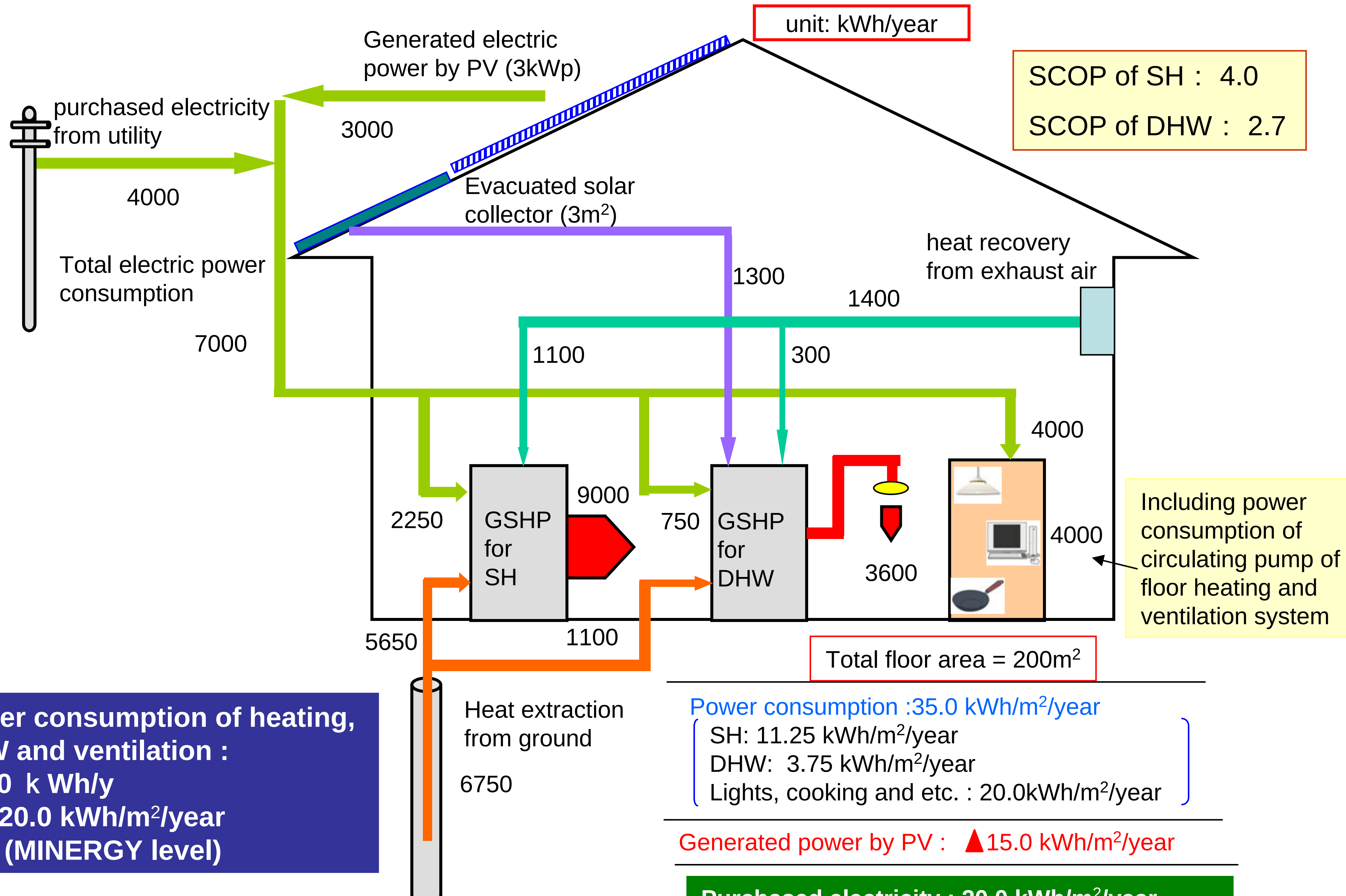


Nano-porous rocks for passive humidity control:
Wakkanai Siliceous Shale Stone 10 kg/bag * 150 bags

Estimated electric power consumption and energy balance



Total floor area = 200m²

Power consumption of heating, DHW and ventilation :
4,000 k Wh/y
→ 20.0 kWh/m²/year
(MINERGY level)

