



“Current issues on innovative GSHP application in Asia and Pacific region”  
FREA, Japan October 19<sup>th</sup>, 2014

# Estimating energy production with GSHP

## - its importance in geothermal direct-use statistics

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# Contents

- Background
- Issues regarding GSHP statistics
- Review of existing guidelines
  - World Geothermal Congress
  - EU Directive
- Principle / methods of measuring and estimating thermal energy production with GSHP
- Discussion and Suggestions

# Background

- Geothermal or Ground-source heat pump (GSHP) has huge potential
  - Almost all over the world
  - High capacity factor in mid-latitude countries for heating and cooling as well as cold countries of big heating load
  - Will become more and more important in world geothermal direct-use
  
- In order to further increase deployment in near future
  - To device and disseminate more effective technologies to utilize thermal energy and/or capacity in shallow earth
  - To provide correct method of estimating potential impacts of GSHP in terms of energy saving and CO<sub>2</sub> emission reduction
  - To help decision makers and public acknowledging the benefits of GSHP in terms of energy saving and environmental protection

# Issues

- **Uncertainty of estimating energy production by GSHP**
  - Difficult to get accurate statistics on installation
  - Even more difficult to estimate load profile and operation period or capacity factor
  - Capacity factor (or full load hours) is strongly dependent on application type so it is hard to define a value representing a country
- **Separating heating and cooling**
  - In some countries, statistics are lumpsum of heating & cooling
  - Cooling COP is different from heating COP  $\Rightarrow$  different 'pure geothermal contribution' (even there is free cooling)
- **Is cooling geothermal use or not?**
  - In thermodynamic principle, cooling is not utilization of geothermal heat
  - However, if we don't account it for, who else will categorize such an important application? (In IEA statistics, renewable cooling is included in 'renewable heat')

# General aspects of geothermal statistics

- Geothermal power generation: fairly accurate and timely data
- Conventional direct use: estimated (inaccurate) and late data
  - Difficult to measure
  - Disseminated nature
  - Possible reluctance by users (hot spring business)
- GSHP
  - Much more disseminated
  - Almost impossible to measure for smaller systems
  - Then, how can we argue that how much TOE we can produce by 2020 or 2030?
  - Furthermore, GSHP ‘consumes’ other energy (electricity):  
Thermal output = geothermal energy + electrical energy

# WGC guideline

- Based on flow rate or capacity factor:

Thermal energy (TJ/yr)

$$= \text{flow rate in loop (kg/s)} \times [\text{inlet temp. (}^\circ\text{C)} - \text{outlet temp. (}^\circ\text{C)}] \times 0.1319$$

or

$$= \text{rated output energy (kJ/hr)} \times [(\text{COP}-1)/\text{COP}] \times \text{equivalent full load hours/yr} \times 10^{-9}$$

- WGC report accounts only for heating

- Cooling energy is used for ‘Energy saving’ and ‘CO<sub>2</sub> emission reduction’
- Many countries do not separate heating and cooling
- Many countries even do not account for electrical energy to run GSHP

⇒ A lot of ambiguity in world statistics of GSHP contribution

# EU guideline and studies

- EU Directive 2009/28/EC

- To define share of energy from renewable source
- Annex VII for heat pump:  $E_{RES} = Q_{usable} * (1 - 1/SPF)$   
(only  $SPF > 1.15 * 1/\eta \cong 2.5$  is considered as RES)
- EU Decision (2013/114/EU)

$$Q_{usable} = H_{HP} * P_{rated}$$

$H_{HP}$ : equivalent full load hours of operation

SPF: the estimated average seasonal performance factor  
(=  $SPF_{H2/C2}$ ;  $SCOP_{net}$  or  $SPER_{net}$ )

