Keynote Speech

GEOTHERMAL ENERGY AND ITS FUTURE

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CONTENT

1. Characteristics of geothermal energy
2. Power generation using geothermal energy
3. Geothermal energy in the world
4. Direct heat use

GEOTHERMAL ENERGY

Major Characteristics

- Natural and sustainable energy
- Less effects on environment
  low CO_2 emmision per kWh
- Domestic energy

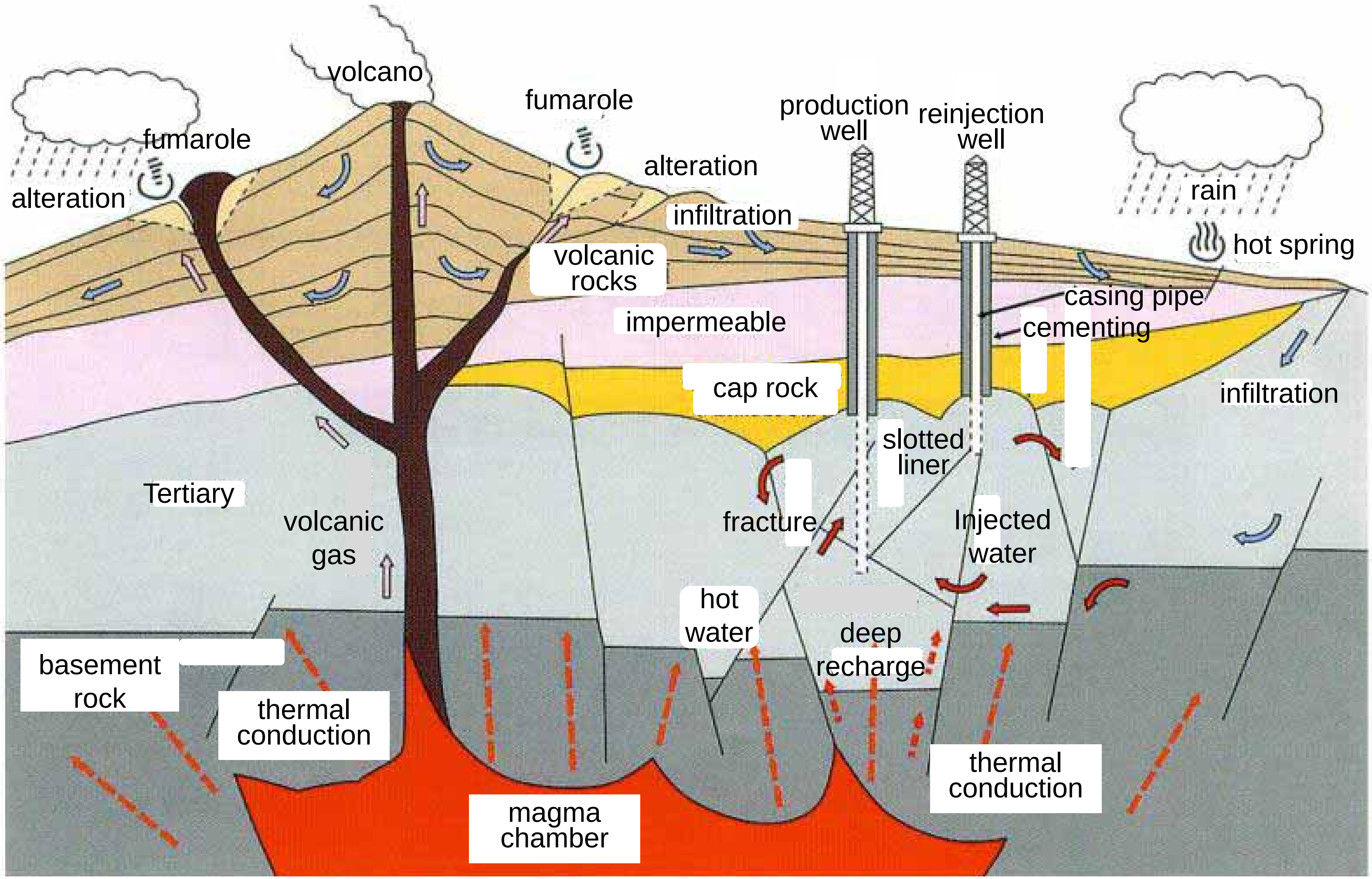
GEOTHERMAL ENERGY

How we can use it

- Power generation
  - Conventional flash system
  - Binary system
- Direct heat use
  - Space heating
  - Green house, Aquaculture
- Tourism
  - Spa
  - Fumaroles

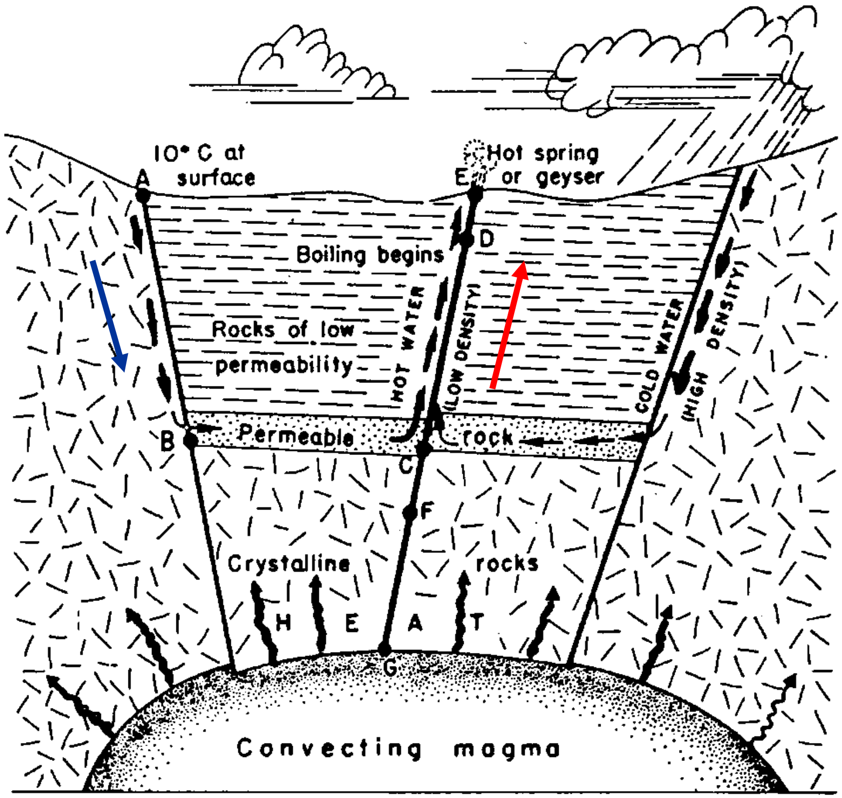
Energy source for multiple utilization

WHAT IS GEOTHERMAL ENERGY?

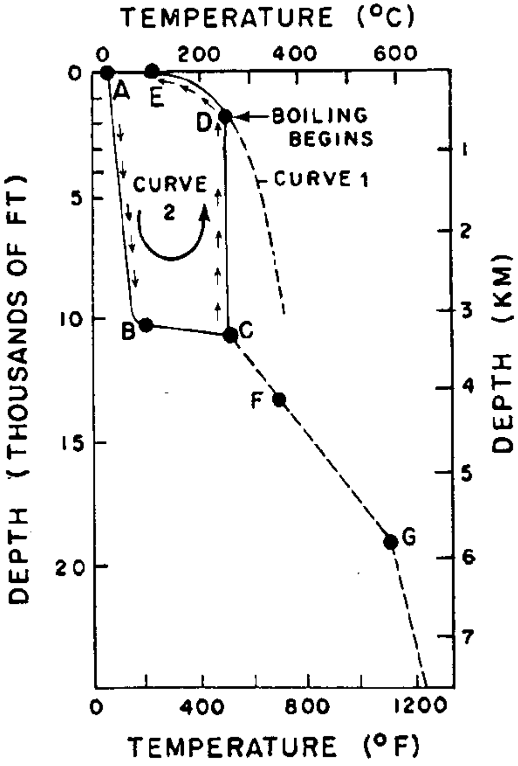


Modified from Mitsubishi Material Co.

GEOTHERMAL SYSTEM



Temperature vs Depth



(White, D., 1973)

