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# Geothermal Resources For the 21<sup>st</sup> Century

—Insights from China's Geothermal Resources Exploration and Development

## Wang Guiling

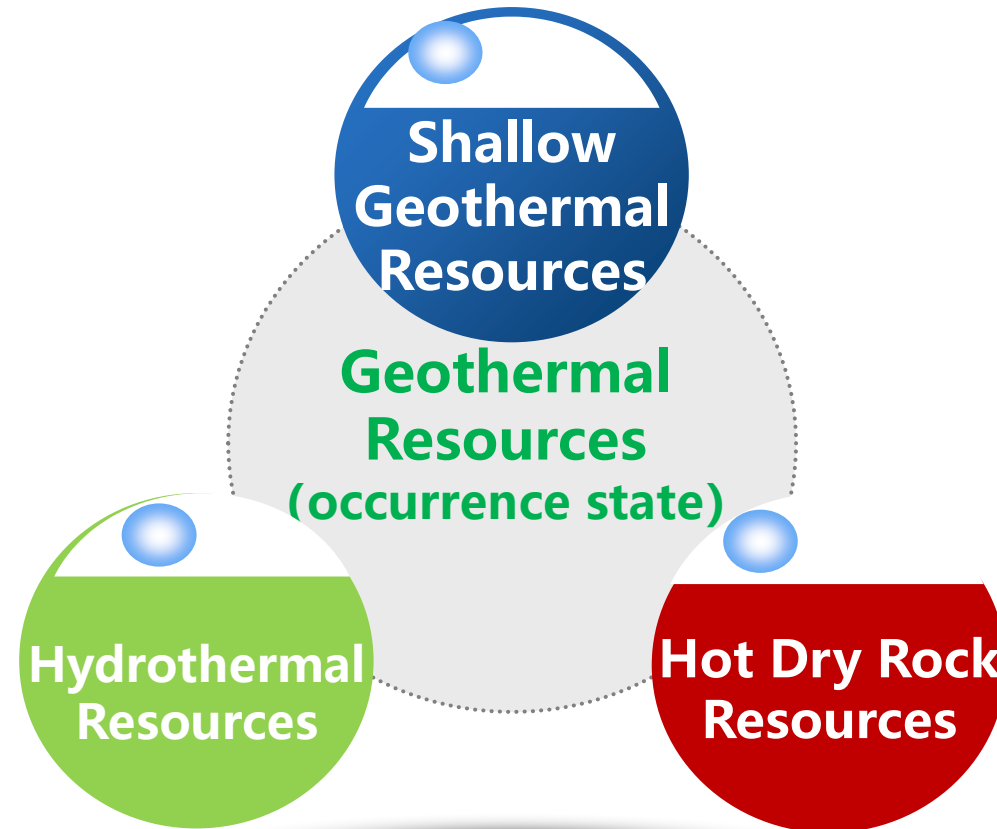
Institute of Hydrogeology and Environmental Geology, CAGS

2024.10.23



- 1. Human Energy Potential of Geothermal Resources**
- 2. Geothermal Resources Development in China**
- 3. Global Geothermal Resources Development Prospects**

# 1.1 Classification of geothermal resources



# 1.2 Utilization of geothermal resources



**Geothermal energy is increasingly valued for its clean, stable, safe and efficient characteristics**

### Advantages of geothermal resources

#### **Excellent thermal continuity**

Local energy source with uninterrupted power supply and stable output loads

#### **High utilization factor**

The geothermal energy utilization factor is up to 72 %, compared to 42 % for hydro, 21 % for wind and 14 % for solar energy

#### **Nearly zero emissions**

No exhaust gases and other fluids or solid wastes



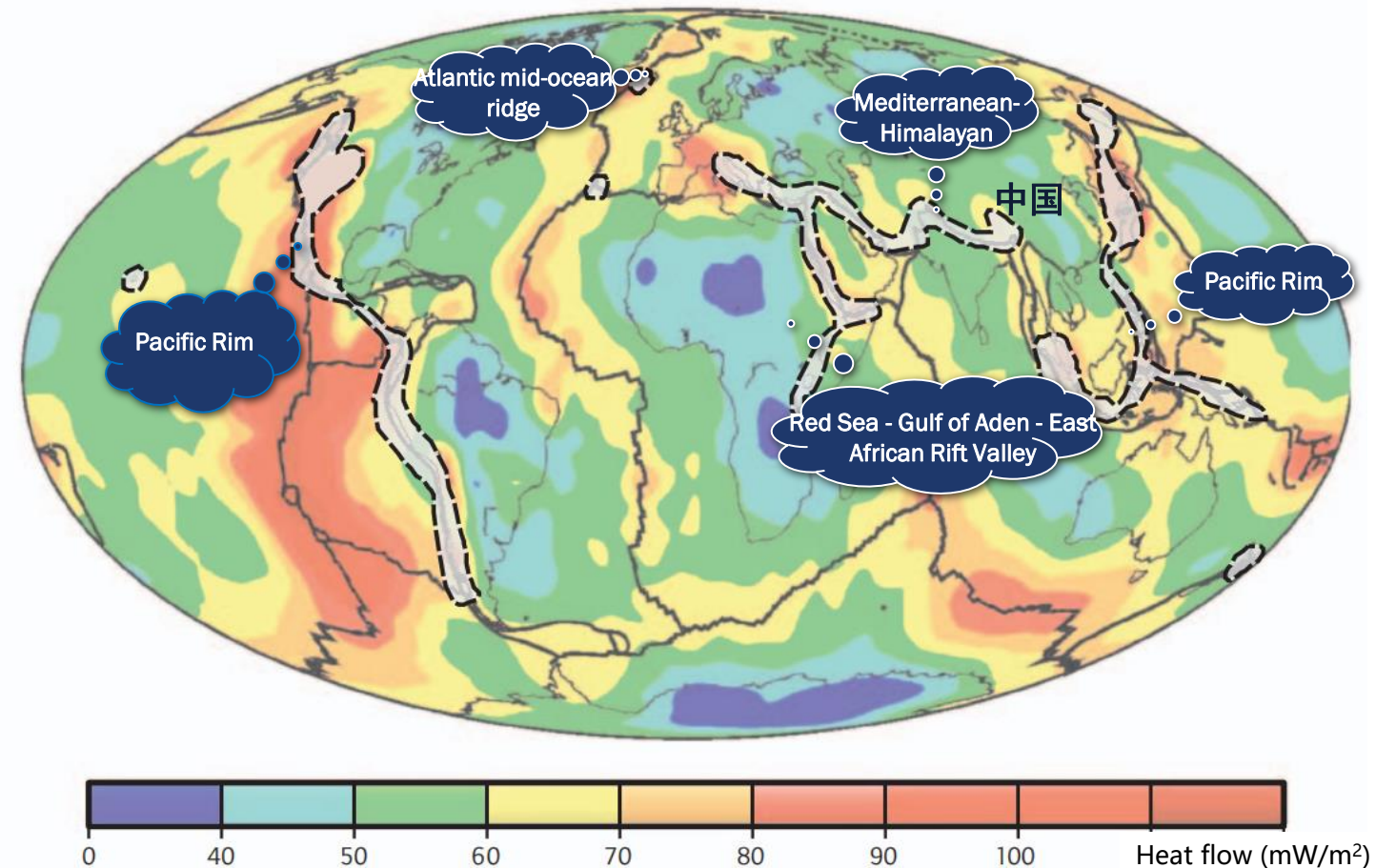


# 1.4 Imbalanced distribution of geothermal resources globally



➤ **Mainly in the following four geothermal zones :**

- ① **Pacific Rim**
- ② **Mediterranean-Himalayan**
- ③ **Red Sea - Gulf of Aden - East African Rift Valley**
- ④ **Atlantic Mid-ocean Ridge**

