Urban Low Energy House integrated with GSHPs in cold region of Japan

N-house Project

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

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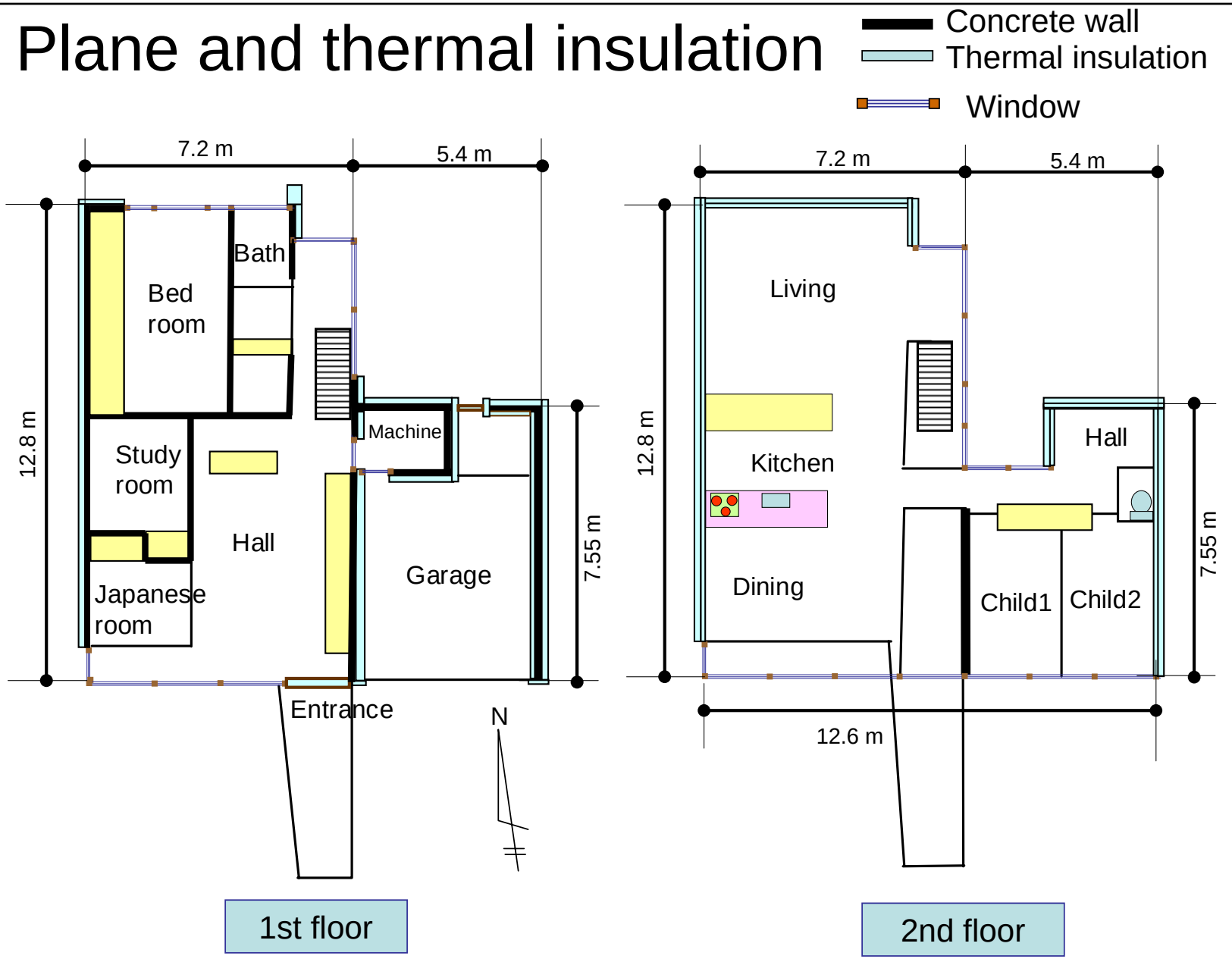
November, 2007 in Kyoto