PRESSURE-ENTHALPY DIAGRAM FOR PURE WATER AND VAPOR

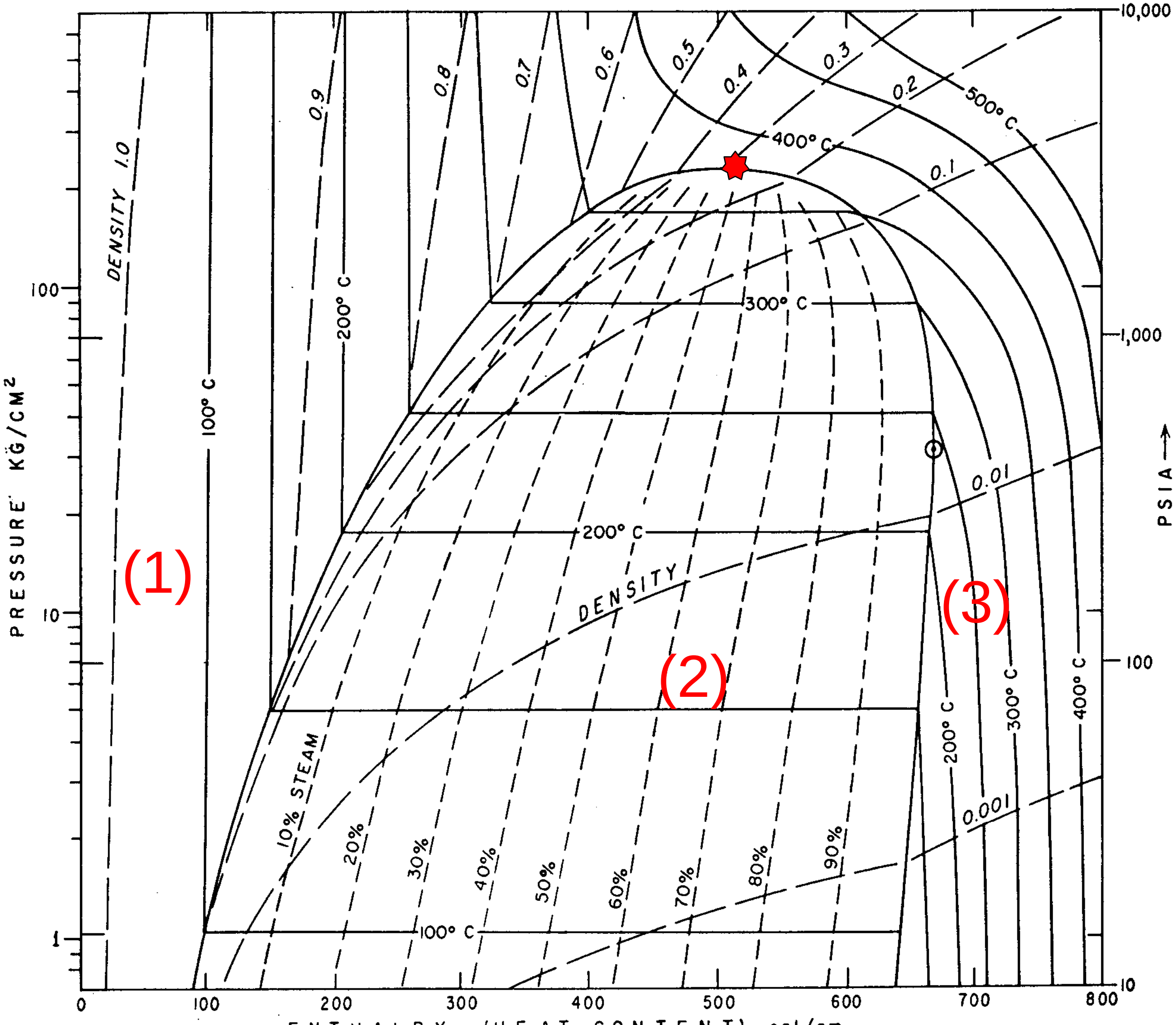


FIG. 2. Pressure-enthalpy diagram for pure water and vapor, showing contours of equal temperature, density, and mass proportions of steam to water (computed from Keenan and Keyes, 1936). Open circle indicates maximum enthalpy of saturated steam, 670 cal/gm at 236° C and 31.8 kg/cm².

- Three thermodynamic regions :
  (1) compressed water
  (2) two-phase steam and water
  (3) superheated steam
- Pressure and enthalpy uniquely define the thermodynamic state
- Other pairs of variables such as saturation and pressure, temperature and pressure, do not.

White et al.(1971)

WATER-DOMINATED GEOTHERMAL SYSTEM

- Reservoir is filled with liquid water
- Well produce steam-water mixture
- Temperature : 210^{o}C to higher than 300 ^{o}C
- Common

  Gunung Salak(Indonesia), Hatchobaru(Japan), Wairakei(NZ), Tongonan(Philippines), Olkaria(Kenya)
- Advantage from engineering point view

  Renewable and sustainable if separated water being properly reinjected

  Separated water can be used for cascade use

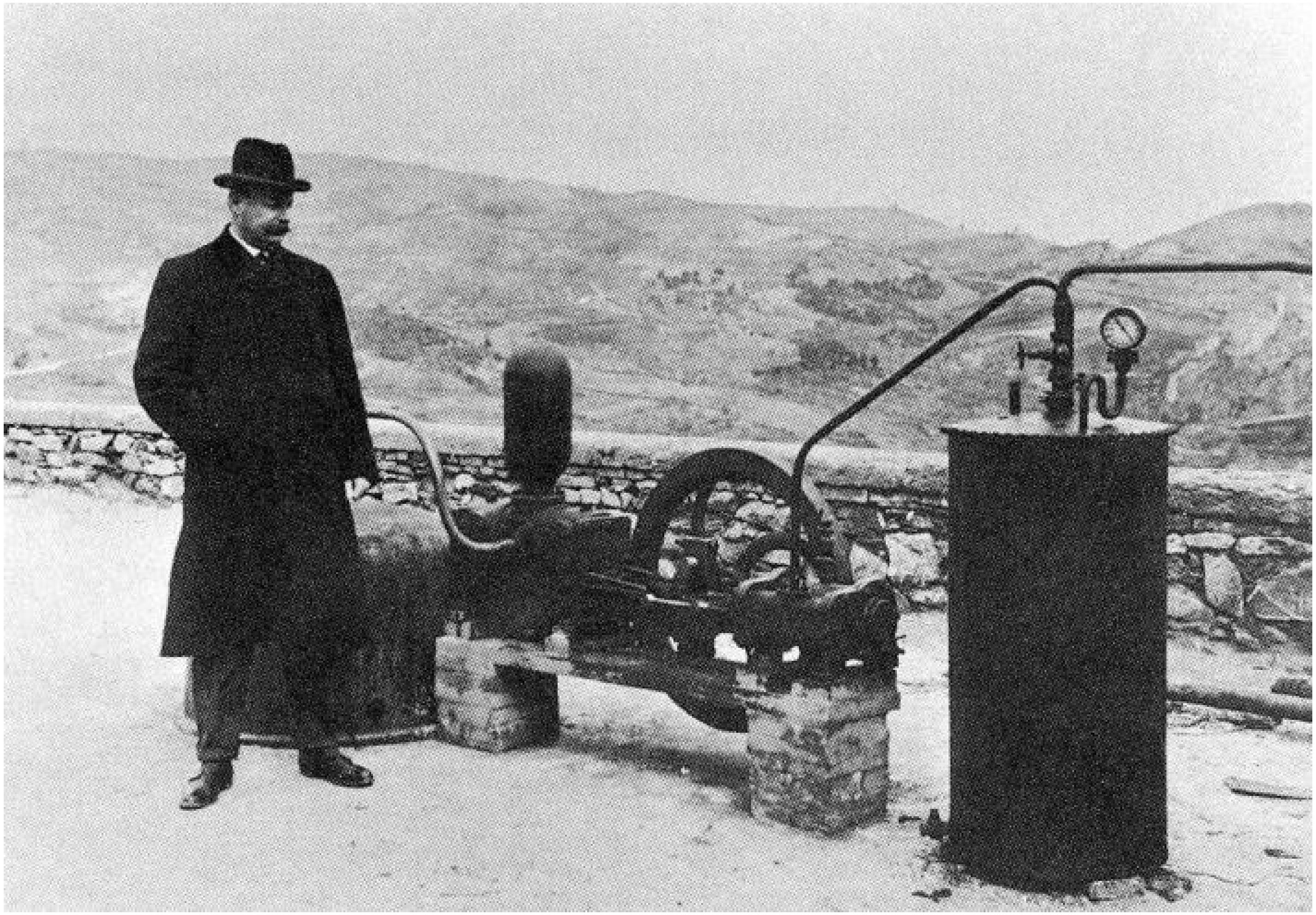
VAPOR-DOMINATED GEOTHERMAL SYSTEM

- Water and vapor coexist in reservoir
- Wells produce only dry steam
- Reservoir temperature : 230 to 260 ^{o}C
- Not common

  Kamojang(Indonesia), Larderello(Italy), The Geysers(USA), Matsukawa(Japan)
- Advantages from engineering point view

  No reinjection well required
  Surface facilities are simple
  → Economical

FIRST POWER GENERATION USING GEOTHERMAL FLUID



Prince Ginori Conti at Larderello, Italy, in 1904

HATCHOBARU GEOTHERMAL POWER PLANT

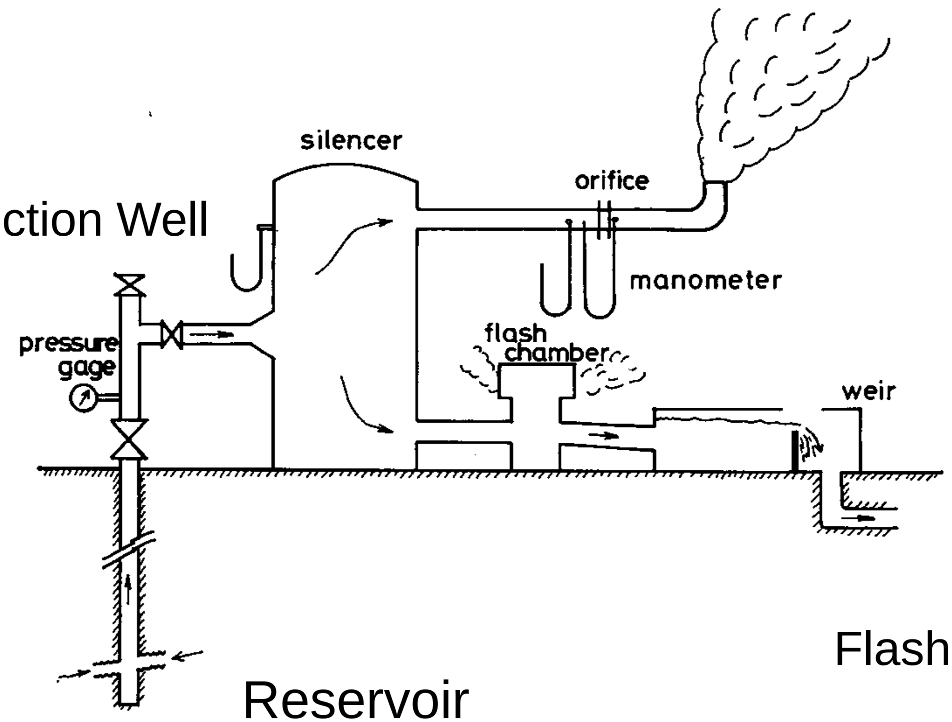
Power Plant

Production Well Pad

- Installed Capacity 110MW
  1977 No.1 Unit(55MW) More than 30yrs
  1990 No.2 Unit(55MW) 20 yrs
- High utilization factor >95%
- Double flash system
  first in the world
- Production well 23 (760- 3000m)
  Reinjection well 6 (800 – 1600 m)
  as of 1999
- Production rate
  primary steam 620 t/h(172 kg/s)
  secondary steam 160 t/h(44 kg/s)
  hot water 1200 t/h (333 kg/s)