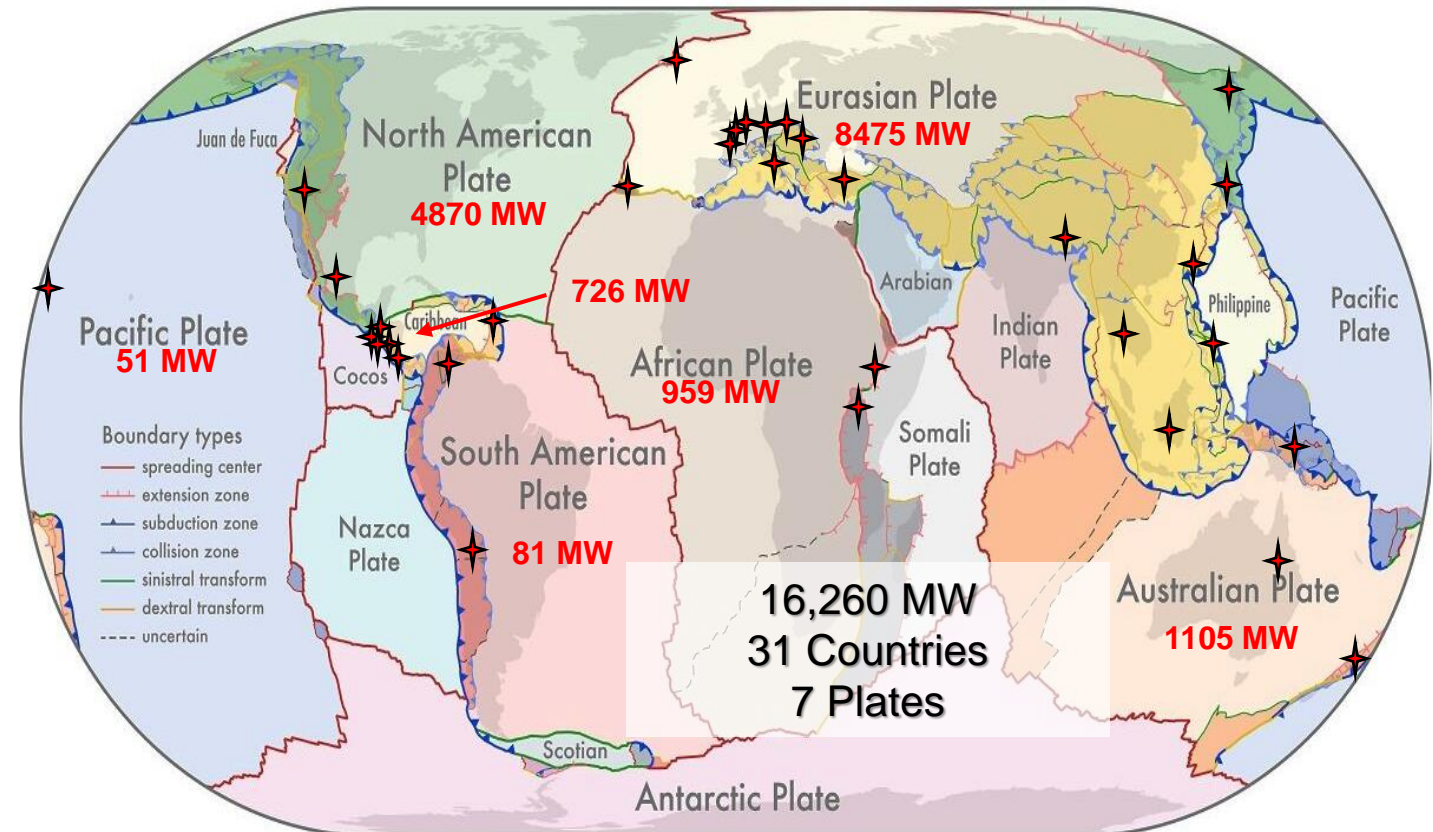
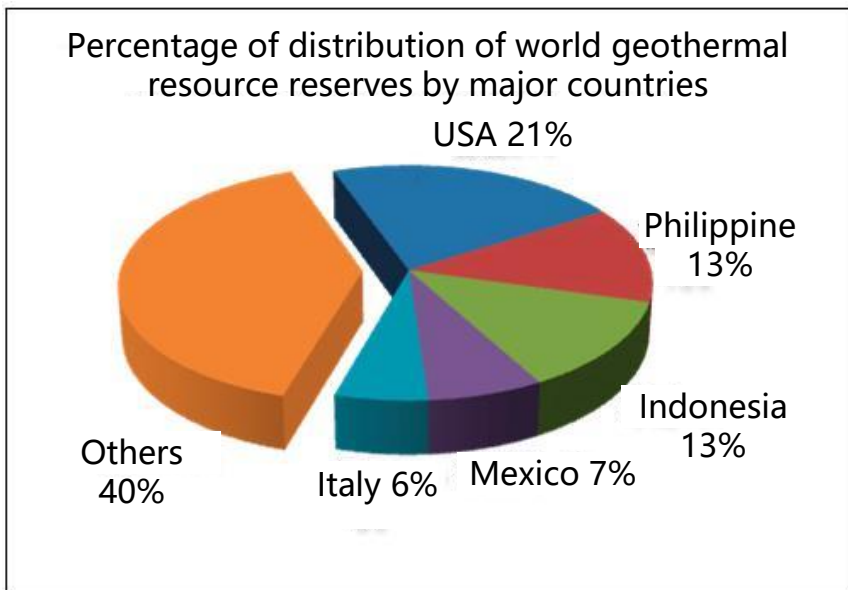


from IEA, Technology Roadmap: Geothermal Heat and Power

# 1.5 Global Geothermal Resource Potential



The heat contained in rocks and groundwater above 15 °C within 5 km below the Earth's surface is equivalent to **46000 trillion tons** of standard coal. It can satisfy the energy needs of mankind for hundreds of thousands of years.



Global Geothermal Power Installation Distribution from Luis C.A.G., 2023 WGC

## 1.6 Distribution of geothermal resources in China is characterized by “three zones and four belts”



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➤ **China's geothermal resources are mainly distributed in seven geothermal areas (belts) :**

- **North China area**
- **Northeast China area**
- **Mid-lower reaches of the Yangtze River area**
- **Tanlu fault belt**
- **Ordos rim belt**
- **Southeast coast belt**
- **Yunnan-Tibetan belt**







**1. Human Energy Potential of Geothermal Resources**

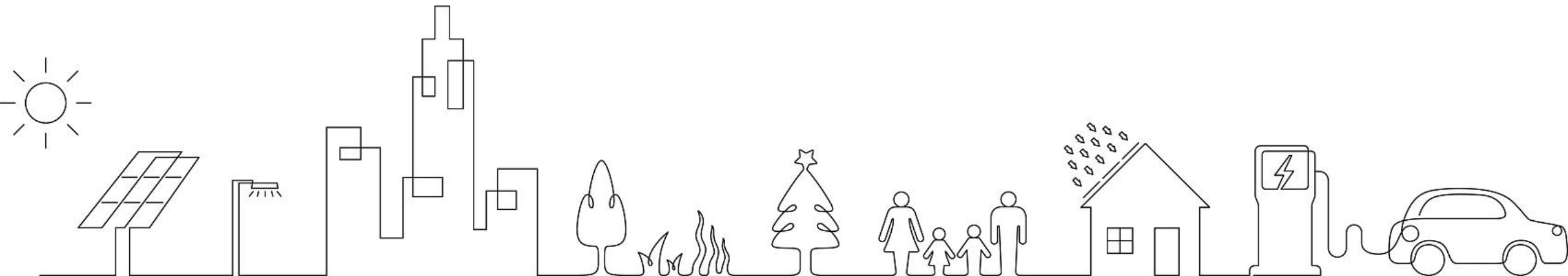
**2. Geothermal Resources Development in China**

**3. Global Geothermal Resources Development Prospects**



# 01

## History of Geothermal Development and Utilization in China



## 2.1 China was one of the first countries in the world to utilize geothermal resources



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- As early as in the Western Zhou Dynasty more than 2800 years ago, there is a record of King Yu of Zhou using geothermal bathing in Huaqing Pond.
- In the 1950s, China began to utilize hot springs on a large scale.
- In the early 1970s, China entered the stage of bathing in hot springs, geothermal heating and cooling, power generation comprehensive utilization.