Outline of the Low energy house

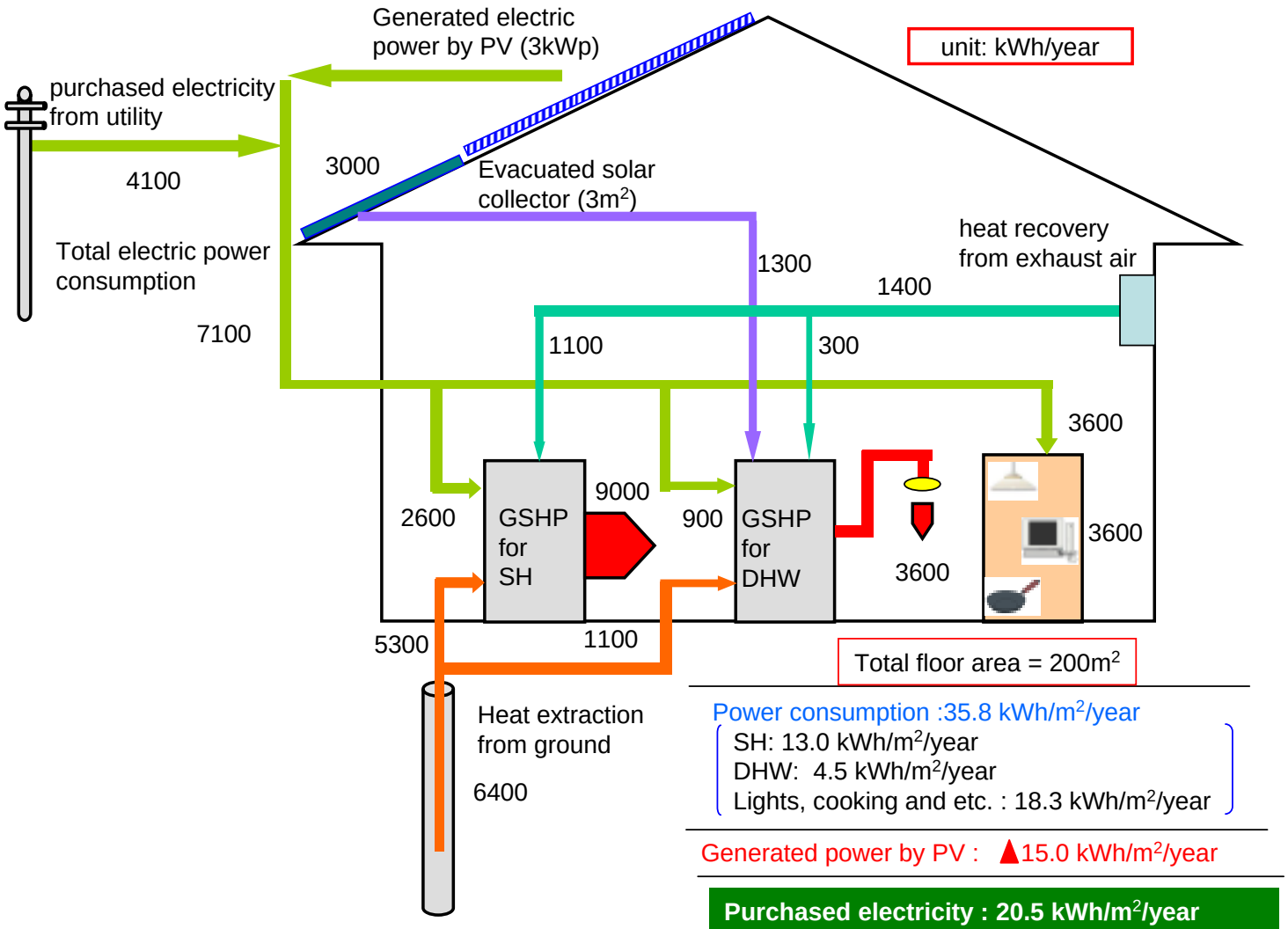
- Living from 19th of November, 2007
- Monitoring from 30th December, 2007

- Overall heat loss coefficient (Q value) : 0.96 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 (10 kWX1)
  - –One for Water heater (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

Plane and thermal insulation



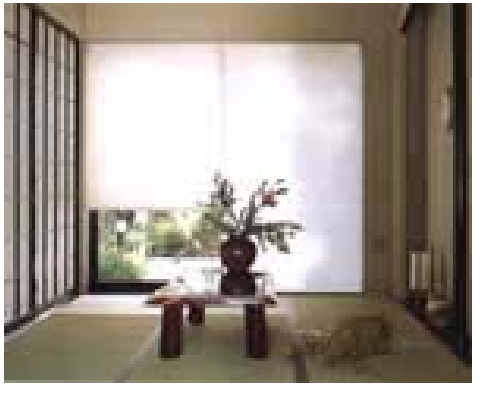
Estimated energy supply and energy consumption



Thermal insulation and U value

- Thermal insulation material:
  Foamed polystyrene board
  (Styrofoam Thermal conductivity λ is < 0.028 W/m/K)
- Thickness of thermal insulation:
  roof: t=300mm (U=0.097 W/m2/K)
  wall: t=250mm for 2nd floor (U=0.116 W/m2/K)
  t=150mm for 1st floor (U=0.185 W/m2/K)
  under floor concrete: t=200mm (U=0.146 W/m2/K)