PRODUCTION WELL

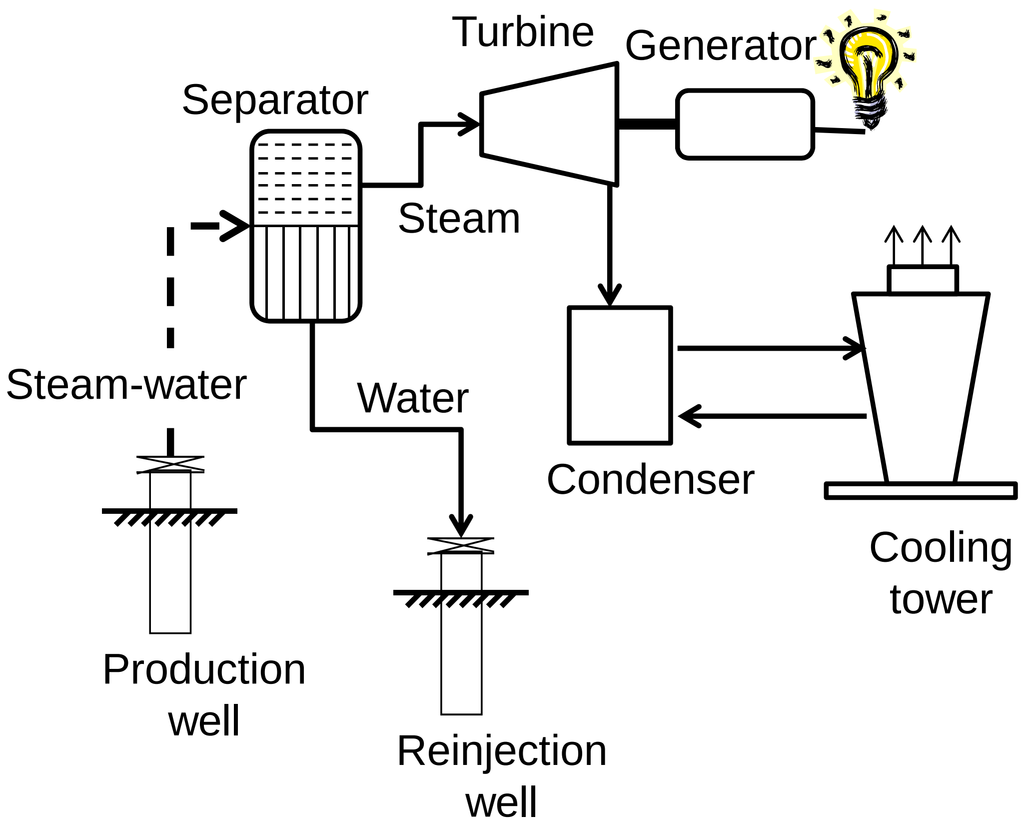
Production Well



Reservoir

Flasher

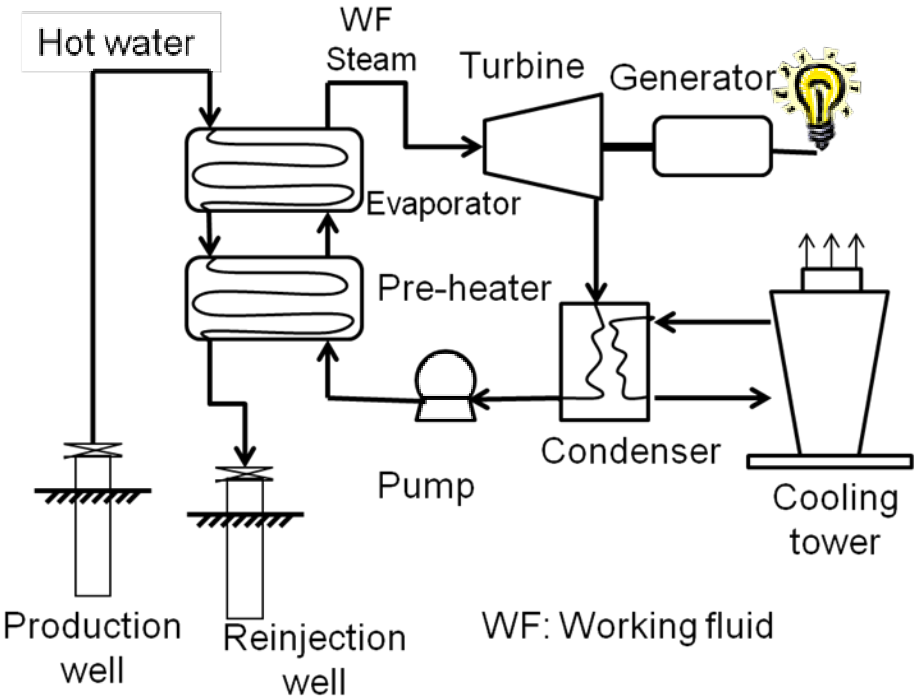
POWER GENERATION SYSTEM-1



Conventional flash system

- <u>Single flash system</u>
  - Steam-water mixture is produced from wells
  - Steam to turbine and water to reinjection wells
  - Otake (Oita Prefecture) G. Salak (Indonesia)
- <u>Double flash system</u>
  - Separated water further flashed for steam
  - 15-20% increase in output
  - Hatchobaru (Oita)

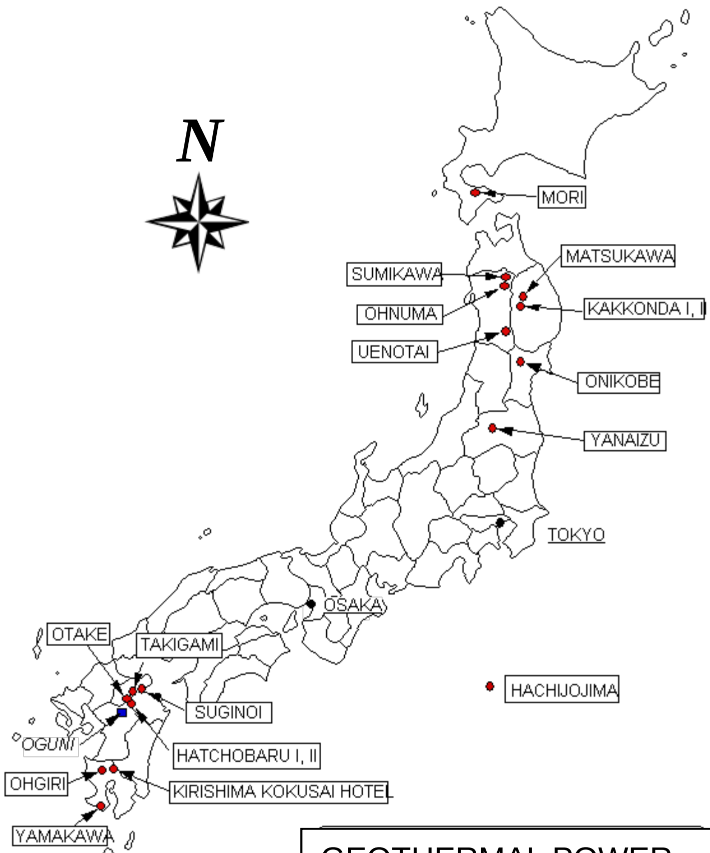
POWER GENERATION SYSTEM-2



Binary system

- <u>Organic Rankin Cycle</u>
  - 150 - 200 °C
  - Working fluid : pentane, propane
  - Hatchobaru 2MW (2003.12)
- <u>Kalina Cycle</u>
  - 70- 100 °C
  - Working fluid : anmonium+water
  - Hot spring power generation 50 kW

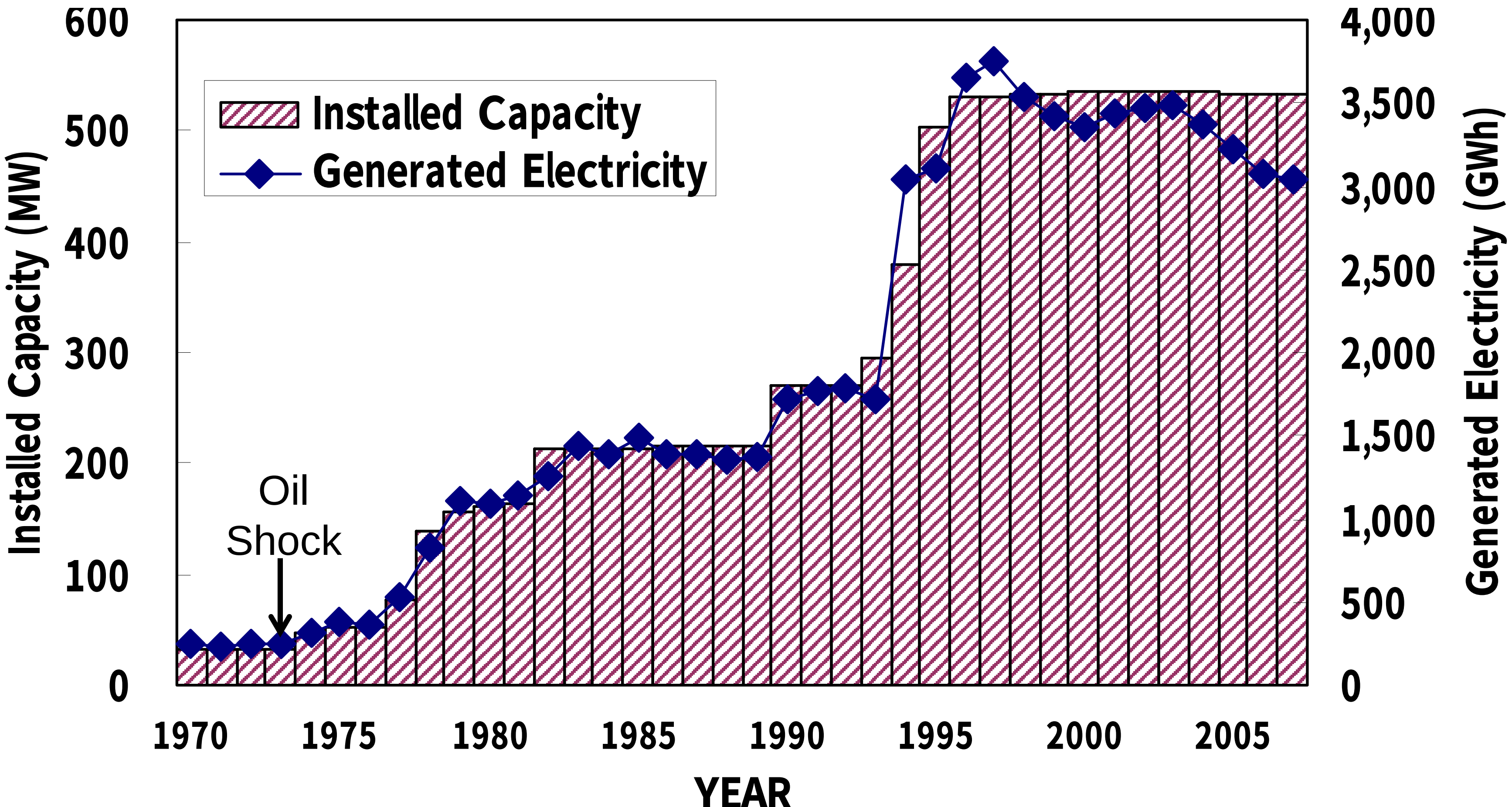
GEOTHERMAL POWER PLANT IN JAPAN(2010)



GEOTHERMAL POWER PLANT IN JAPAN(2010)