## 2. Oil crisis promotes geothermal exploration and development

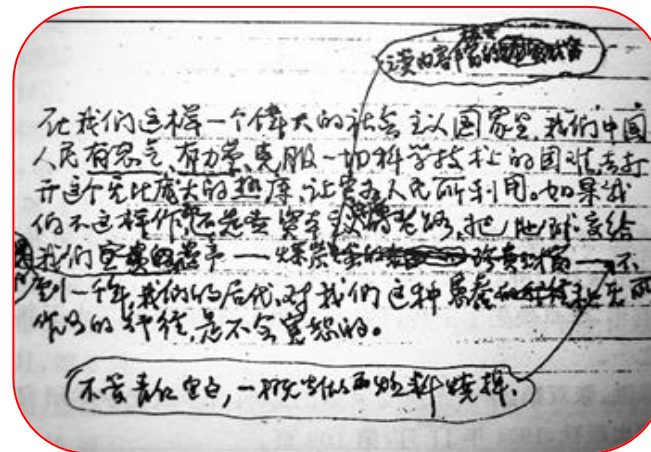


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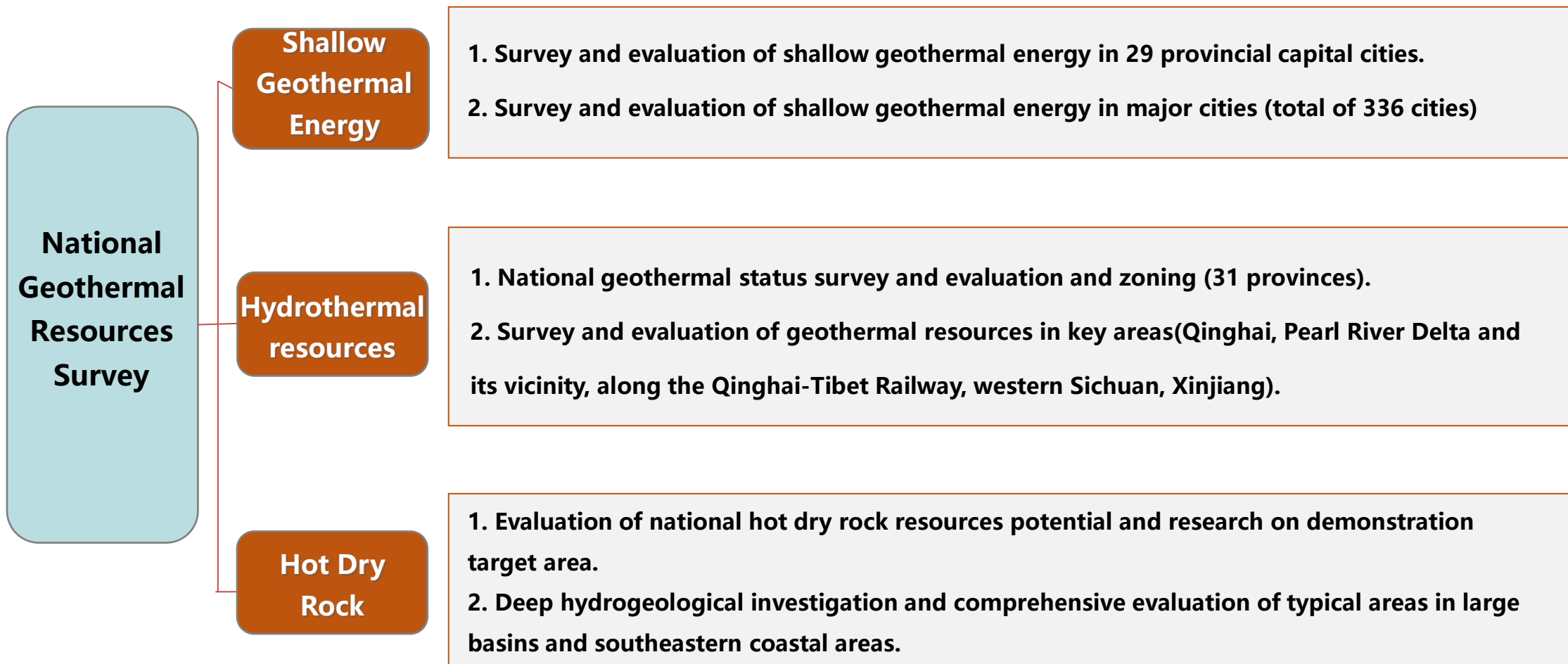
Mr. Li Siguang noted that: “the earth is a big heat reservoir, and geothermal resources are new natural resources opened up by mankind, as important as mankind's discovery that coal and petroleum can be heated and burned. What we know now is only a beginning and spark.”

**Along with the first world oil crisis, Mr. Li Siguang advocated and promoted the first geothermal exploration and development.**





### 3. Survey of geothermal resources nationwide during the Twelfth Five-Year Plan period



## 4. Geothermal exploration in key areas in the Thirteenth Five-Year Plan period



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### *Beijing-Tianjin-Hebei area*

Investigate the characteristics of geothermal resources in Beijing, Tianjin and Hebei and potential for sustainable development, and carry out the evaluation of geothermal resources in Xiong'an New Area.

### *Southeast coastal area*

Investigating the distribution and burial conditions of magmatic rocks in the key target areas along the southeast coast and evaluating the potential of hot dry rock resources.

### *Xining-Guinan*

Investigate the geological conditions and heat source of hot dry rock in Xining-Guinan, Qinghai, and identify profitable areas for exploration and development.

### *Songliao Basin*

Investigate the geological conditions in key target areas and evaluate the potential for development of sedimentary-basin-type hot dry rock resources in the Songliao Basin.

### *Sichuan-Tibetan area*

Research on heat flow distribution characteristics of different tectonic units to support the construction of the Sichuan-Tibet Railway.

## 5. Demonstration of typical geothermal system mining in the Fourteenth Five-Year Plan period



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Gonghe county in Qinghai carried out on-site hydraulic fracturing with stimulated volume greater than **10 million** cubic meters based on microseismic monitoring data.

Implemented production enhancement process of **hydraulic injection acid fracturing** in the 3024-3174m section of the Jizhong Depression in North China.

**Long gravity heat pipe:** The long-term stable heat capacity of heat pipe site in Xiong'an New Area is over 650kW, which can support the heating of over 20,000 square meters.