- Window: Triple glazing with low-E coating and Argon gas filled (U=1.0 W/m2/K for glazing and 1.3 W/m^2/K for window of W0.9m*H2.1m including wooden frame)
- Total window area is 103 m^2
- 53 m^2 of windows face to south
- High thermal insulated screens
  (Honeycomb-Thermo-screens) are used in the night time



Construction of thermal insulation

Building foundation is surrounded by Styrofoam

Inner walls of the garage are covered by Styrofoam

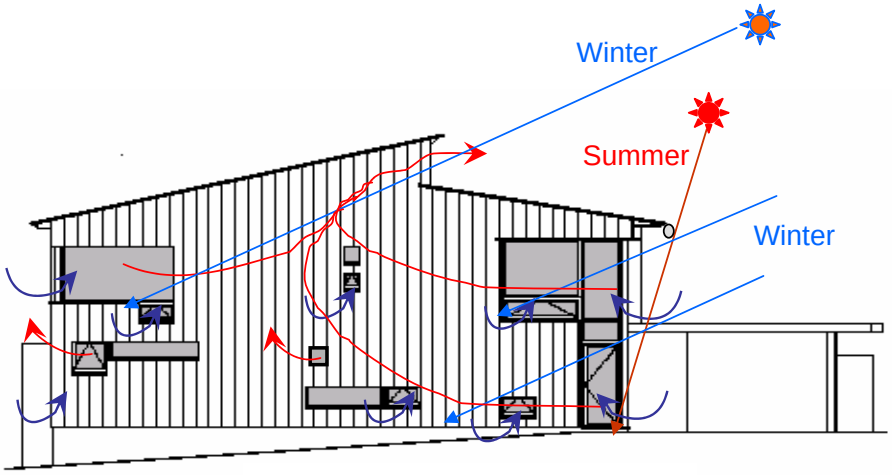
Passive Solar House

Southern glazing curtain wall construction

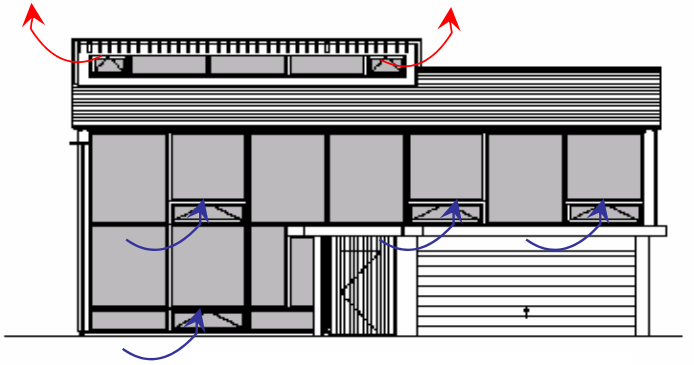
Entrance hall and conservatory

Eastern conservatory space

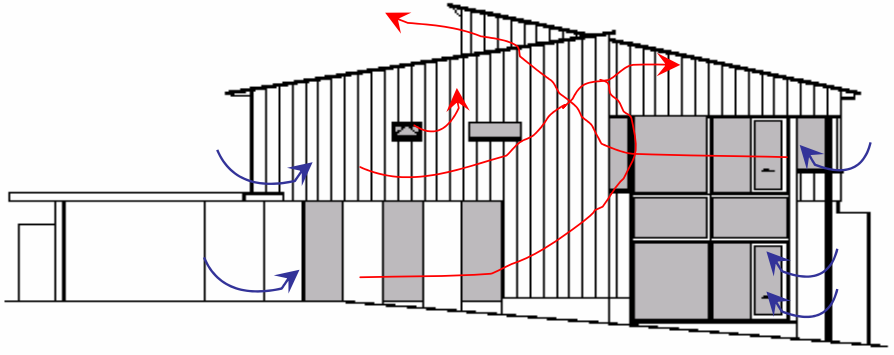
Elevations and natural ventilation passes



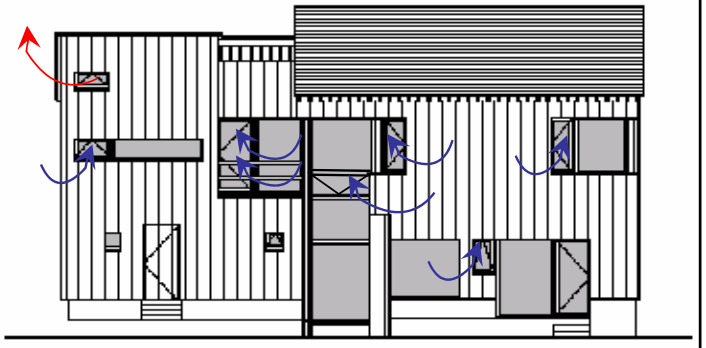
Western side view



Southern side view



Eastern side view



Northern side view

High side windows are effective to release the hot updraft air in summer season and cool outside air enters through lower windows