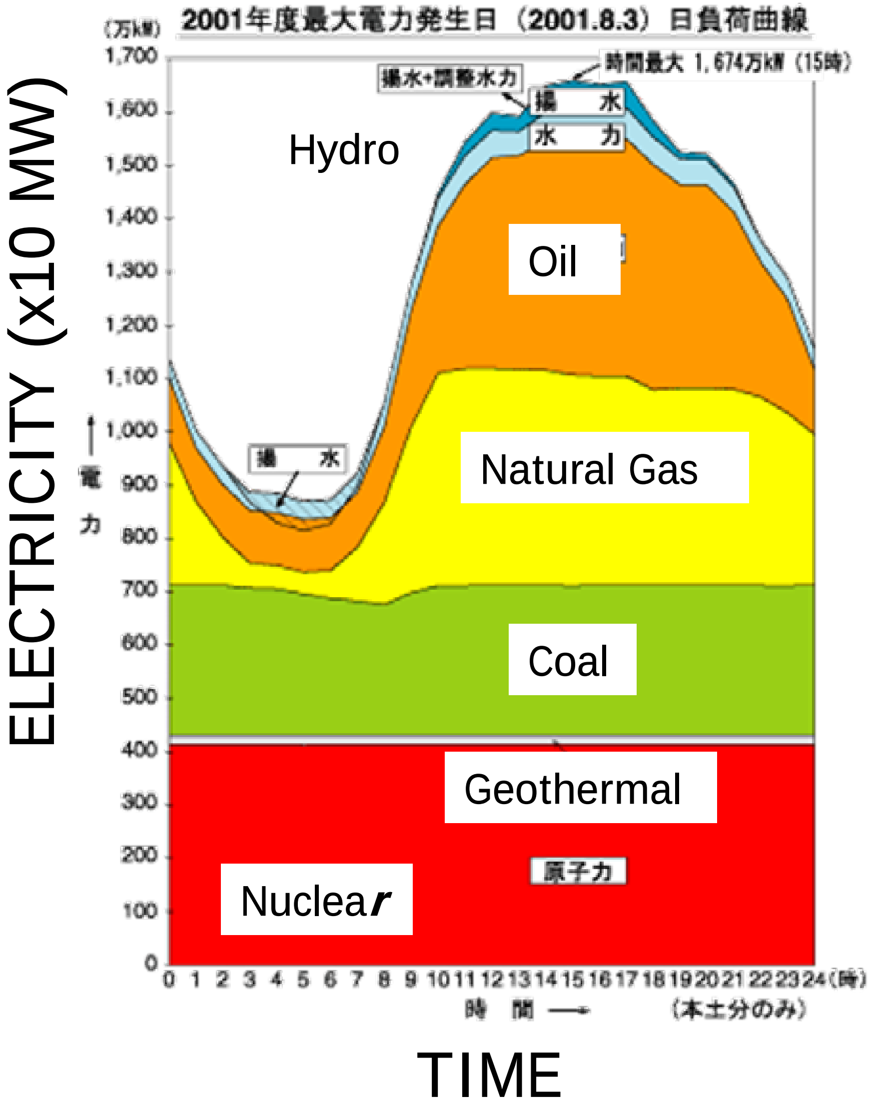
- 20 Geothermal PP
- Installed Capacity 535 MWe
- 0.2% of total generated power (1 % in Kyushu)

HISTORY OF GEOTHERMAL POWER GENERATION IN JAPAN



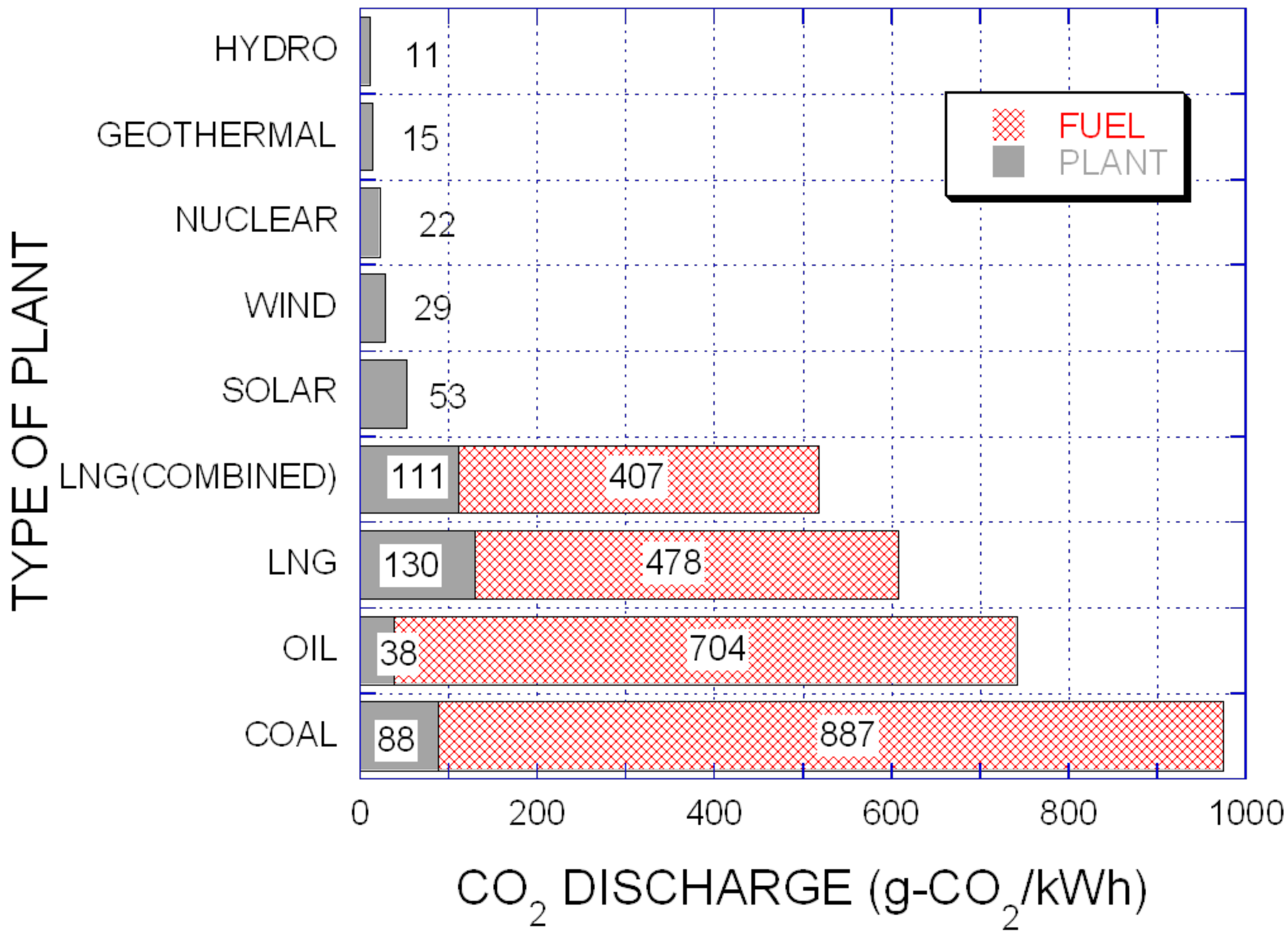
- ➢20 Geothermal PP
- ➢Installed Capacity 535 MWe

ELECTRICITY SUPPLY AND DEMAND IN KYUSHU (2001.8.3)



- Maximum demand 16,740MW (Supply capacity 17,780MW)
- Geothermal 1% baseload
- Population 13.46 million

LIFE-CYCLE CO_2 EMISSIONS

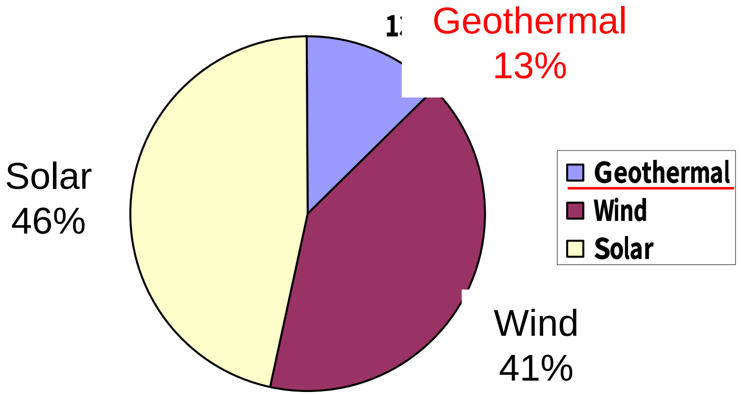


Japan Atomic Energy Relations Organizations(2003 .12)

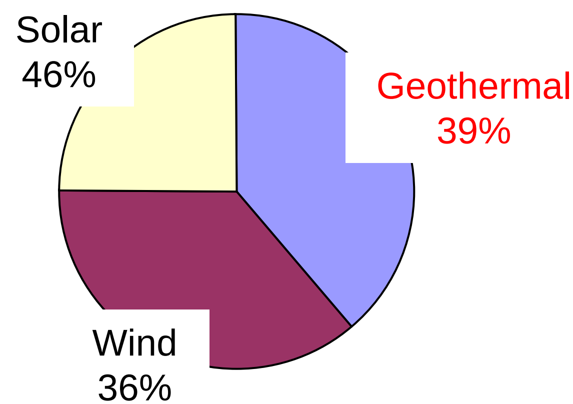
Plant cost includes contribution to CO_2 discharge by construction of the plant, transportation of fuels and maintenance etc

ELECTRICITY BY RENEWABLE ENERGY IN JAPAN (2007)

Installed Capacity (4,114 MWe)



Generated Electricity (80 TWh)