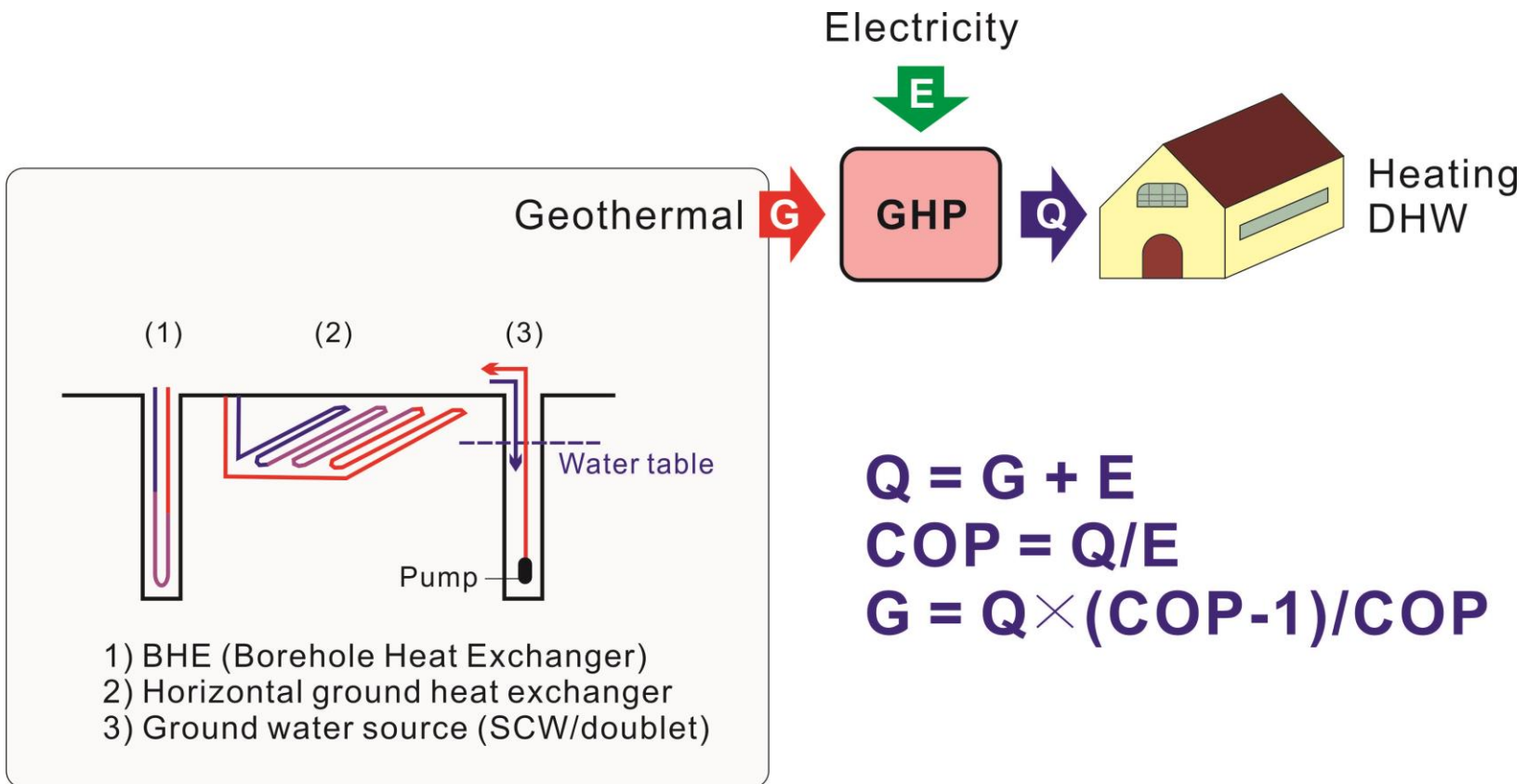
$\eta$ : power system efficiency  
 $\cong 0.455$  as of 2010  
(EU Decision 2013/114/EU)

- For system efficiency validation (not only for GSHP)

- Annexes under IEA Heat Pump Centre (research on HP statistics as well)
- IEE (Intelligent Energy Europe) project SEPOMO
- Fraunhofer ISE studies in Germany, SP reports in Sweden, FAWA in Switzerland, EST in UK,,,