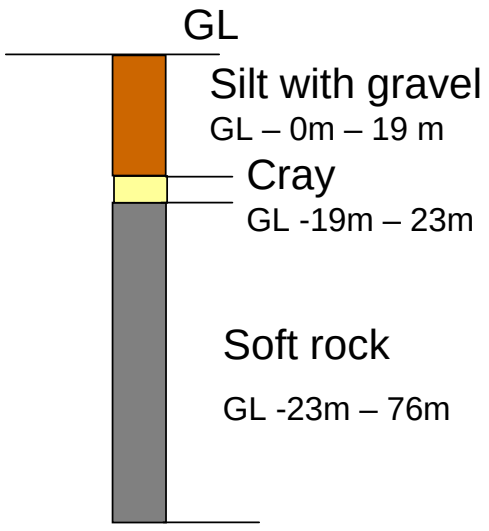
Velux windows
(Open and shut)

Operation of GSHP for HP

- Contract with Hokkaido Electric Power Company to Electric power supply
- For SH, DHW and domestic usage
- Three different price system of EP supply according to time in a day, commercial code name is “e-time 3” :
  (1)Morning and night (8-13, 18-22): 22.94 JPY/kWh
  (2) Afternoon (13-18): 29.83JPY/kWh
  (3) Nighttime(22-8 for 10 hours): 7.43 JPY/kWh
- When the non- thermal storage SH system is applied, monthly specific electricity price during winter season is discounted.

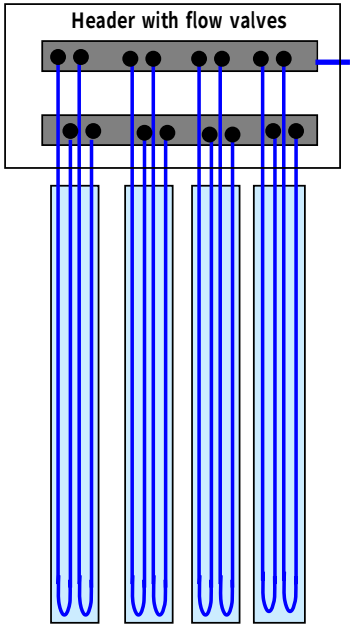
Geological conditions and Ground heat exchanger

Central area of Sapporo city (+50 m SL)