Qinghai EGS site



Acid fracturing in North China



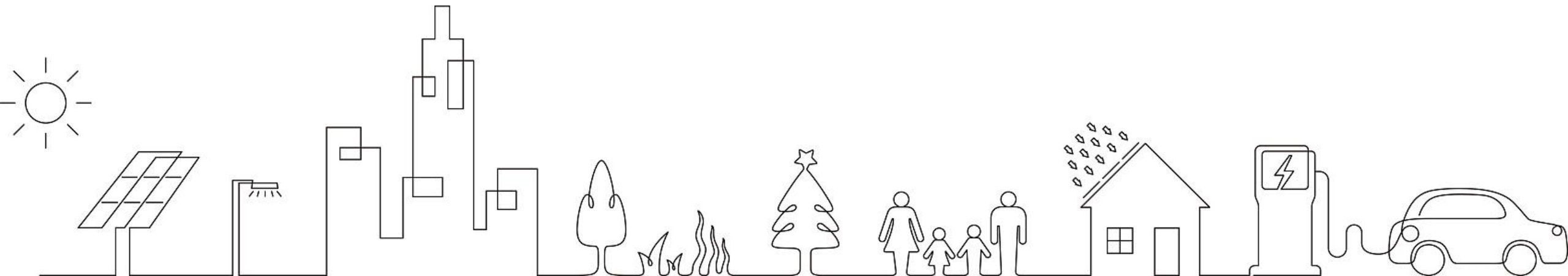
Gravity heat pipe in Xiong'an New Area





# 02

## Current Situation of Geothermal Development and Utilization in China



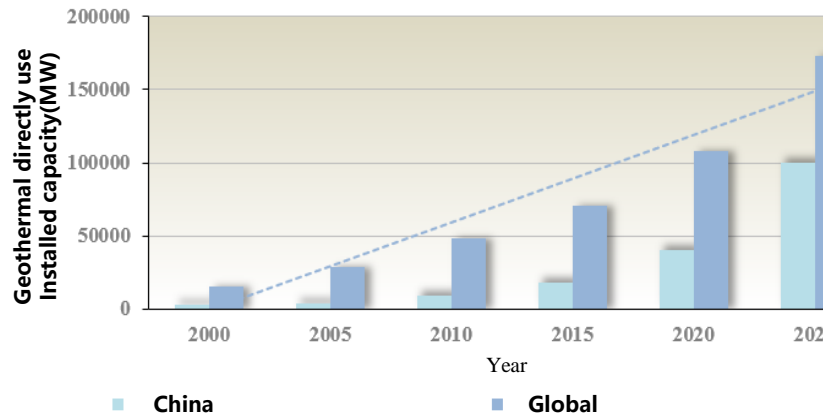
# 6. The utilization of geothermal resources in China is mainly for heating and tourism



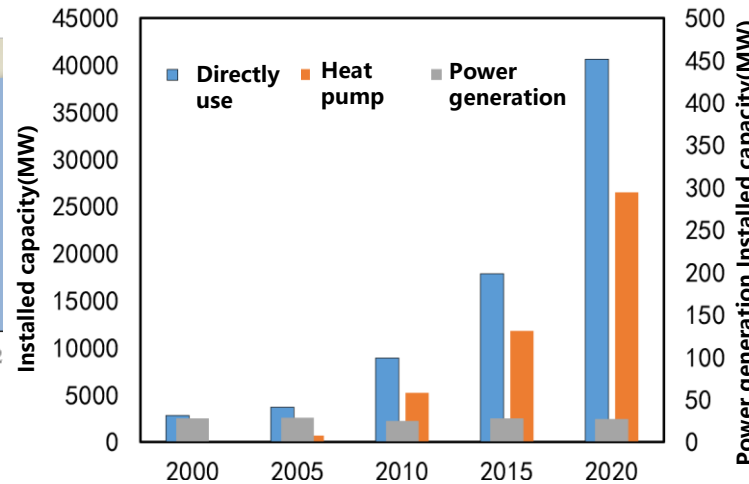
At present, the direct utilization of geothermal heat in China ranks first in the world, with mature shallow heat pump and hydrothermal geothermal heating technology, showing exponential growth after the year of 2000.

China's geothermal resources development and utilization amount trends

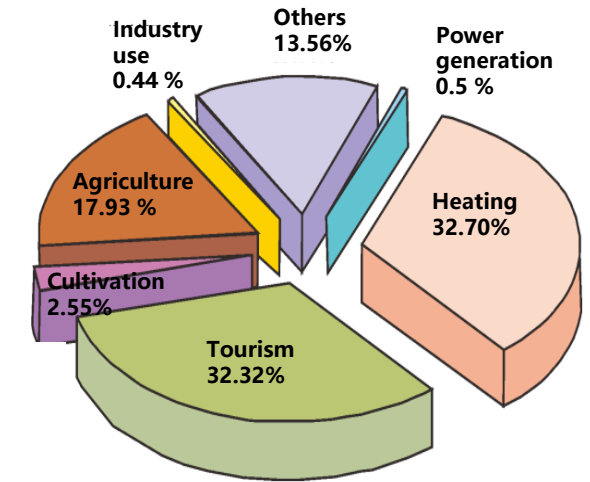
| Utilization                                   | index                                  | 2000  | 2005  | 2010  | 2015   | 2020   | 2021  |
|---|--|-------|-------|-------|--------|--------|-------|
| Shallow geothermal energy Heating and cooling | Installed capacity(MW)                 | 9.7   | 631   | 5210  | 11781  | 26450  |       |
|   | Area (10 <sup>4</sup> m <sup>2</sup> ) | 16    | 767   | 10070 | 33000  | 66500  | 80000 |
|   | Utilization amount (TJ/a)              | 83    | 6569  | 29035 | 100311 | 246212 |       |
| Hydrothermal resources Heating and cooling    | Installed capacity(MW)                 | 248   | 550   | 1040  | 2940   | 6089   |       |
|   | Area (10 <sup>4</sup> m <sup>2</sup> ) | 495   | 960   | 3020  | 6032   | 47800  | 53000 |
| Geothermal power generation                   | Utilization amount (TJ/a)              | 2889  | 6391  | 11992 | 33710  | 74041  |       |
|   | Installed capacity(MW)                 | 27.78 | 28.78 | 24.48 | 27.78  | 44.56  | 51.2  |