# Energy flow in GSHP system for heating

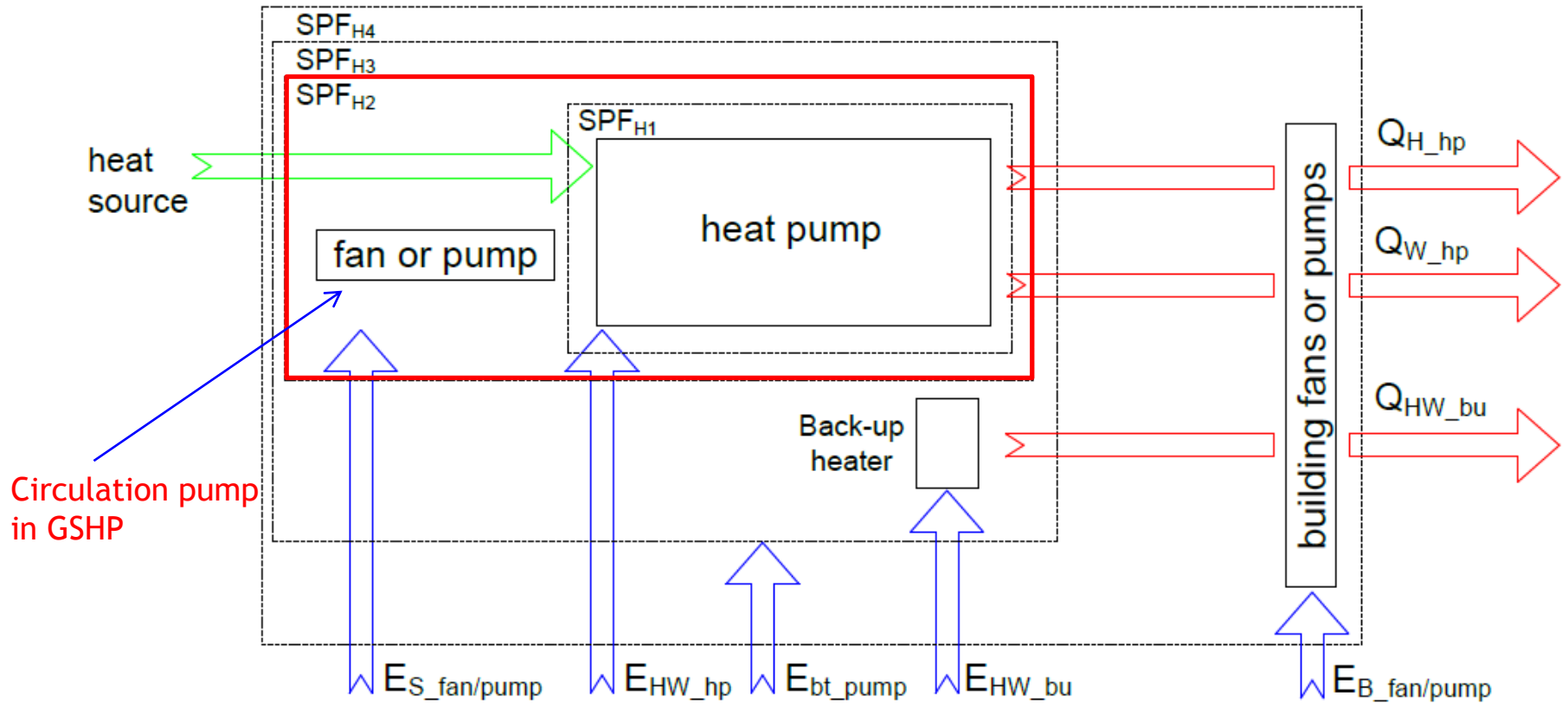
We need to know  $G$ , but most of information are on  $Q$  not  $G$ !