Power consumption :35.0 kWh/m²/year

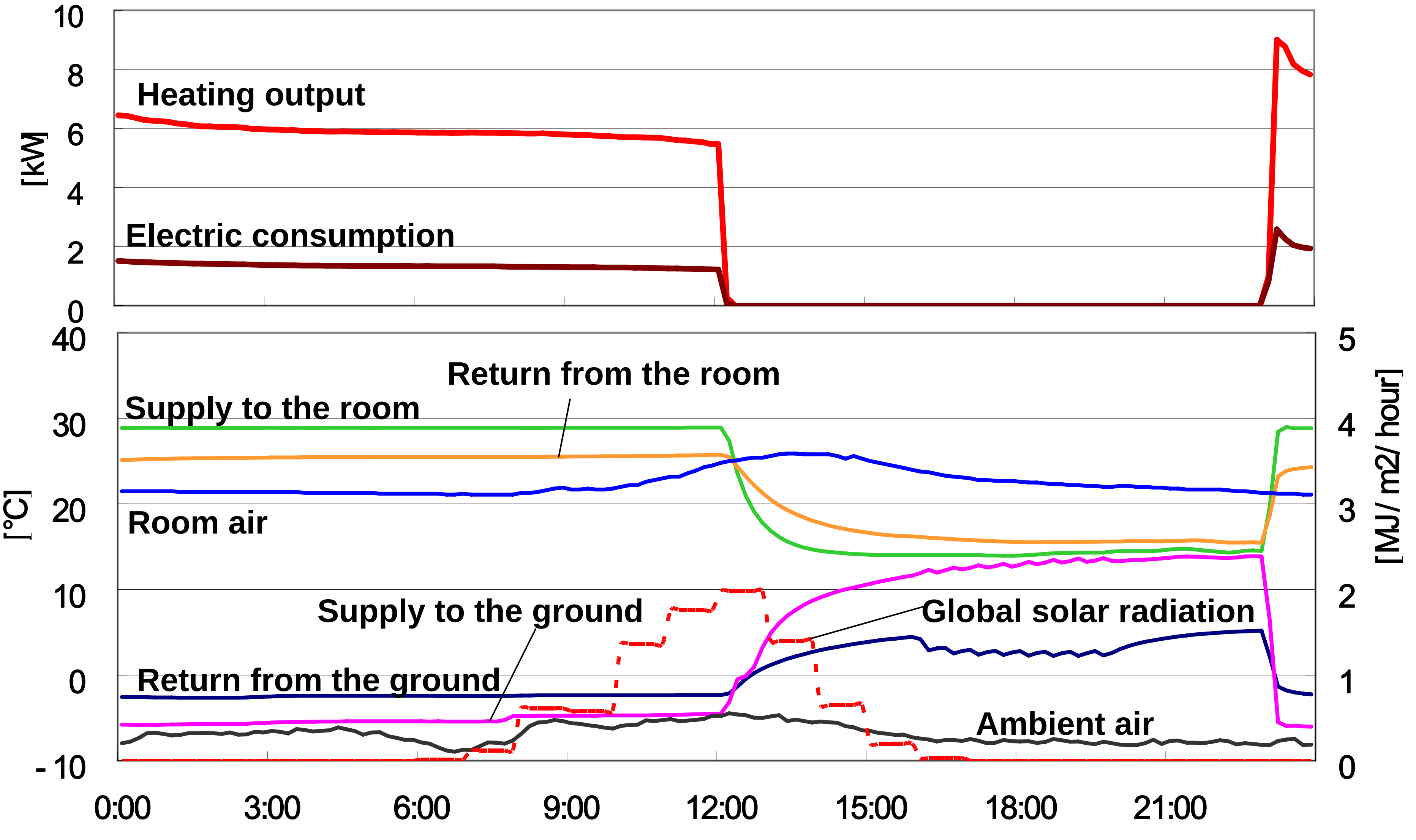
SH: 11.25 kWh/m²/year
DHW: 3.75 kWh/m²/year
Lights, cooking and etc. : 20.0kWh/m²/year

Generated power by PV : ▲15.0 kWh/m²/year

Purchased electricity : 20.0 kWh/m²/year

Temperature variations and performance of the GSHP

Jan.20th, 2008



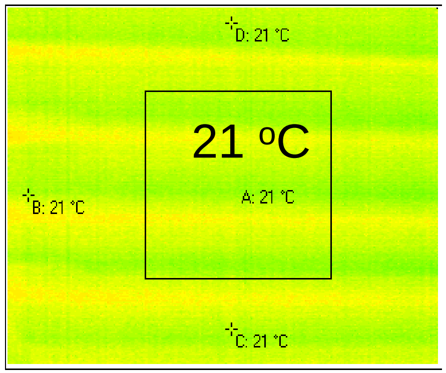
Heating performance for one day operation

Jan.20th, 2008

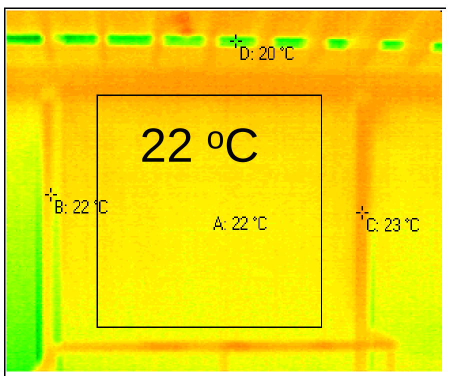
Heating period [hr]	Ambient temp. [°C]	Return from the ground [°C]	Supply to the ground [°C]	Return from the room [°C]	Supply to the room [°C]
14 (Jan.20th 2008)	-6.1	-1.5	-5.1	25.3	28.7