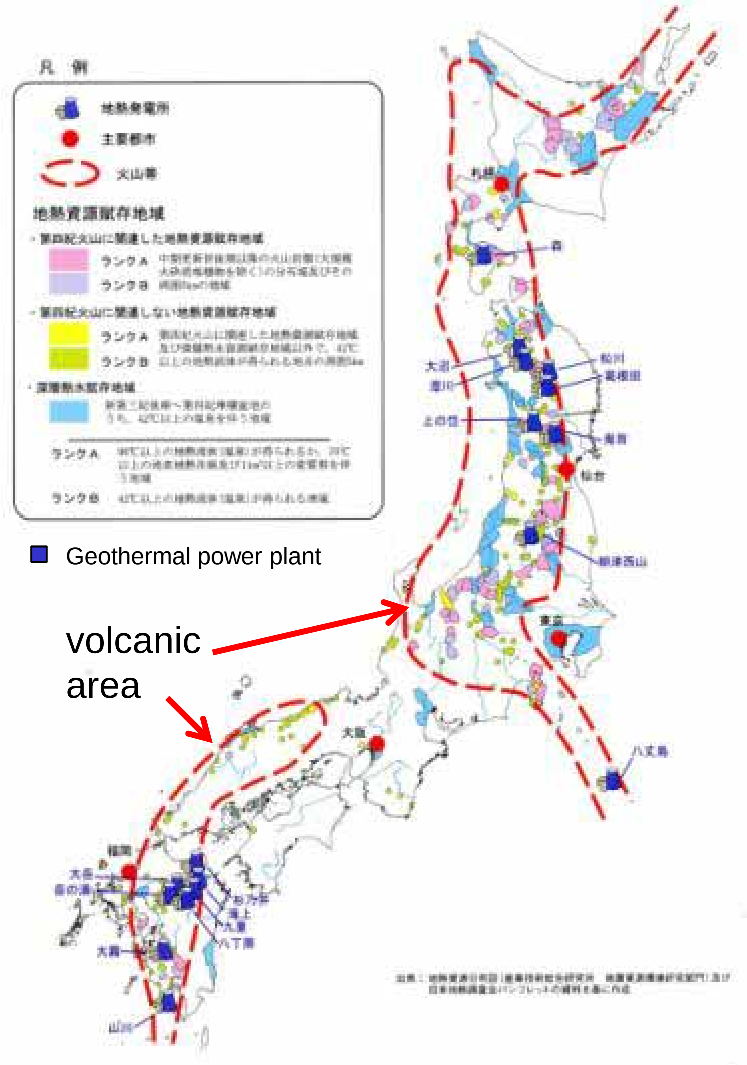
Utilization efficiency

Geothermal	70%
Wind	20%
Solar	12%

$M=10^6$
$T=10^{12}$

(Annual Energy Report 2008, MITI)

GEOTHERMAL POTENTIAL IN JAPAN



POWER GENERATION POTENTIAL：
22,070 MW (Miyazaki et al., 1991)

Installed Capacity ：535 MW

Unit：
$1MW = 10^3 kW = 10^6 W$

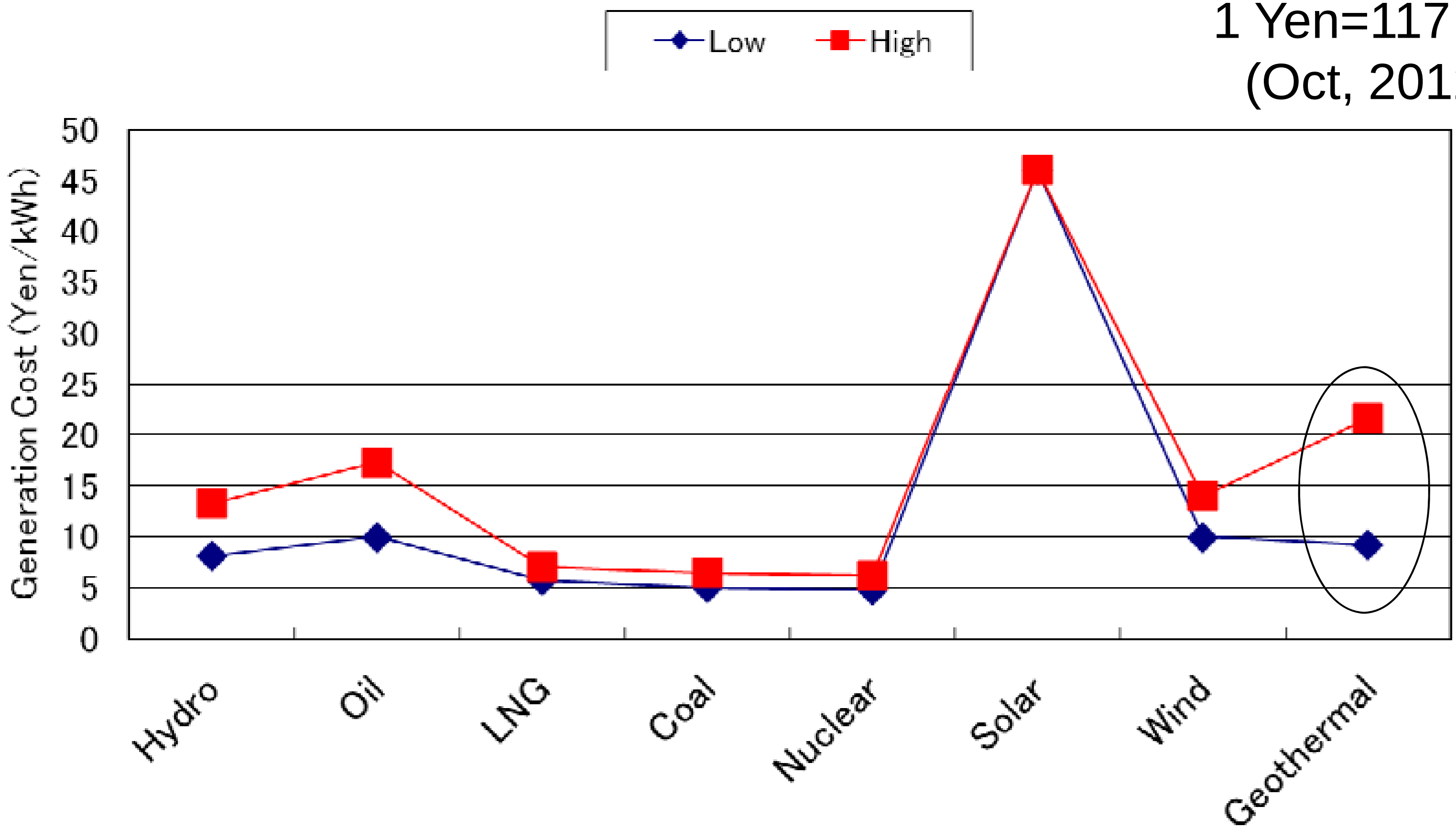
Nuclear Power Plant
1,000MW@unit x 20 unit

Problems :

- High cost and resource risk
- Long lead time
- Natural park
- Hot spring

COST OF POWER GENERATION IN JAPAN

1 Yen=117 Rp
(Oct, 2012)



Annual Energy Report 2008, Agency of Natural Resources and Energy
Mid-term report on Geothermal Power Generation 2009

GENERAL PLAN FOR 30MW PLANT DEVELOPEMENT

- Surface surveys : 2yrs

  geology, geochemistry, geophysics

  → Target selection !!

26.4 billion Yen

- Well drilling : 2yrs+1yr

  exploration well, production well(8), reinjection well(8)
  1500m – 2000 m

- Discharge test : 1yr
- Integrated analysis : 1yr

  reservoir, economic and power generation assessments

- Environmental survey : 2yrs

  evaluation of environmental effects

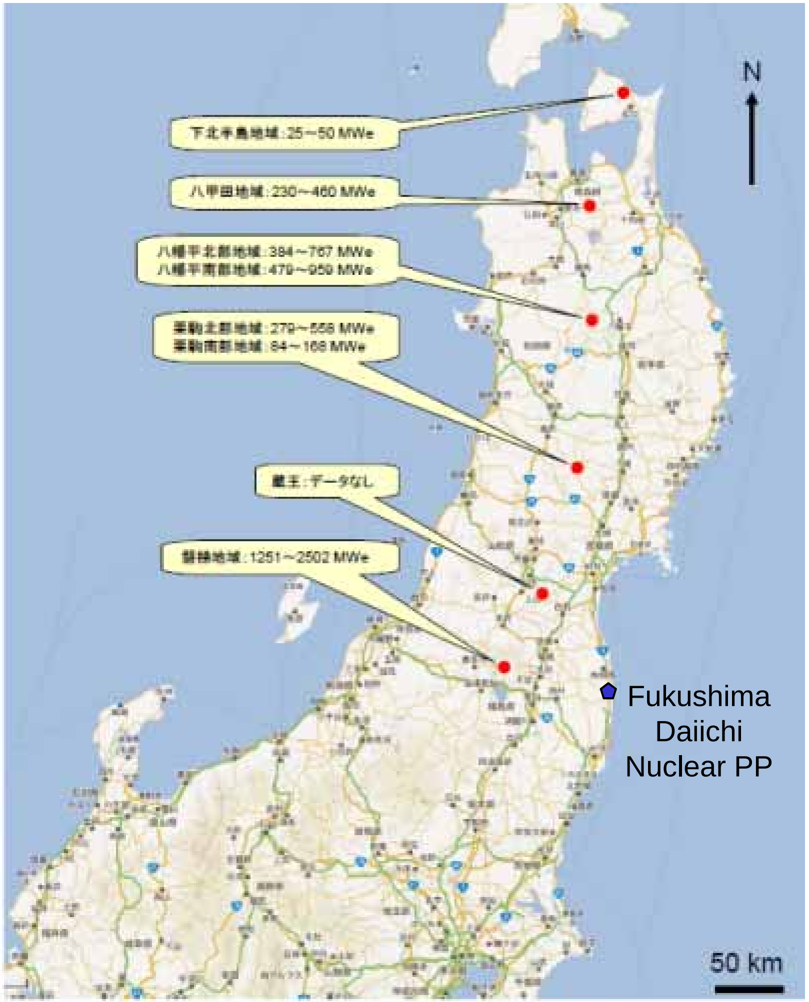
- Construction of power plant : 2yrs

10 yrs

POWER GENERATION

(Chikaikyo.com)

NATIONAL PARK



東北地方地熱資源開発可能出力 検討地域

<u>Potential area for power generation in Tohoku</u>

- 17 areas in 6 locations
- 740 MW potential
  - 570 MW in national park
  - 170 MW outside of park
- <u>270 MW in Fukushima</u>

Candidate areas for development in Tohoku district

(Chikaikyo.com)