*cf*> for cooling,  $G = Q + E$



# Definition of System boundaries

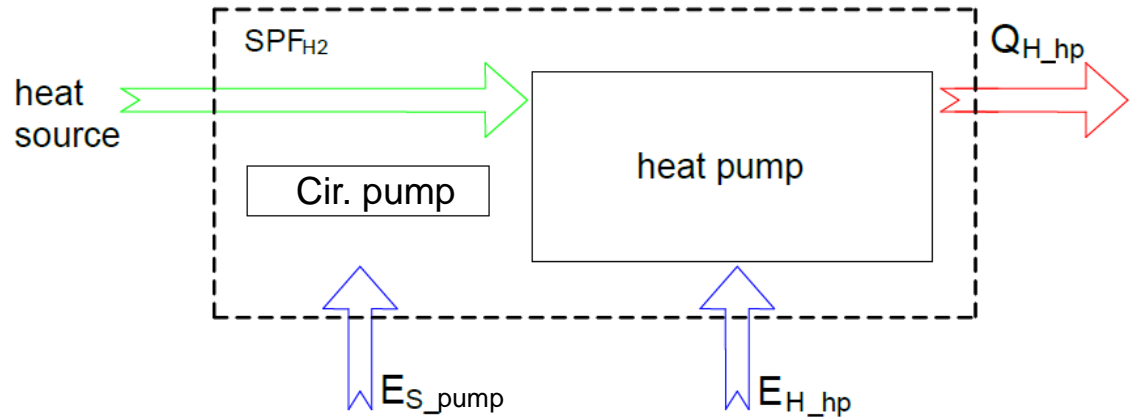


Circulation pump in GSHP

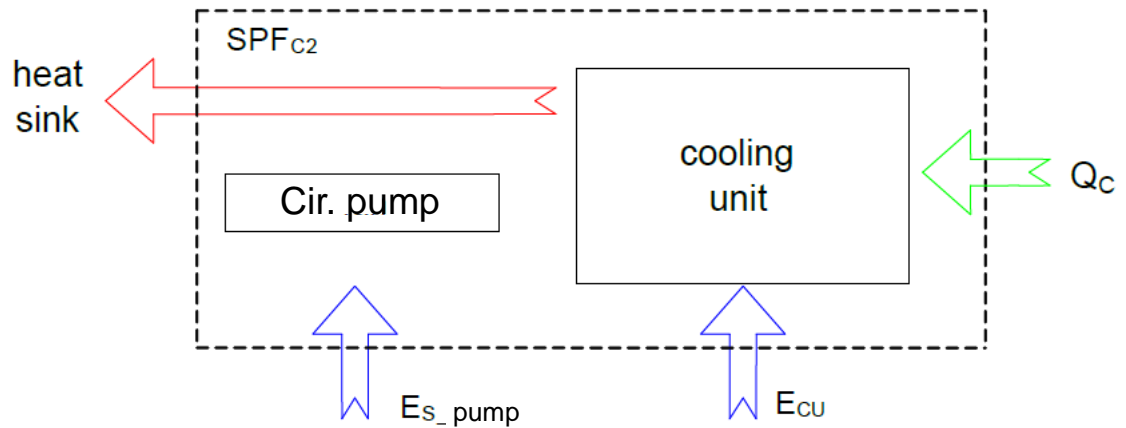
From the view point of geothermal,  
 we are interested in  $SPF_{H1}$  (COP) or  $SPF_{H2}$  (COP<sub>net</sub>)  
 (SEPEMO build.)

# For heat and cooling: $SPF_{H2}$ vs. $SPF_{C2}$ ( $COP_{net}$ )

$$SPF_{H2} = \frac{Q_{H\_hp}}{E_{H\_hp} + E_{S\_pump}}$$

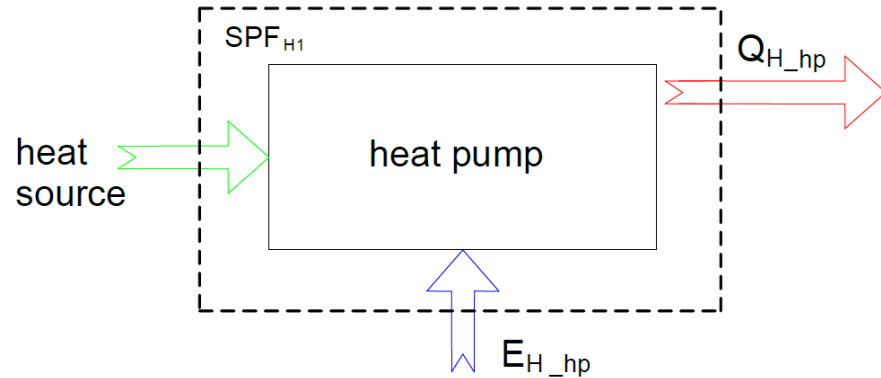


$$SPF_{C2} = \frac{Q_C}{E_{CU} + E_{S\_pump}}$$

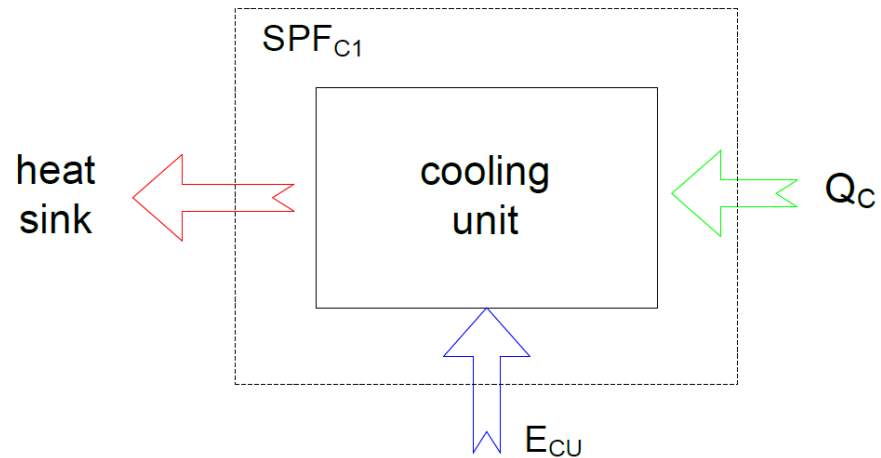


# For heat pump only: $SPF_{H1}$ vs. $SPF_{C1}$ (COP)

$$SPF_{H1} = \frac{Q_{H\_hp}}{E_{H\_hp}}$$



$$SPF_{C1} = \frac{Q_C}{E_{CU}}$$



# Energy production vs. Energy saving

- Geothermal energy utilization or production
  - $G_H = Q_H * (1 - 1/SPF_{H1})$
  - Concept of gross production
  - Coincides with WGC estimation
  - For cooling,  $G_C = Q_C * (1 - 1/SPF_{C1})$ : cooling energy with help of ground
  