China tops the list for direct geothermal utilization



Major geothermal utilization type in China



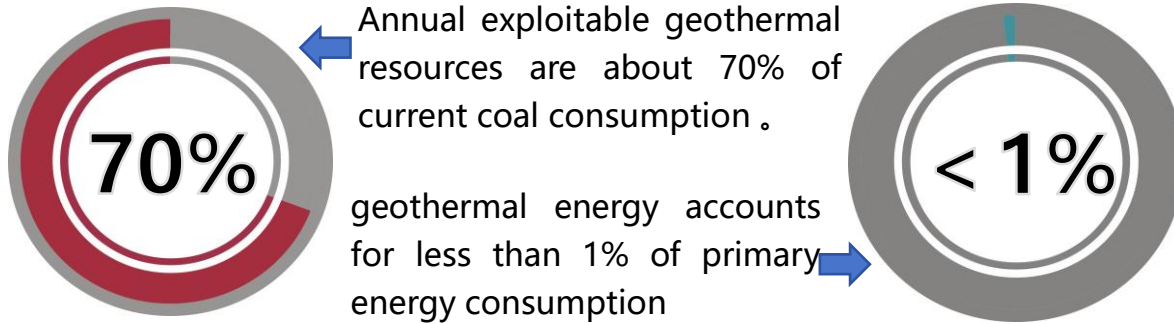
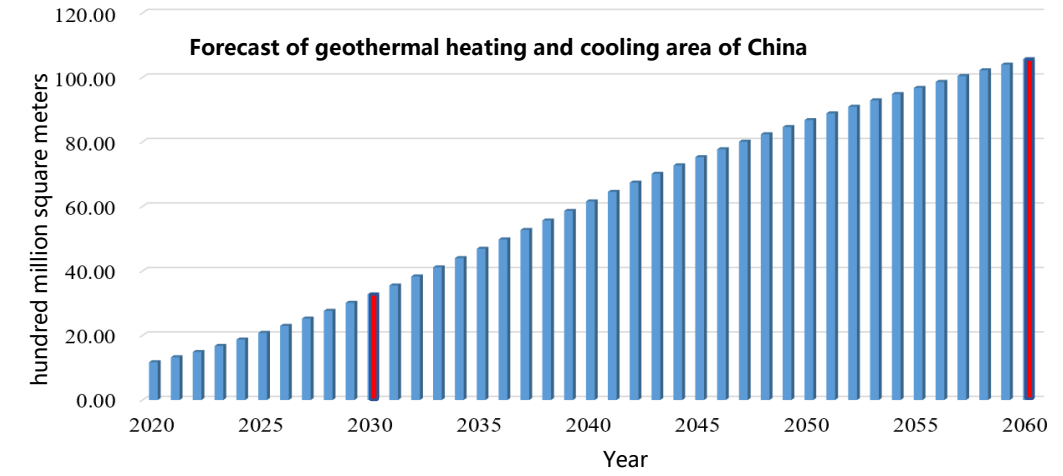
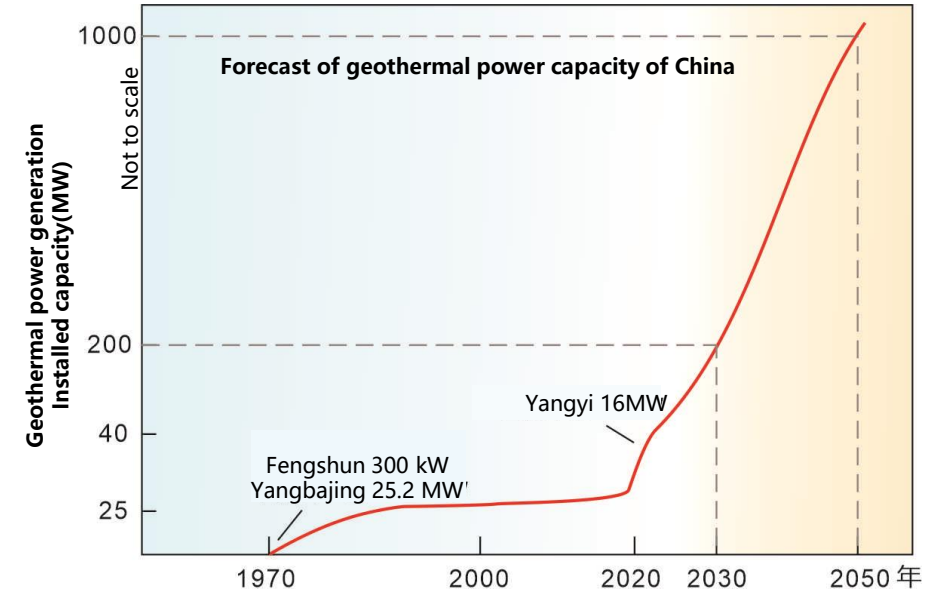
Percentage of different utilization types



# 7. Geothermal energy is underutilized compared to other energy sources, but is growing rapidly



- At present, China's geothermal energy accounts for less than 1% of primary energy consumption, but growing at a high rate.
- China is expected to have an installed geothermal power generation capacity of **200 MW** in 2030 and more than **1000 MW** in 2050. China's heating and cooling area is expected to be **3.3 billion** square meters in 2030 and **10.6 billion** square meters in 2060.



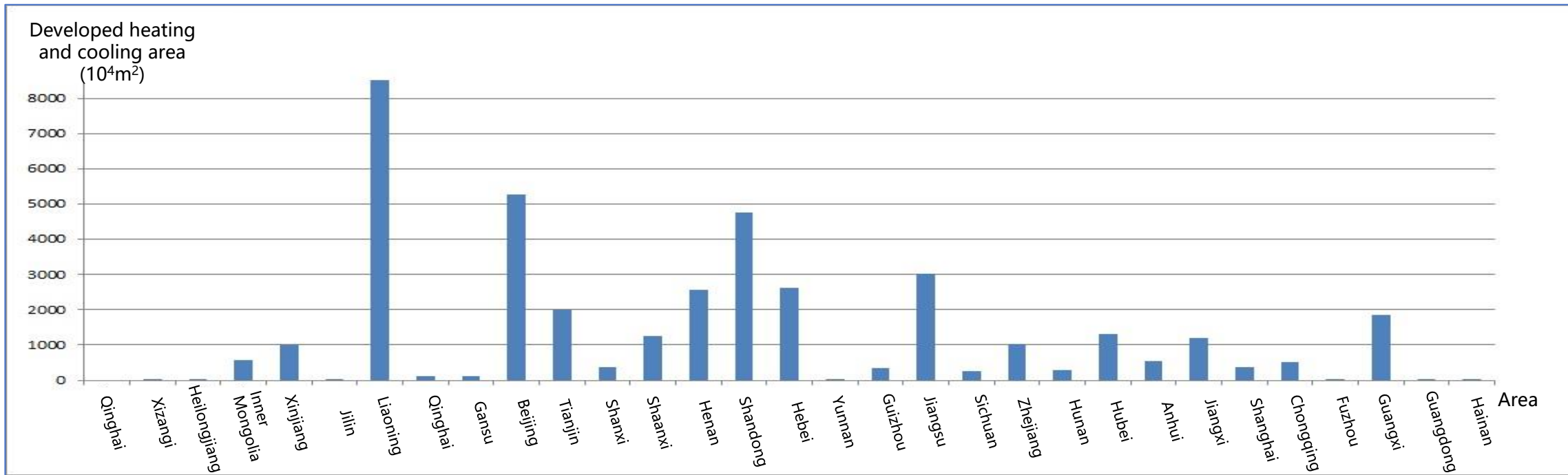
## Forecast results of heating and cooling area under the current development scenario:

- By 2030, geothermal heating and cooling nationwide can replace 77.11 million tons of standard coal annually.
- By 2060, geothermal heating and cooling nationwide can replace 173 million tons of standard coal annually.

## 8. Rapid development of shallow geothermal energy for both heating and cooling



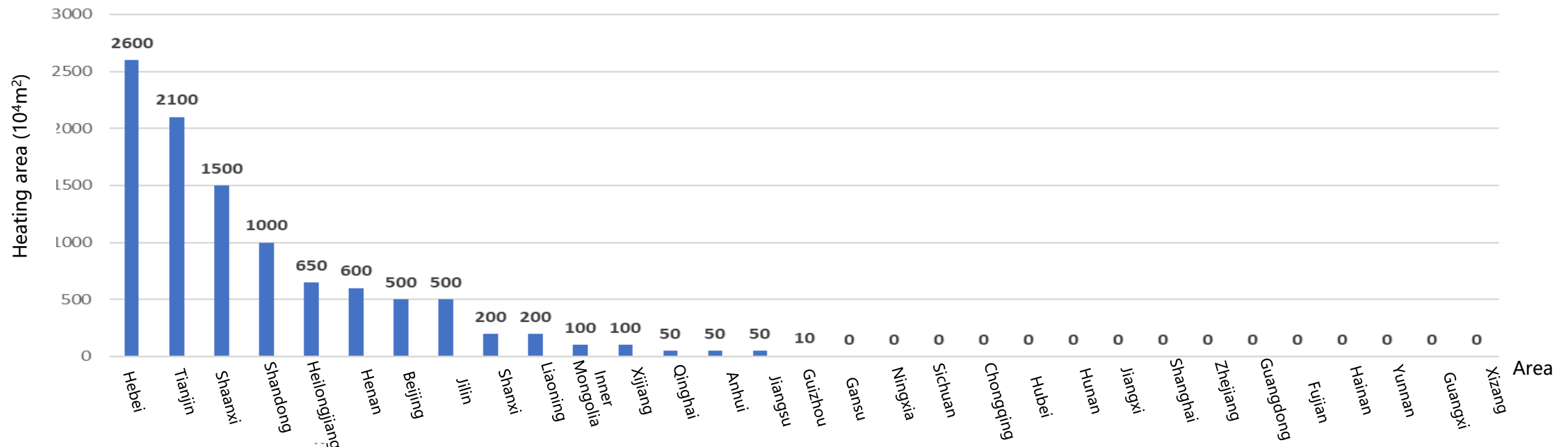
The utilization of shallow geothermal energy in China started at the end of the last century, with 7.67 million square meters of building area for heating (cooling) in 2004, and has been increasing at an average annual rate of 28% since 2010. **By the end of 2021, China's shallow geothermal heating (cooling) capacity of 800 million square meters, ranking first in the world.** It is mainly distributed in the urban areas of Beijing, Tianjin, Hebei, Liaoning, Shandong, Hubei, Jiangsu, Shanghai and other provinces and cities, of which Beijing, Tianjin and Hebei have the largest scale of development and utilization.