Geological Condition

Effective thermal conductivity is 2.5 W/m/K

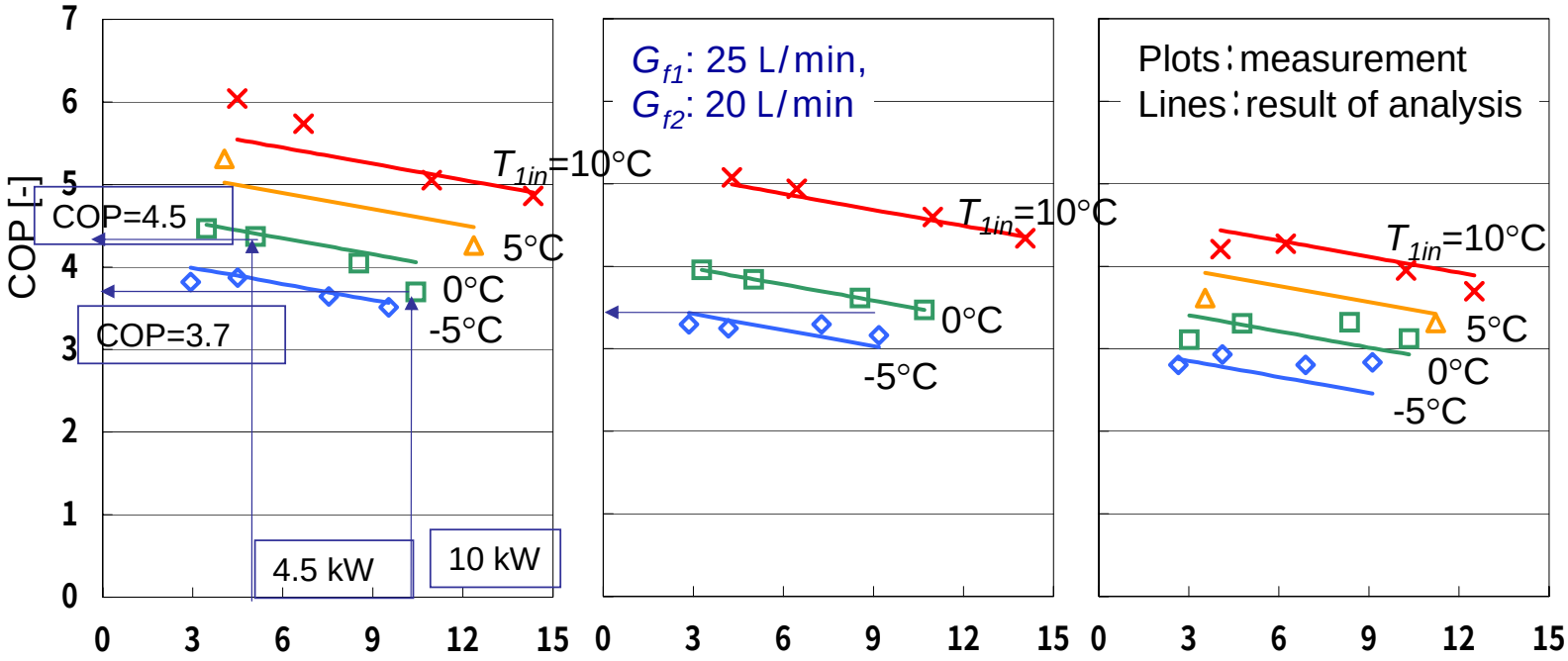


Ground Temperature at 75m deep is 11.8 ^{o}C

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

Performance of applied heat pump unit for SH

- Inverter-control GSHP unit, Max. heating and cooling power is 10 kW (GSHP-1001 made by SUNPOT company in Japan)



COP function obtained by multi-regression analysis:

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

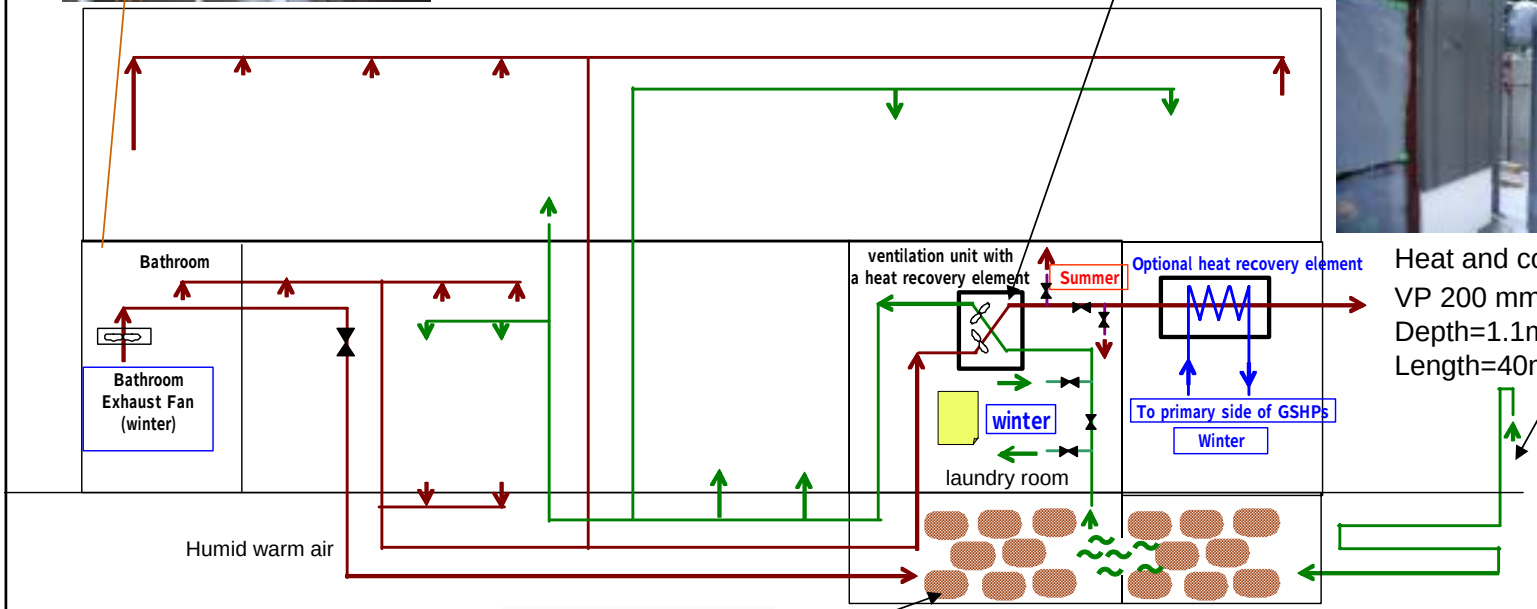
G_f: Flow rate [L/min], T: Temperature [°C]