- Energy saving or in the context of CO<sub>2</sub> emission reduction
  - We must consider electricity to run circulation pump: concept of net production
  - Coincides with  $E_{RES}$  of EU Directive 2009/28/EC
  - $E_H = Q_H * (1 - 1/SPF_{H2})$
  - $E_C = Q_C * (1 - 1/SPF_{C2})$

⇒ Now, the issue is how to estimate Q and SPF as accurate as possible

# How to estimate energy production

- Direct calculation with measured data
  - Accurate estimation of thermal energy produced
  - Practically impossible to apply to all installations
  
- Estimates based on rated capacity of GSHP, COP (or SPF) and representative capacity factor
  - Practical way of estimating energy production
  - Very difficult to assign representative values of capacity factor according to use type
  - Electricity consumption must be considered because thermal output of GSHP is driven by electricity as well
  - Note: COP (or  $SPF_{C1}$ ) for cooling is different from that of heating ( $SPF_{H1}$ ) as capacity is

# Direct Calculation

- Heat extracted from ground

$$Q_H = \int \dot{m}_H \times (T_{out} - T_{in}) \times C_p dt$$

- Heat rejected into ground

$$Q_C = \int \dot{m}_C \times (T_{in} - T_{out}) \times C_p dt$$

- in WGC report (heating only)

- Annual Energy Use (TJ/yr) = Ave. flow rate in loop (kg/sec) × [inlet temp. (°C) - outlet temp (°C)] × 0.1319
- cf>  $4,184 \times 3600 \times 24 \times 365 \times 10^{-12} = 0.1319$

⇒ This is only an approximate way since heating (and/or cooling) load changes according to season: difficult to get average flow rate

# Possible (or practical) estimates

- Heat extracted from ground (usually in TJ/yr)

$$Q_H = C_p \sum_{m=1}^{12} \dot{m}_{H,ave}(m) \times \Delta T_{H,ave}(m) \times t_H(m) \times 10^{-12}$$

$$\cong Q_{rated,H} \frac{COP_H - 1}{COP_H} \sum_{m=1}^{12} L_{f,H}(m) \times hr_H(m) \times 10^{-9}$$

Equivalent full load hours/yr in WGC

- Cold energy with help of ground (TJ/yr)

$$Q_C \cong Q_{rated,C} \frac{COP_C - 1}{COP_C} \sum_{m=1}^{12} L_{f,C}(m) \times hr_C(m) \times 10^{-9}$$

$t(m)$ : operating period (in seconds)  
 $hr(m)$ : operating period (in hours)  
 $Q_{rated}$ : rated capacity (in kJ/hr)  
 $L_f$ : load factor

Note:  $Q_{rated}$  and  $COP$ 's are accredited values by manufacturer or Energy Authority (However, we still don't know  $COP_{net}$  or  $SPF_{H2/C2}$ )

# Load factor?

- Actual load ÷ rated capacity ( $Q_{rated}$ )
  - Can be estimated hourly values according to usage
  - Between 0 (no usage) and 1.0 (full load)
  - Hardly exceeds 0.9
  - Can be averaged over the month  $\Rightarrow$  monthly load factor  $L_f$
  
- Useful to estimating capacity factor
  - Capacity factor: full load hours in year ÷  $(24 \times 365)$
  - $CF = \Sigma(L_f \times hr) / (24 \times 365)$
  - $CF$  is assumed to be 0.25 (= 2,200 full load hours) for residence building in WGC report (heating only)
  
- Load factor significantly varies not only to season but also to usage (building type or crop type in greenhouse and so on,,)