## 9. Continued growth in hydrothermal resources utilization and low heating operating costs



Over the past 10 years, the direct utilization of hydrothermal resources in China has grown at an average annual rate of 10%. The direct utilization of geothermal resources in China is mainly for heating, followed by tourism and Cultivation. By 2021, the nation's hydrothermal resources heating area will reach **530 million square meters**, and together with shallow geothermal energy, it will achieve a heating (cooling) capacity of **1.33 billion square meters**.



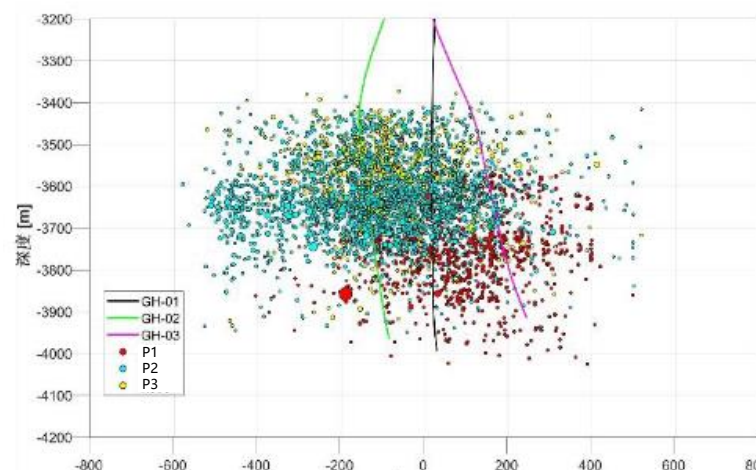
Data source: 《Thirteenth Five-Year Plan for Geothermal Energy Development and Utilization》

# 10. Exploration and development hot dry rock resources is in an initial stage

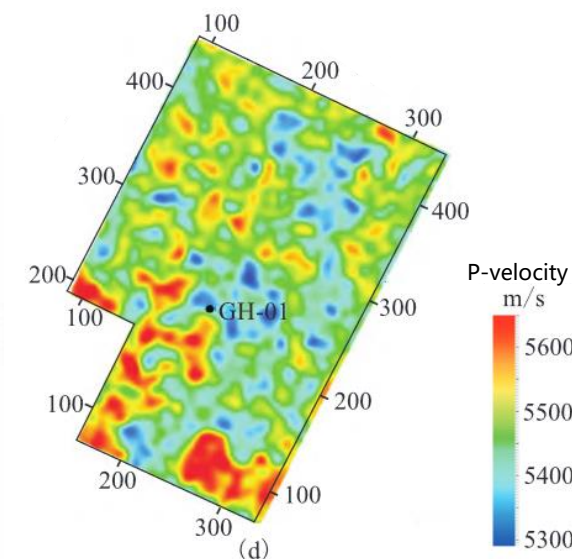


- ❑ Hot dry rock resources in China is still in the stage of exploration and trial mining.
- ❑ The Gonghe Basin has drilled and obtained hot dry rock exceeding 200 °C, and has completed hot dry rock scale-up to create reservoir and experimental power generation.

- Limited distribution of volcanic hot dry rock resources.
- High-quality hot dry rock resources ( $\geq 180^\circ\text{C}$ ) are buried at larger depths.
- Hydrothermal-dry heat geothermal resources “homologous symbiosis” features prominent
- Hydrothermal-dry heat with the same exploration and extraction is the direction of development



Microseismic monitoring in the Gonghe Basin  
(Xu et al., 2024)



Velocity modeling of the Gonghe Basin  
(Chang et al., 2024)



# 11. The pattern of “Northern China mainly for heating, western for electricity and southern for cooling” is initially formed



**China's geothermal utilization is mainly for heating, and has reached an initial scale in the north China.** By the end of 2020, the cumulative area of medium-deep geothermal heating had reached 582 million square meters, accounting for 2.76% of the total heating area and 5.02% of the clean heating area.

**Geothermal power generation is growing slowly.** Yangyi power station will soon complete a total installed capacity of 32 MW, Ruili newly complete 1 MW, in addition to Yangbajing will revitalize 20 MW power generation capacity.

**Geothermal cooling in the south China is showing its start.** Medium and low-temperature underground hot water in the southern region of the application of broad prospects. At present, a 100-kilowatt geothermal cooling demonstration has been established in Meizhou, Guangdong.



Yangyi power generation station



京津冀首个地热资源梯级综合利用科研基地初步建成  
河北台 苏明山 沧州台 刘会丽 周晓楠 报道 邢辉全 编辑





**1. Human Energy Potential of Geothermal Resources**

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**3. Global Geothermal Resources Development Prospects**

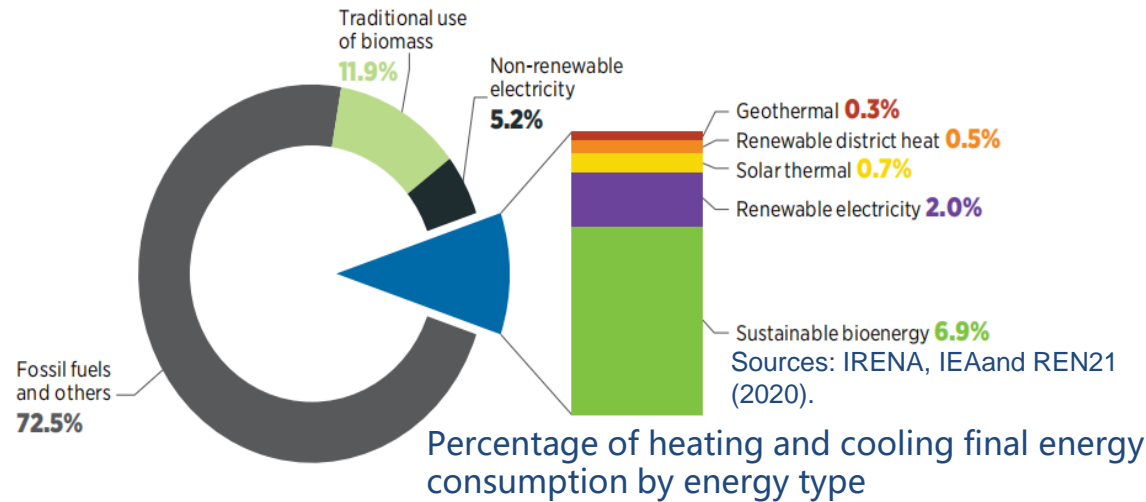
# Uneven development of global geothermal resources, with huge utilization potential