SOLUTIONS

1. High cost

   2012.7 Feed in Tarrif (FIT) system

   27.2 Yen@kWh >15 MW

   42 Yen@kWh <15MWe

   → invoke incentives for new development among private sectors

2. Long lead time

   USA 5 yrs ⟺ Japan 10 yrs

   shorten environmental survey

3. National Park

   2012.3 Ministry of Environemnt

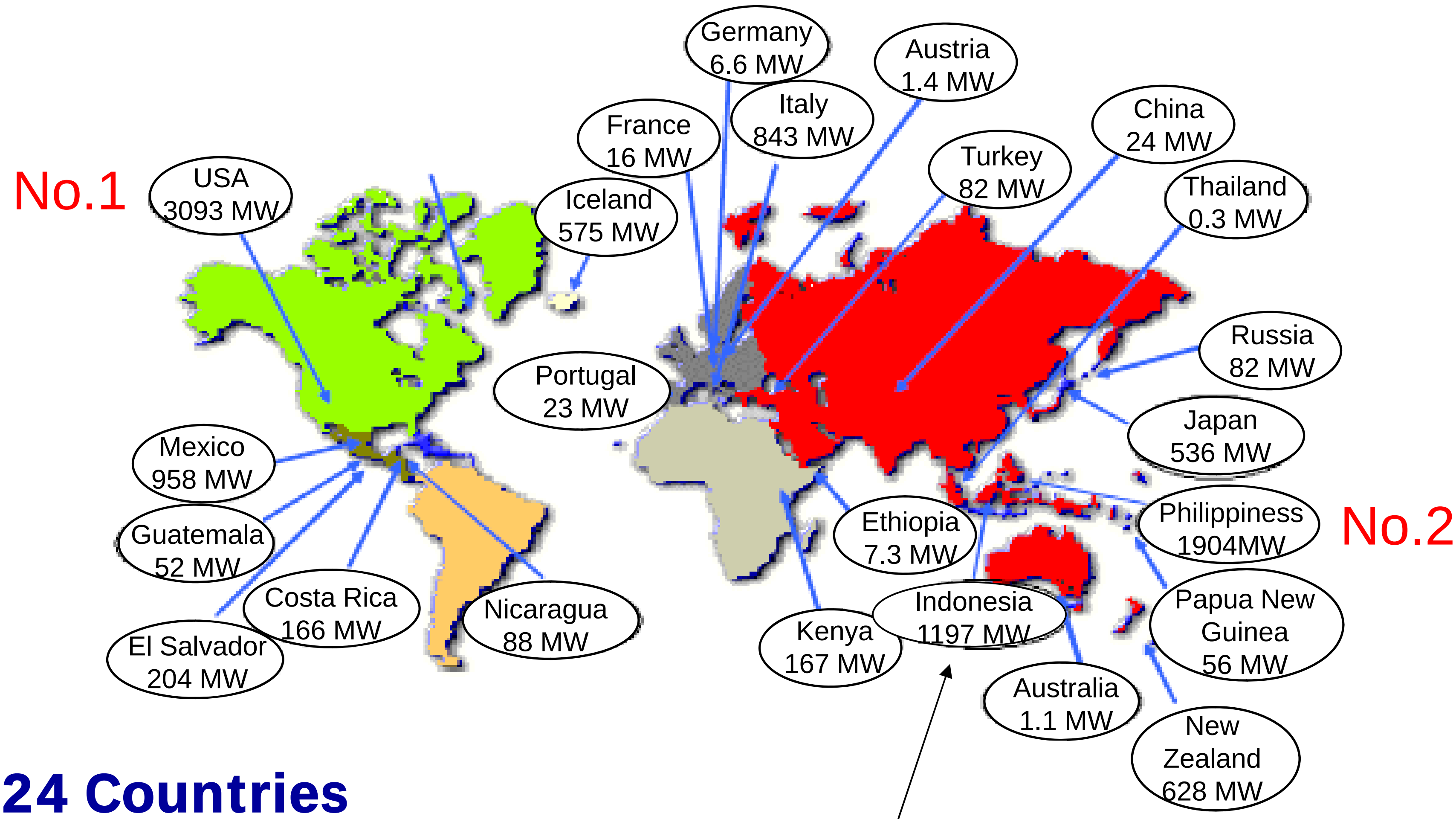
   Restriction for exploration in national park modified

4. Hot spring

   monitoring for any affects due to exploitation

   more communication with stake holders

GEOTHERMAL POWER PLANT IN THE WORLD (2010)



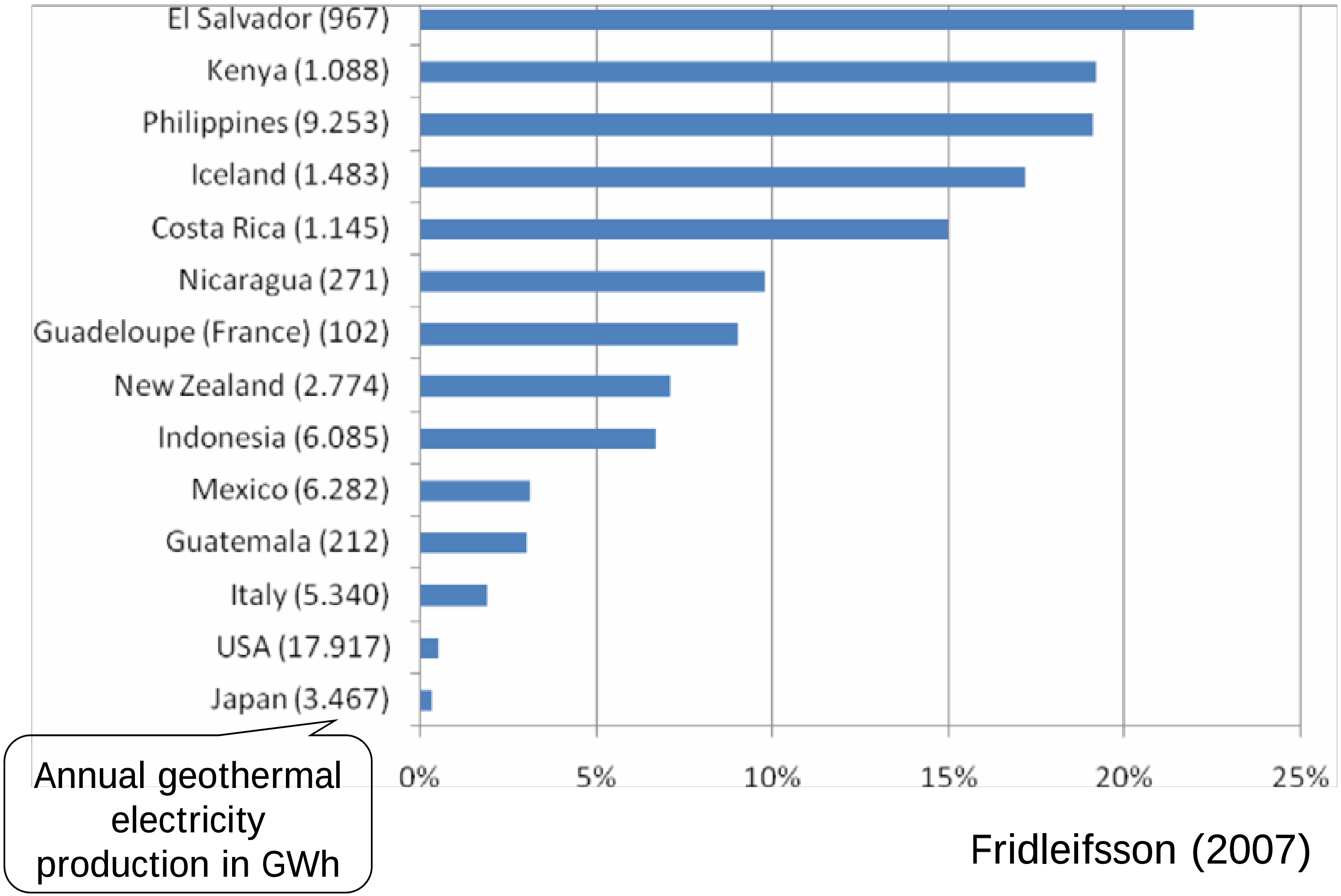
24 Countries

Installed capacity:10,700MW

No.3

(Bertani, 2012)

SHARE OF GEOTHERMAL IN NATIONAL ELECTRICITY PRODUCTION



Fridleifsson (2007)

GEOTHERMAL POTENTIAL IN THE WORLD

Country	Power Potential (MW)
Indonesia	27,791
USA	23,000
Japan	20,540
Philippines	6,000
Mexico	6,000

No.1

(Bertani, 2012)

GEOTHERMAL POWER GENERATION IN 2015

Total : 19,800MW

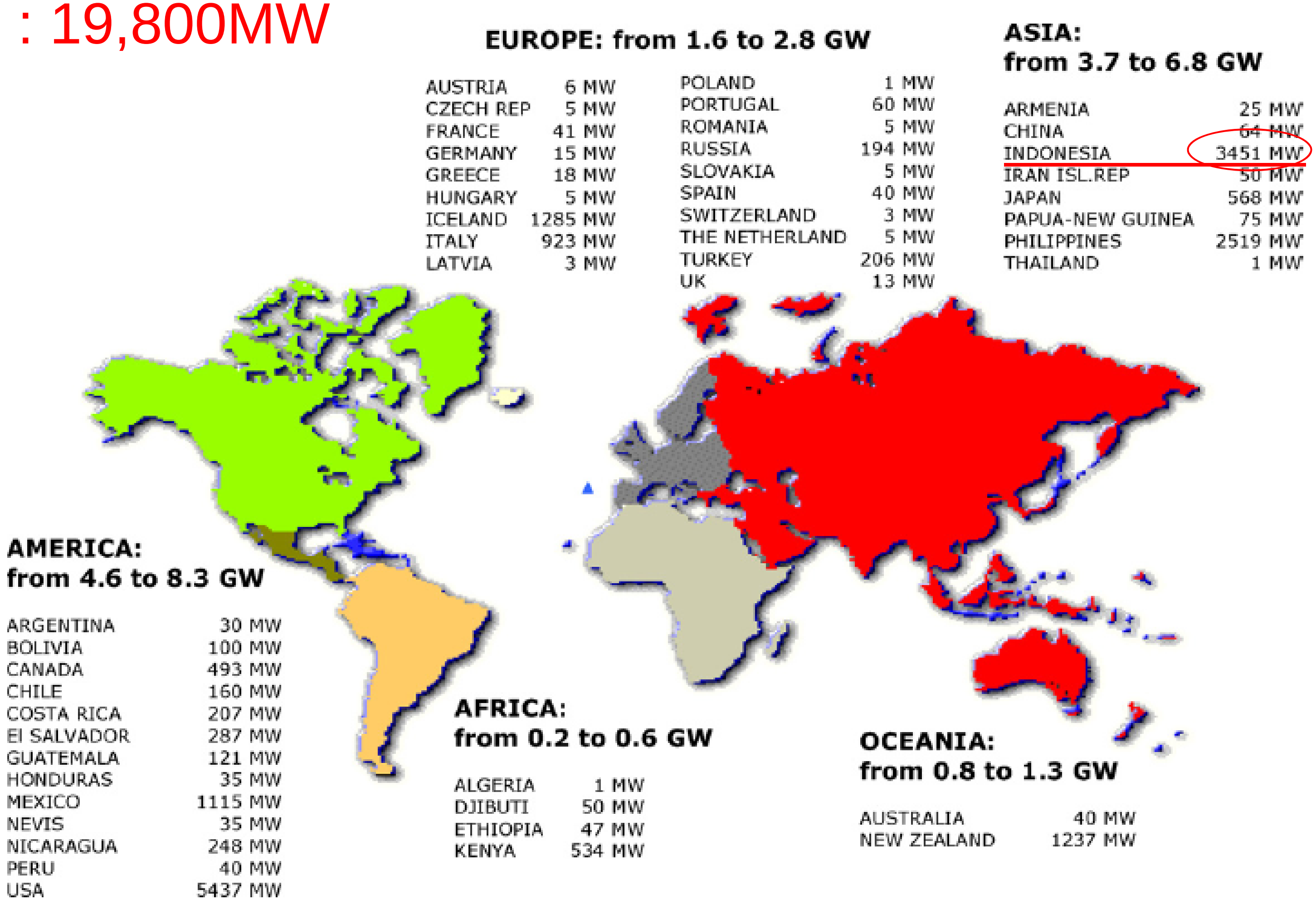


Fig. 3. Forecast of the installed capacity in 2015 (19.8 GW).