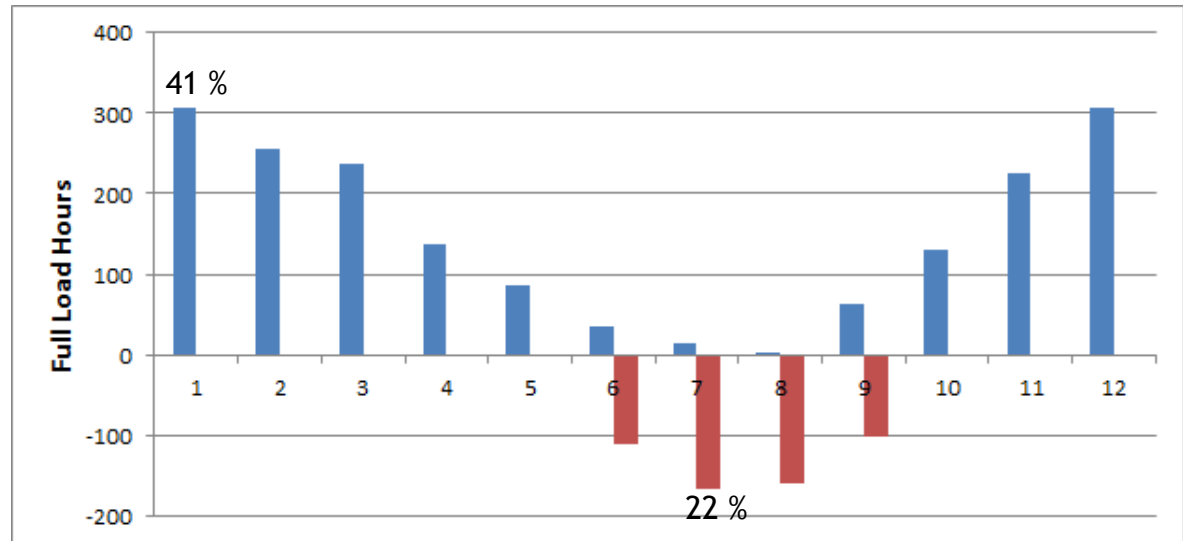
# Load factor into full load hours: An example in Korea

## Residence Building (Apartment):

1,800 hrs for heating  
540 hrs for cooling

$\Rightarrow CF = 0.27$

(can be higher if we account for DHW or individual houses)

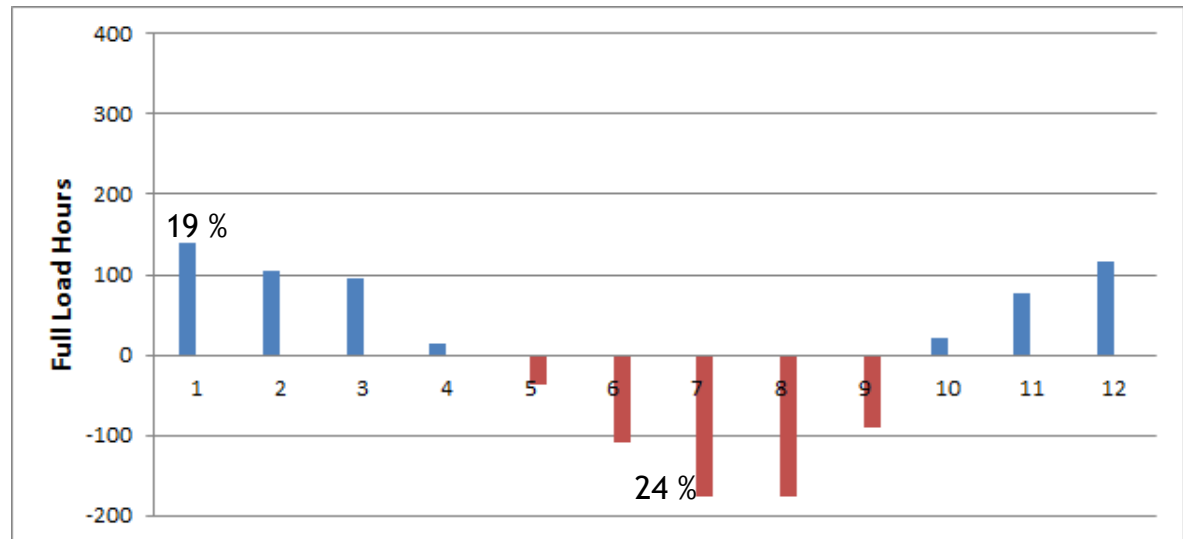


## Office Building (City Hall):

570 hrs for heating  
590 hrs for cooling

$\Rightarrow CF = 0.13$

(10 hr/day, 21.5 day/m)



cf>  $24 \times 30 = 720$

# Example of Switzerland (1/2)

- Consider heating only
- Based on sales data and performance monitoring results:
  - Collect sales data and consider replacement rate
  - Categorize the type (brine/water or water/water) and size (<5 kW, 5-10 kW, 10-20 kW, 20-50 kW, 50-100 kW, 100-300 kW, >300 kW)
  - Apply 'standard running time' (full load hours) for calculating annual thermal production: 1,932 hr/yr for brine/water and 1,634 hr/yr for water/water
  - Apply climate condition with Heating Degree Days
  - Apply annual average SPF (COP=1.194 SPF) to estimating 'pure geothermal contribution'