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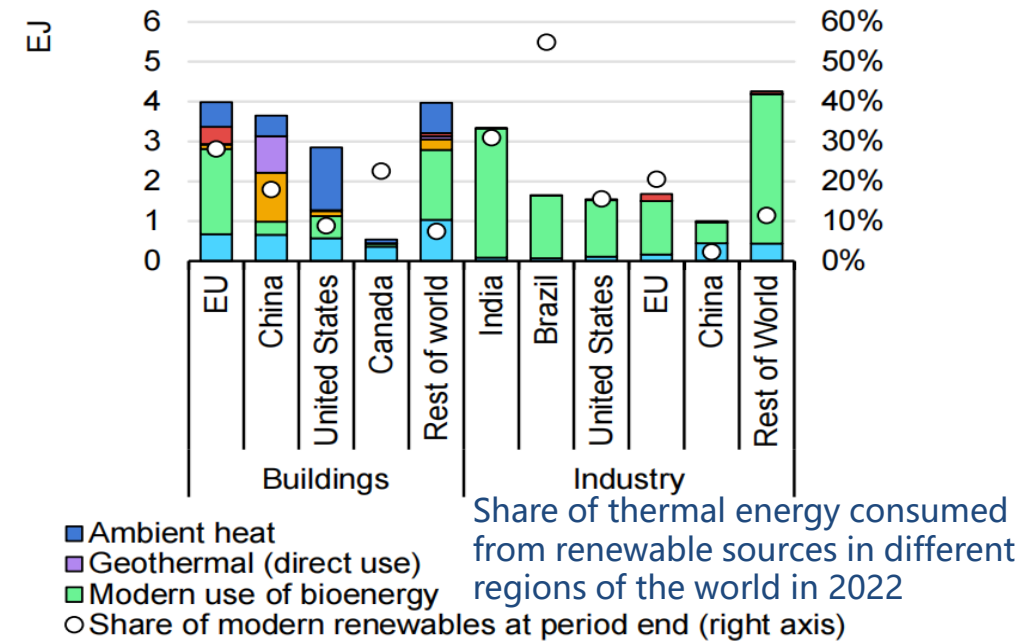


- Global geothermal resources development and utilization scale is uneven, China's geothermal energy direct utilization in renewable energy heat utilization accounted for a significant proportion.
- As of 2019, the global utilization of geothermal energy heating and cooling accounted for about 0.3% of the total energy consumption, but the potential is huge. It is expected to experience rapid growth once the technological breakthroughs are achieved.



**NEW  
TECHNOLOGY**

- EGS technology
- effective drilling
- Single well heat exchange and closed loop systems
- Multi-energy complementary

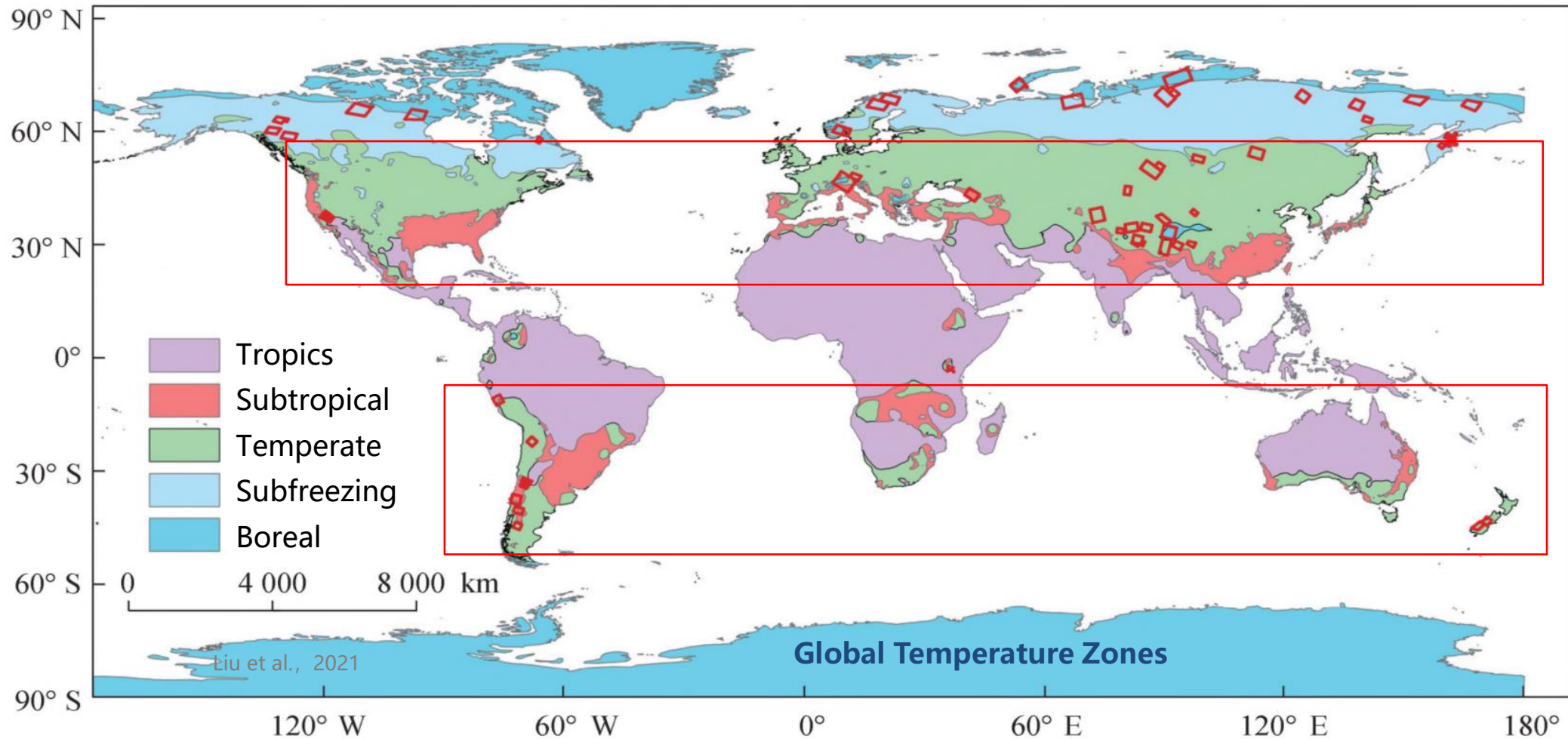


Sources: IEA (2023), World Energy Outlook 2023; IEA (2023), Global Energy and Climate Model

# 1. The main suitable regions for shallow geothermal energy are the temperate and subtropical zones



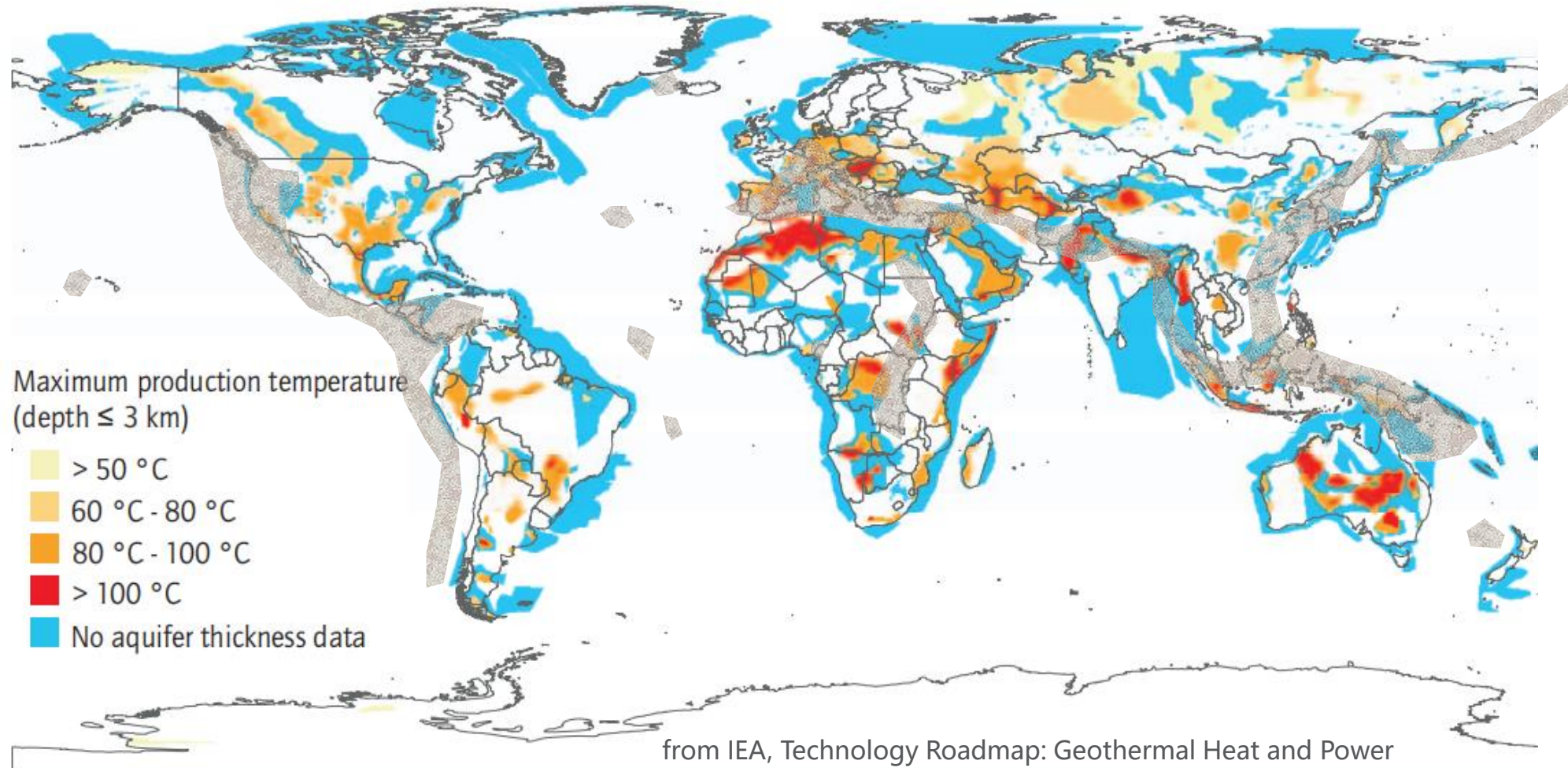
□ Referring to China's shallow geothermal energy suitability zoning experience, the global shallow geothermal energy suitability zones are concentrated in temperate and subtropical zones.