(Bertani,2012)

FUTURE OF GEOTHERMAL DEVELOPMENT IN INDONESIA

- Resource assessment
  11,405MWe : MEM and JICA(2007)

- Total 1197 MWe as of 2010
  Sibayak 13MWe, Lahendong 60 MWe
  G. Salak 375 MWe, Kamojang 200MWe, Wayang Windu 227 MWe, Darajat 260 MWe, Dieng 60 MWe

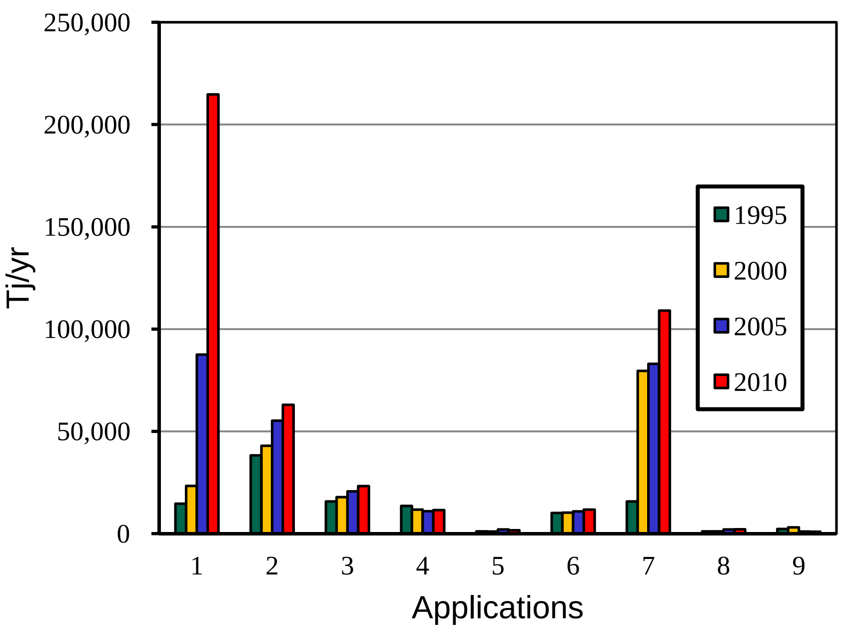
- Road map of geothermal development
  2015 3451 MWe (affordable 2000-2500 MWe)
  2025 9500 MWe

Sumatra	4,520 MWe
Sulawesi	735 MWe
Java-Bali	3,645 MWe
Nusa Tenggara	146 MWe
Maluku	40 MWe

→ Big challenge!

DIRECT HEAT USE OF GEOTHEMAL ENERGY

Worldwide direct energy use

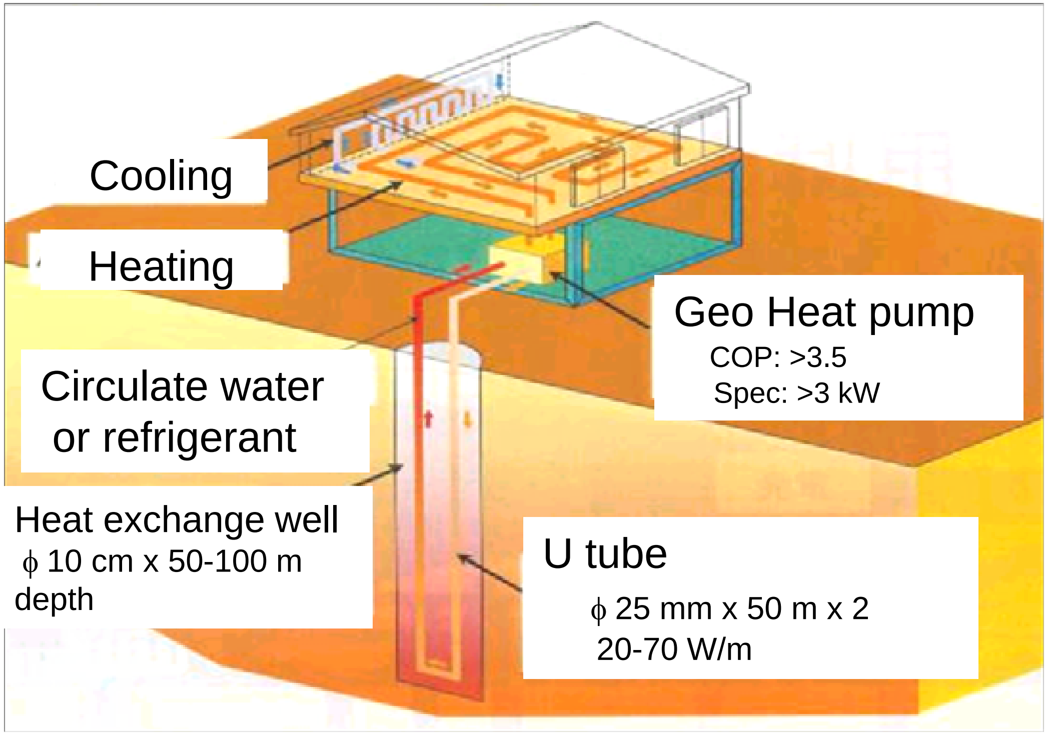


(Lund et al., 2010)

- Direct use
  1. Geothermal heat pump
  2. Space heating
  3. Green house
  4. Aquaculture
  5. Agriculture
  6. Industrial use
  7. Bathing & swimming
  8. Cooling / Snow melting
  9. Others
- Capacity
  World 50,583 MWt
  Japan 2,099 MWt

Geothermal Heat Pump (GeoHP)

- Energy utilization system of low level geothermal energy in shallow ground with heat exchange well
- Utilization
  - Air conditioning for private house to large scale building
  - Snow melting of road and parking
  - Hot water supply
- Started 1940' in USA, quickly introduced in 1980'