Subscripts 1: Primary side, *2*: Secondary side for SH or SC, *d*: Secondary side for DHW, *in*: inlet, *out*: outlet

Ventilation system with passive temperature and passive humidity control

Plastering wall made from powder of Wakkanai Siliceous Shale

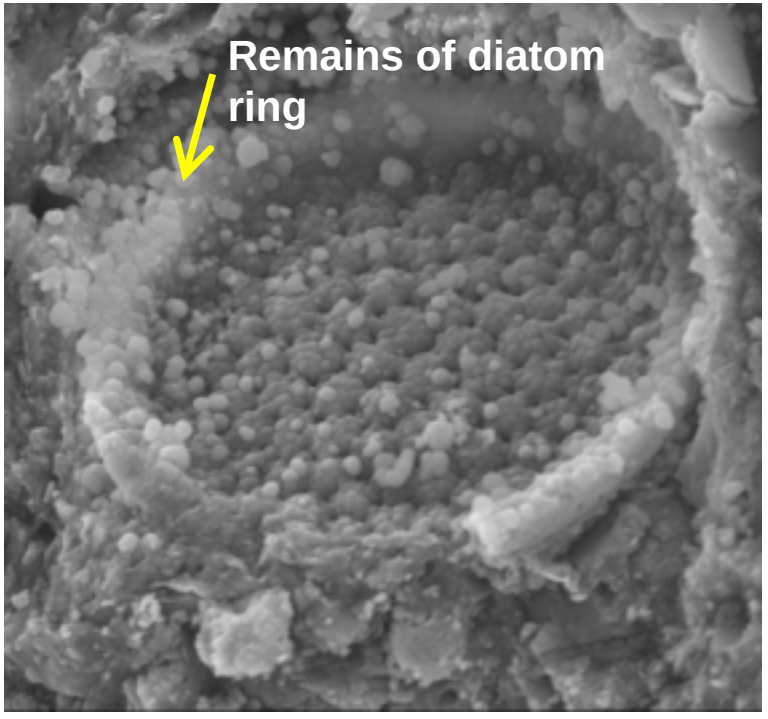
ventilation unit with a heat recovery element In a laundry room as an air chamber room



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

Extraction site of Wakkanai siliceous shale in northern part of Hokkaido island

Difference between Siliceous shale and normal diatomaceous soil (SEM pictures)



Wakkanai Siliceous shale

Normal diatomaceous soil

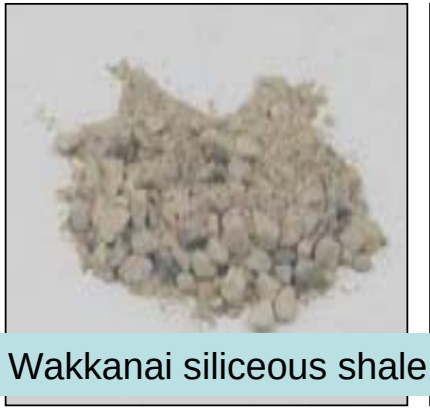
Wakkanai siliceous shale is metamorphic rock which was changed from diatomaceous soil under high temperature and high pressure in the earth .