Electric power consumption [kWh]		Heating output [kWh]	COP	SCOP
System	Circulation pump			
18.3	1.3	78.8	4.3	4.0

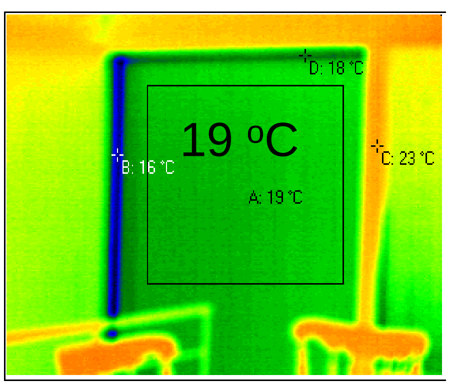
Thermal pictures of surface temperatures

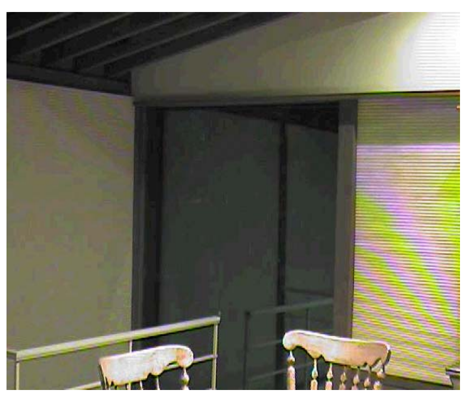


Ceiling

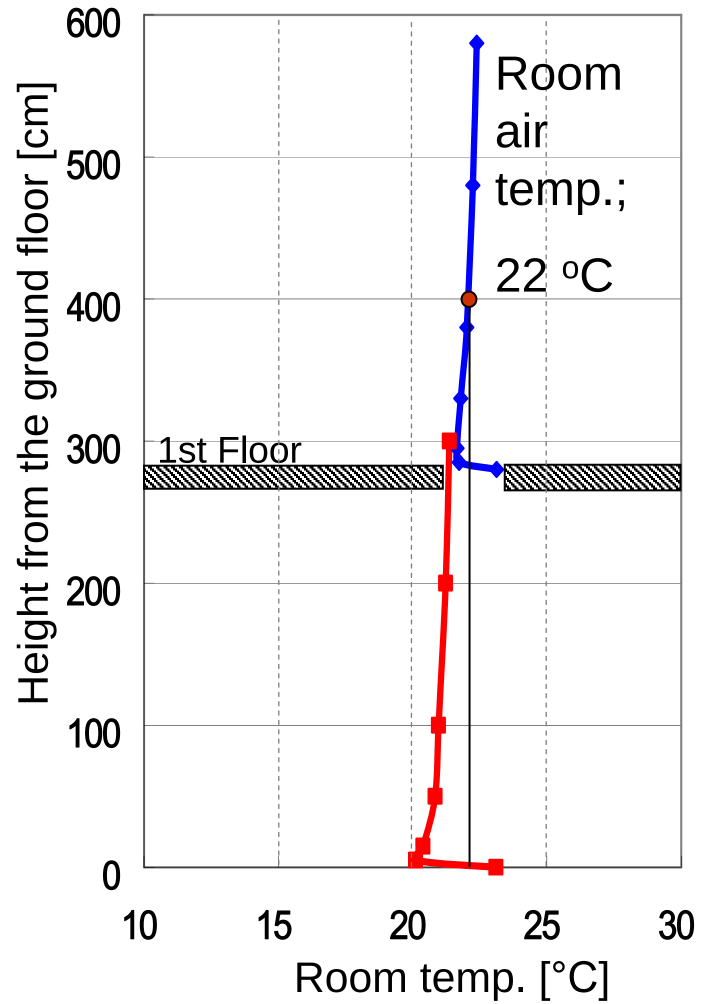


Window (without thermally insulated shade)





Window (without thermally insulated shade)



Water heating performance for one day operation

Feb.20th, 2008

Return from the ground [°C]	Supply to the ground [°C]	Initial water temp. in the tank [°C]	Stored hot water temp [°C]	Flow rate (primary side) [l/min]	Flow rate (secondary side) [l/min]
2.1	0.7	9.0	65.0	8.3	1.4

Electric power consumption [kWh]		Heating output [kWh]	COP	SCOP
System	Circulation pump			
6.7	0.8	18.5	2.8	2.5

Conclusion

- Integrated heat pump unit for heating, cooling, DHW, ventilation with desiccant is needed for the future development
- It has to apply to multiple heat sources, which are ground, exhaust air, outside air and gray water etc.
- Waste heat of cooling can use not only water heater but also regeneration of desiccant material