Schematic of GeoHP system

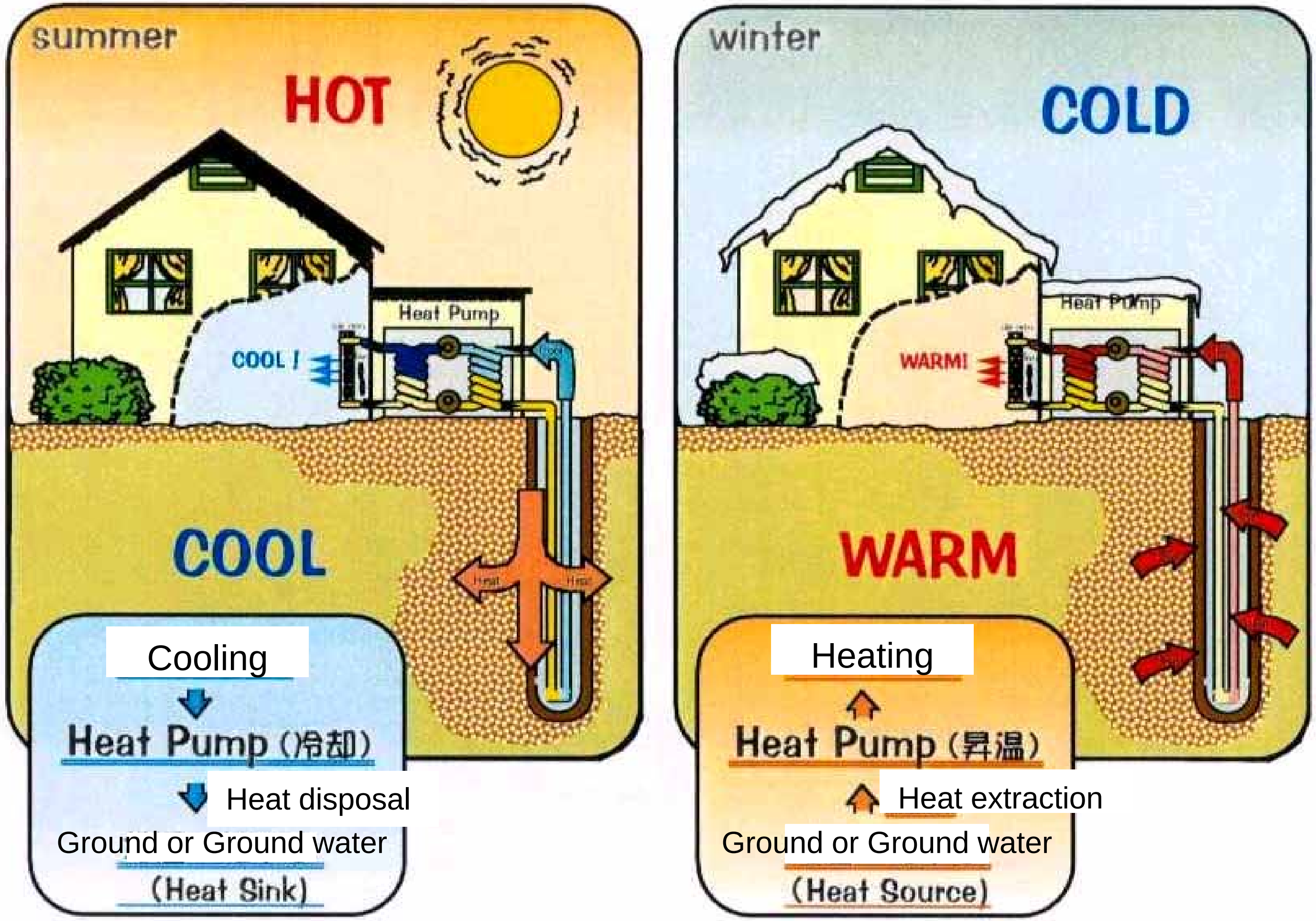
GeoHP SYSTEM

Summer: Exhaust heat into ground

Winter: Pump up heat from ground

Ambient
30℃

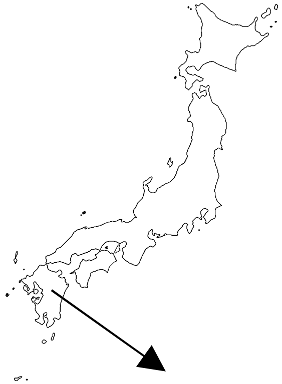
Ground
15℃



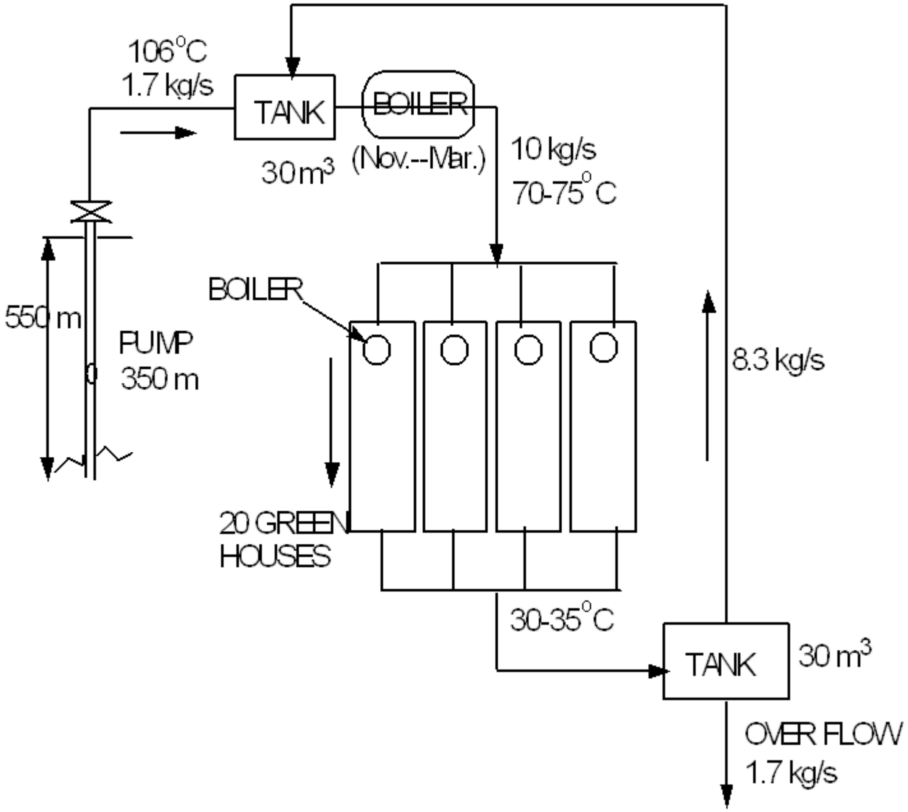
0°C

15°C

Utilize the nature of constant temp. of ground



GREEN HOUSE USE
- Sensui Rose Garden -



- Heating System (Engineer)
- Farming (Farmer)
- Market Survey (Farmers Union)

Collaboration

HOT SPRING (Spa)

Blue Lagoon, Svartsengi geothermal field, Iceland

Swimming pool, Yambajin geothermal field, 4300m a.s.l., Tibet, China

HOT SPRING (Spa)

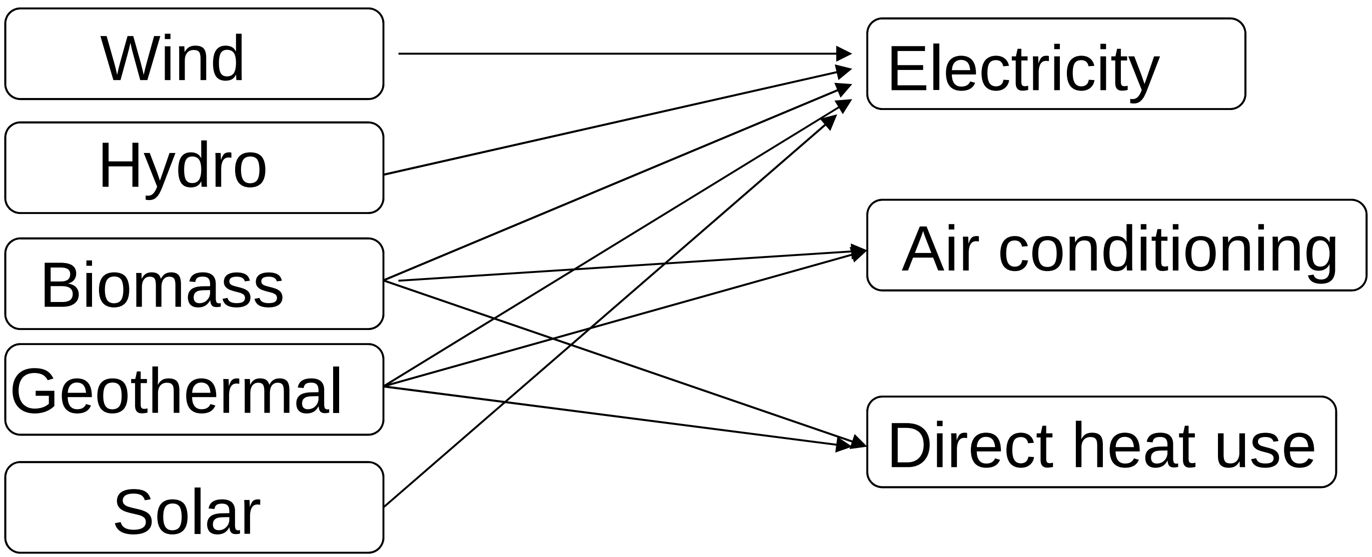
Roten buro (Outdoor bath)

Even Japanese monkies ・・・

LOCAL ENERGY PRODUCTION FOR LOCAL CONSUMPTION

Energy source

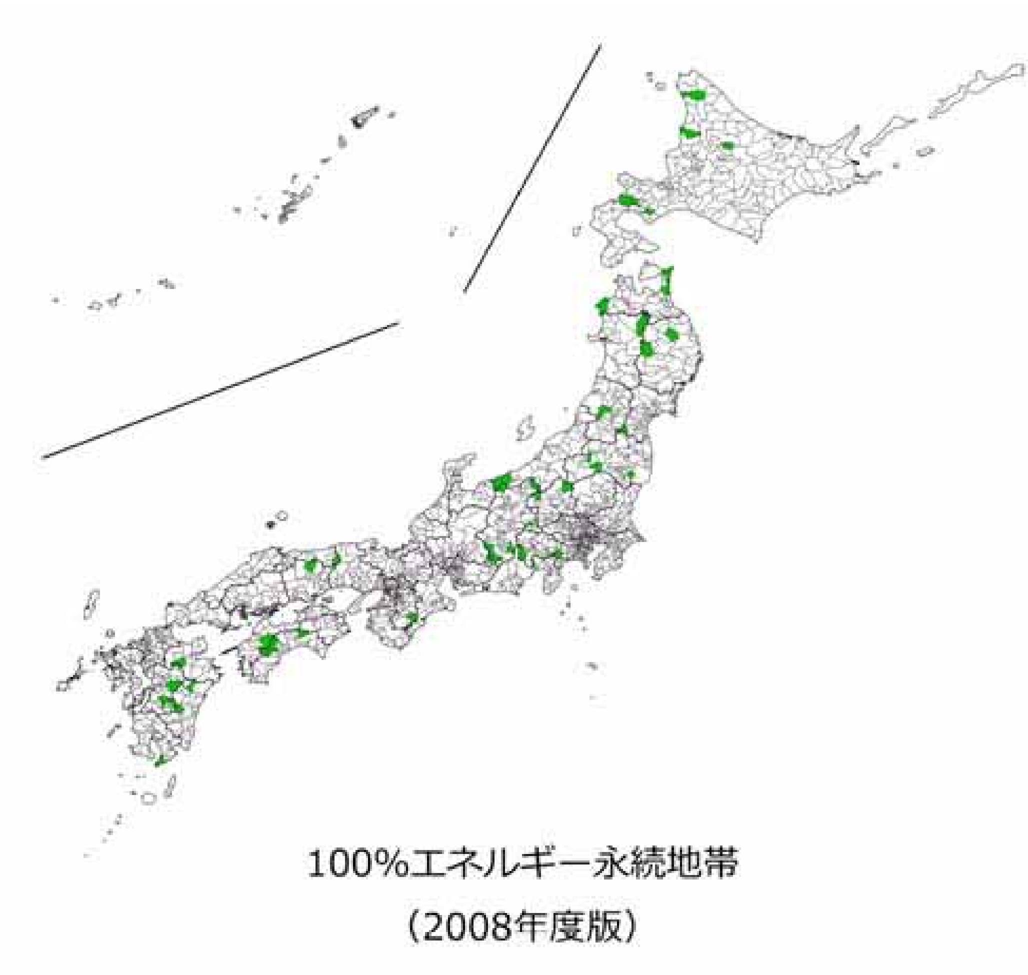
Utilization



Large scale & centralized → Small scale & distributed

Approach to clean energy develoment by Kuzumaki town, Iwate
http://www.town.kuzumaki.iwate.jp/index.php?topic=kankyo

EVERLASTING ENERGY SUPPLY AREA



Map of everlasting energy supply area

- Japan produce only 4 % of total energy demand
- Renewable energy fully satisfies local energy demand : 57 local districts (2009)

Self-supply ratio ＞100**%**

http://sustainable-zone.org/

LOCAL ENERGY PRODUCTION AND CONSUMPTION

Kuzumaki Town, Iwate Prefecture, JAPAN
- Town of milk, wine and clean energy -

No. of family : 2,890, Population: 7,678 as of January 2010

1. Wind
   21000 kW+1200 kW
2. Biomas
   Wood 120 kW
   Cow manure(bio gas) 37 kW
3. Solar 50 kW
4. Woody pellet boiler
5. Geo Heat Pump

Energy self-supply ratio 117**%**
Electricity self-supply ratio 200**%**
(Sustainable Zone 2011)

SUMMARY

1. Geothermal energy is a renewable energy resource and has less impacts on environment compared with fossil fuels. It can be used for various purposes depending on its temperature

2. Development of geothermal energy for power generation is to be started as soon as possible because of its long lead time

3. Development of energy supply system by combining various renewable and sustainable energy sources will be promoted as a local energy supply system