Measurement of water-vapor adsorption isotherm


Charcoal


Zeolite


Volcanic ash

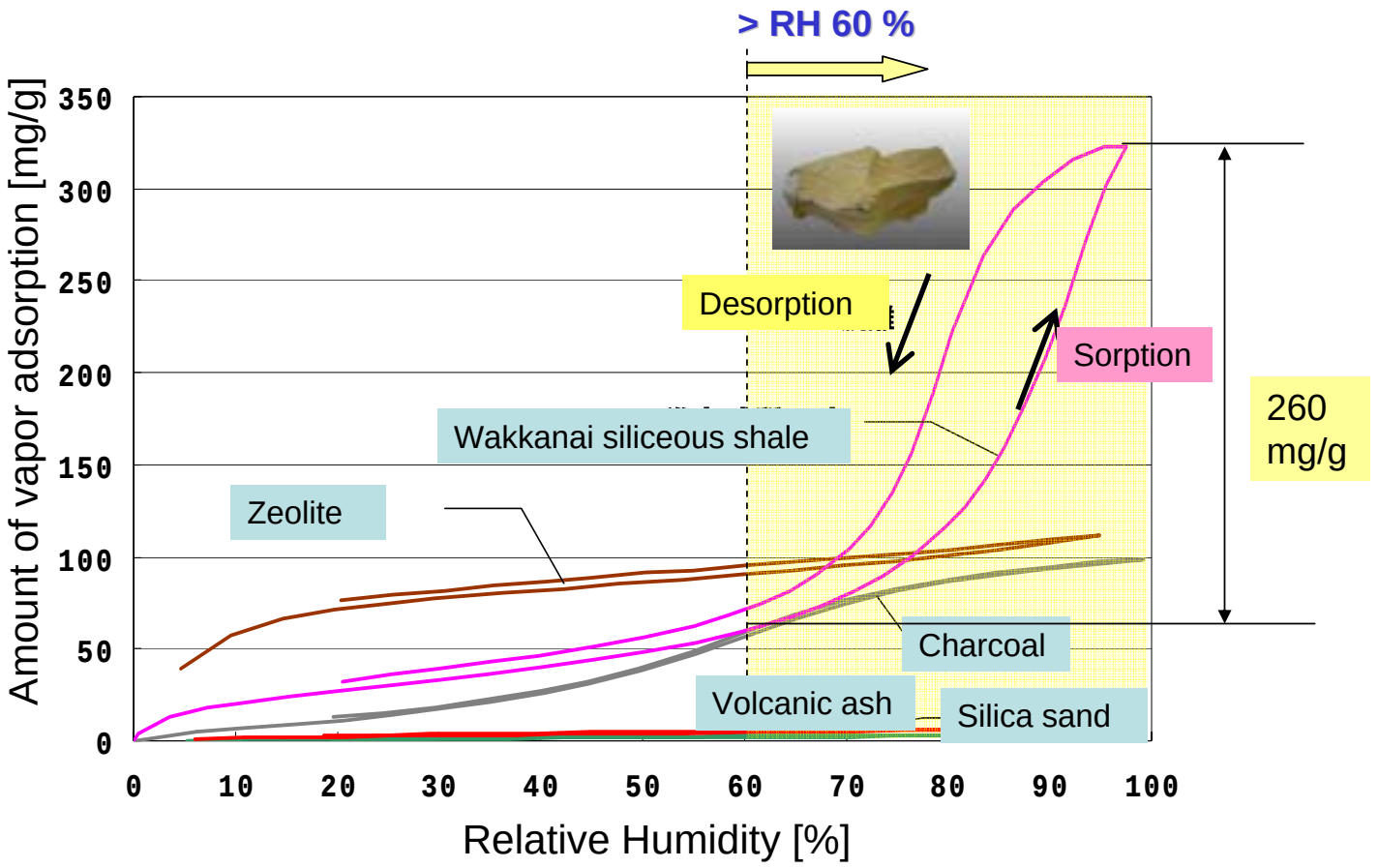

Wakkanai siliceous shale


Silica sand

Measured samples

Automatic water-vapor adsorption measurement apparatus

Characteristics of adsorption and deadsorption

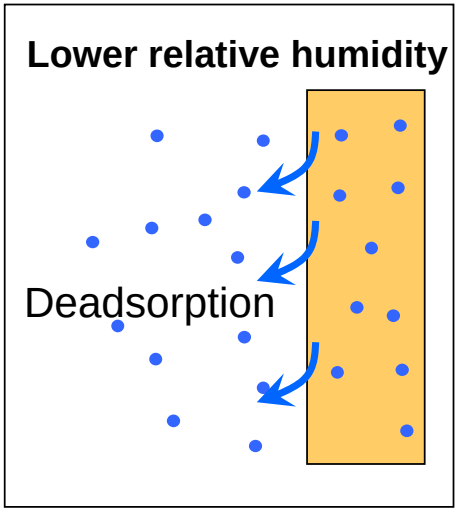


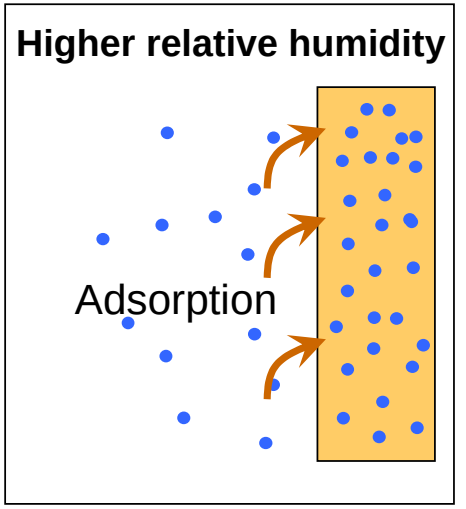
Amount of vapor adsorption is 260 mg/g from RH 60% to RH 95%