## *Ref>*

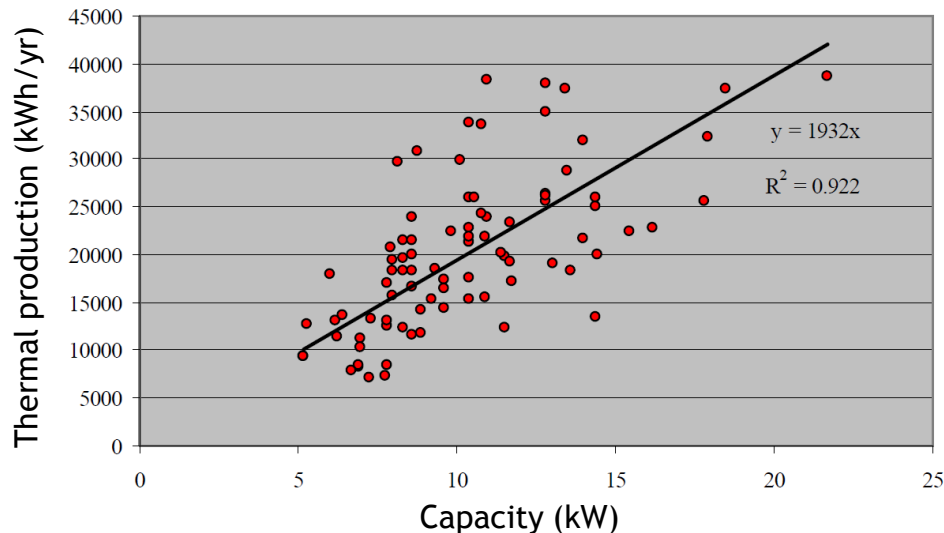
Geowatt AG, "Statistik der geothermischen Nutzung in der Schweiz, Ausgabe 2012"

Basics AG, 2007, "Erweiterung der schweizerischen Elektrowärmepumpendatistik"

# Example of Switzerland (2/2)

## ■ Discussion

- Fairly reasonable approach
- Cooling is not accounted for although they agree on the importance: free cooling must be separately considered
- ‘Standard running time’ may not be accurate for bigger installation such as in large office building



For brine/water  
(Basics, 2007)

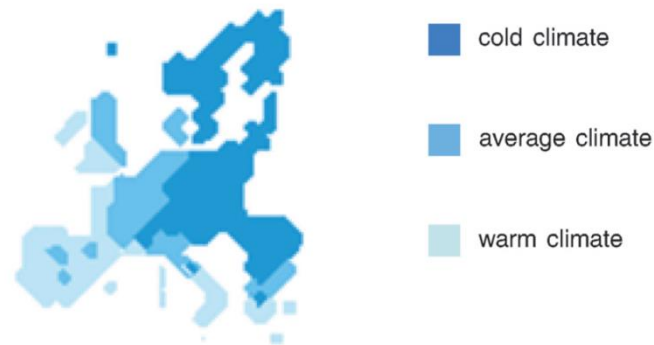
# Discussion: to make reasonable estimate

- Accurate statistics on GSHP installation
  - Not only for number of HP and total capacity, but also for category of installation or individual capacity
  - To determine test sites for long-term monitoring at each category (according to capacity or application)
- Monitoring of field data
  - To get representative load profile: separation of heating and cooling is important
  - To estimate representative  $SPF_{H1/C1}$  and  $SPF_{H2/C2}$
- Set a guideline and update
  - Pursueing comparable statistics to international standards
  - Annual update according to continuous monitoring results

# If we don't have sufficient monitoring

- Example from EU Decision 2013/114/EU

Climate condition areas



	Warm		Average		Cold	
	$H_{HP}$	$SPF_{H2}$	$H_{HP}$	$SPF_{H2}$	$H_{HP}$	$SPF_{H2}$
Ground-Air	1,340	3.2	2,070	3.2	2,470	3.2
Ground-Water	1,340	3.5	2,070	3.5	2,470	3.5

Note: this is for residential houses and cooling is not considered here, yet

# What we are doing in IEA Geothermal?

- As a Task under Annex VIII: Direct Use of Geothermal Energy
  - To collect information on statistical methods of each country
  - To compare methods and information level
  - To device a guideline considering each country's available data
  
- Comparing to other guidelines or standards regarding HP
  - Our focus is not to validate the efficiency of GSHP
  - We try to make a reasonable estimate of GSHP uses in terms of
    - geothermal utilization (source side)
    - environmental benefits (load side)
  
- Why this is important?
  - To find accurate energy production by GSHP in geothermal utilization and world renewable energy uses
  - Accurate input to RHO (Renewable Heat Obligation)

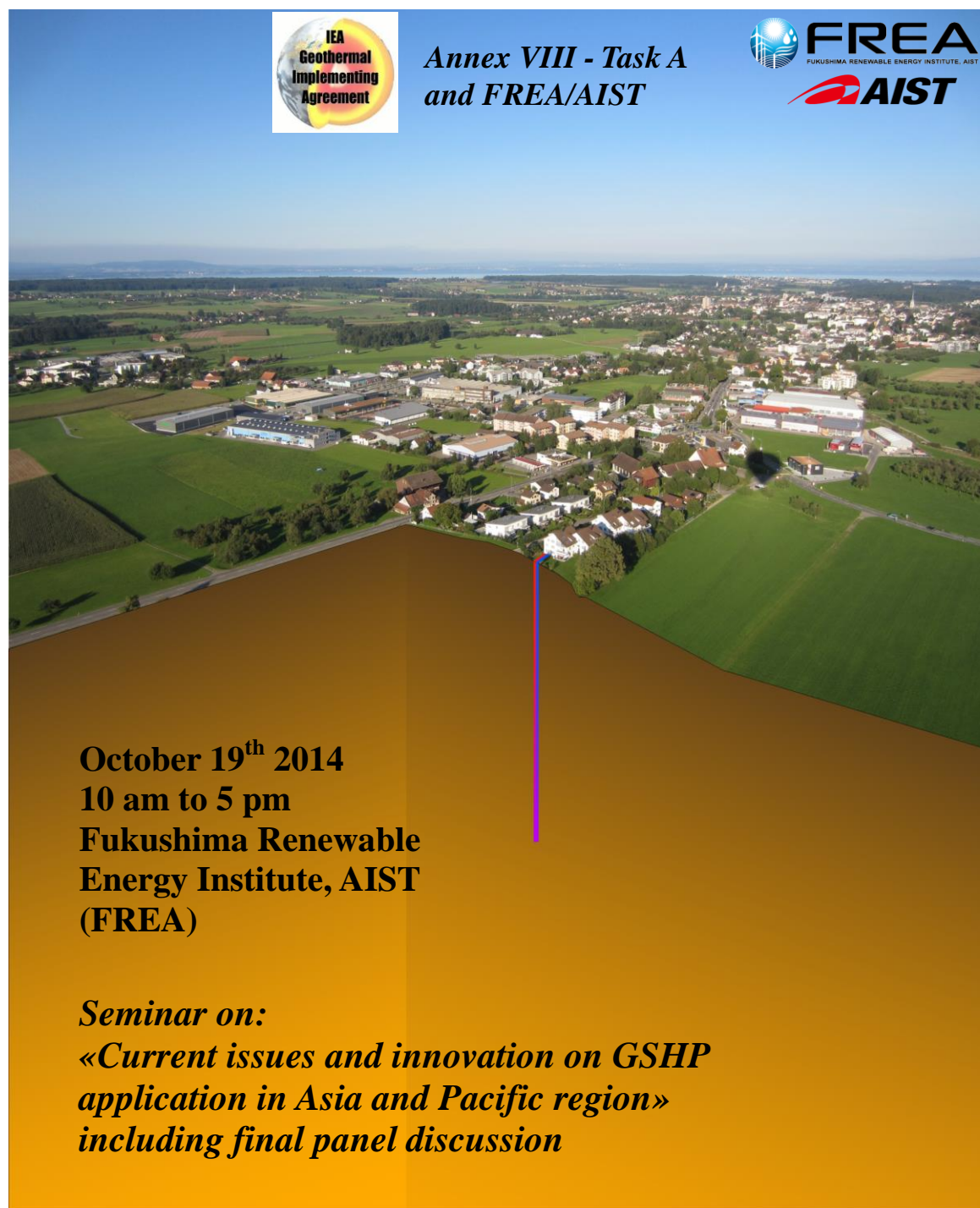


*Annex VIII - Task A  
and FREA/AIST*



Thank you for  
attention!

ありがとう  
ございます!



**October 19<sup>th</sup> 2014  
10 am to 5 pm  
Fukushima Renewable  
Energy Institute, AIST  
(FREA)**

***Seminar on:  
«Current issues and innovation on GSHP  
application in Asia and Pacific region»  
including final panel discussion***