Autonomous humidity adsorption and deadsorption

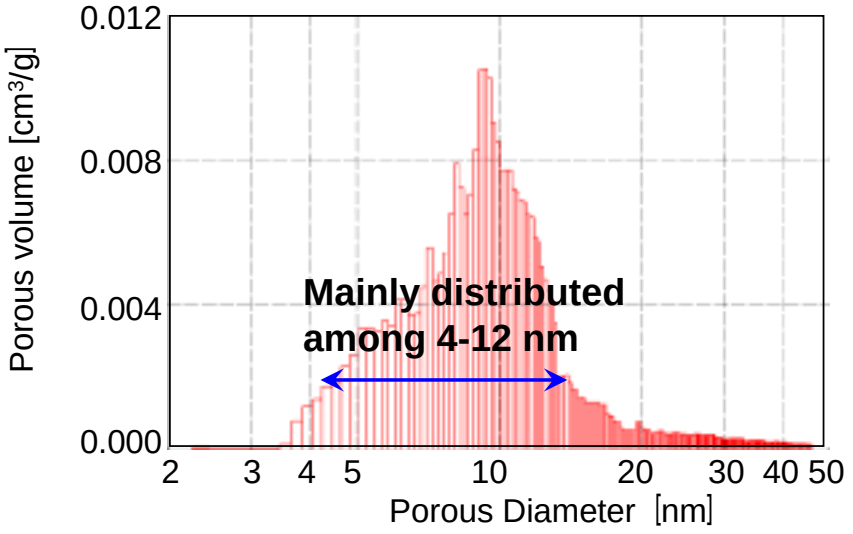
Effective nano-Porous range for autonomous humidity control

3.2 – 7.4 nm (Meso-porous)





Distribution of porous diameter of Wakkanai siliceous shale



BET specific surface area : 149.0 m²/g

Porous volume: 0.328 cm³/g

Average porous diameter: 9.4 nm

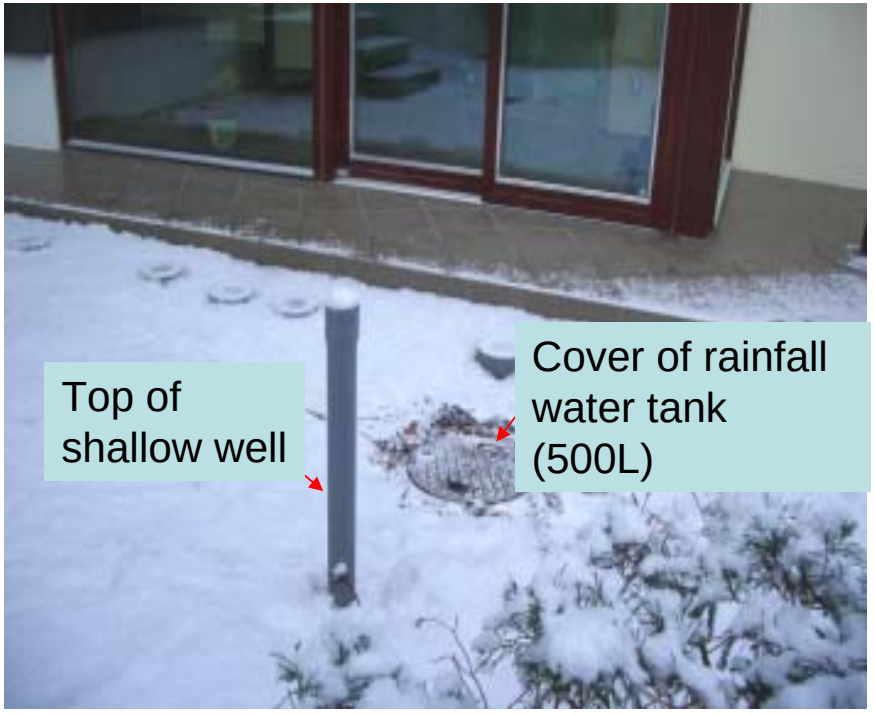
A wooden pellet stove is useful to adjust the room temperature when stored heat by GSHP in concrete slab is insufficient to maintain room temperature in severe cold nighttime

Automatic Forced-Flow type wooden pellet stove made by SUNPOT Co.ltd.

Polly crystalline PV modules integrated on the roof with snow melting function by using inverse current (Capacity; 3 kWp)

Estimated annual amount of generation is 3000 kWh

Use of rainfall water stored in a ground tank (500L) and shallow ground water (GL -4m ->-7m) for garden spraying and car washing



Conclusion

- Low energy house with massive heat capacity integrated with GSHPs for SH, DHW and snow melting has been designed and built in November of 2007.
- A new idea of passive humidity control is applied into the mechanical ventilation system.
- This house is the second demonstration project in the northern part of Japan.
- Estimated purchased electricity is 20.5 kWh/m^2/year.
- Commissioning has started from the end of 2007.