## 2. The utilization of hydrothermal resources is still mainly concentrated in four geothermal zones.



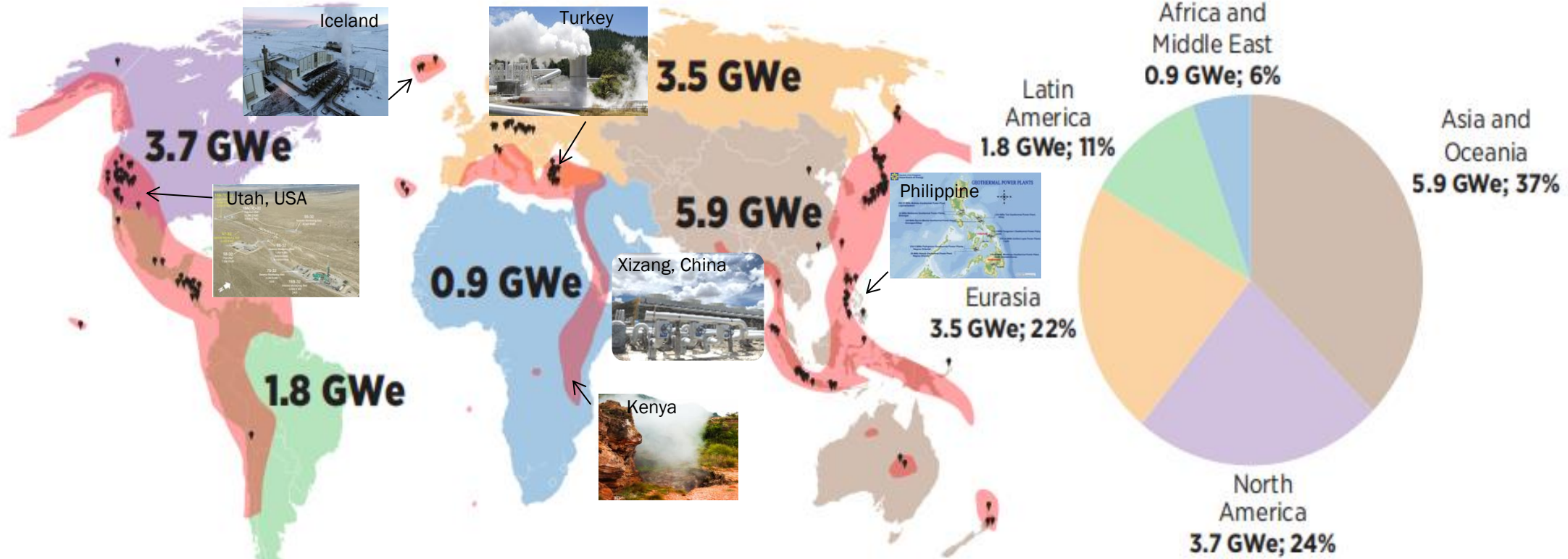
- The global geothermal utilization is concentrated in four major geothermal fields, which are expected to remain dominated by power generation, heating and cooling, and tourism and recreation.





# 2.1 The development of geothermal power generation is dominated by Eurasia and North America

Geothermal power installations are concentrated in the high-temperature geothermal zone, with Eurasia, North America and Oceania accounting for more than 80% of global geothermal power generation.



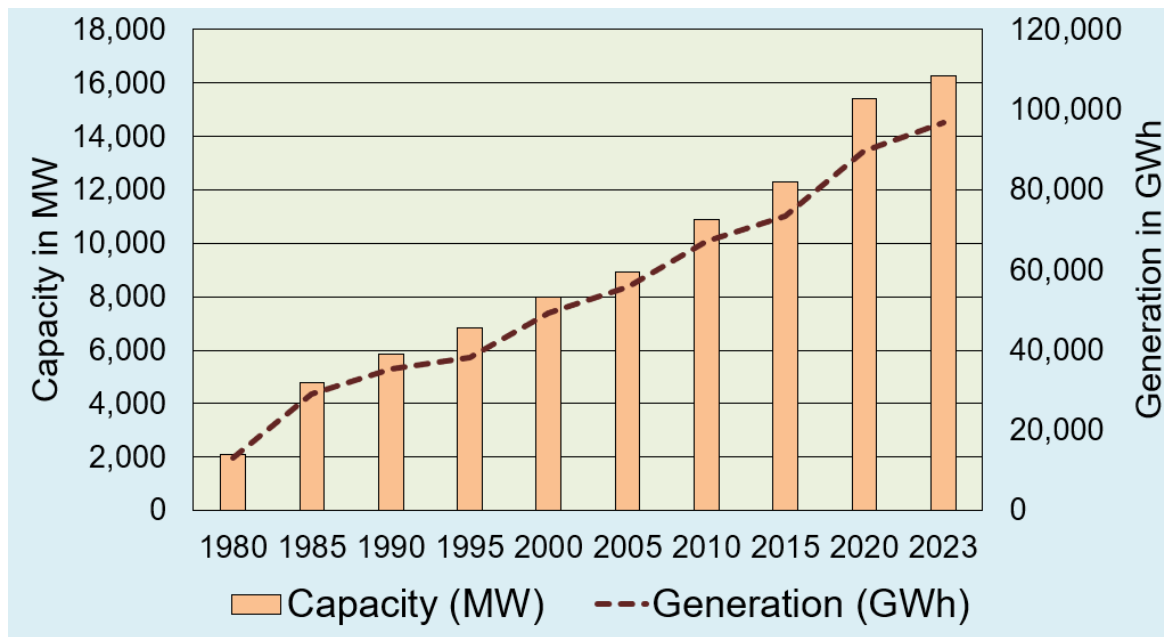
Sources: IRENA (2022); ThinkGeoEnergy, 2022; Hutterer, 2021

Global installed geothermal power generation in different regions in 2021

## 2.2 Total installed capacity is increasing rapidly and is expected growth

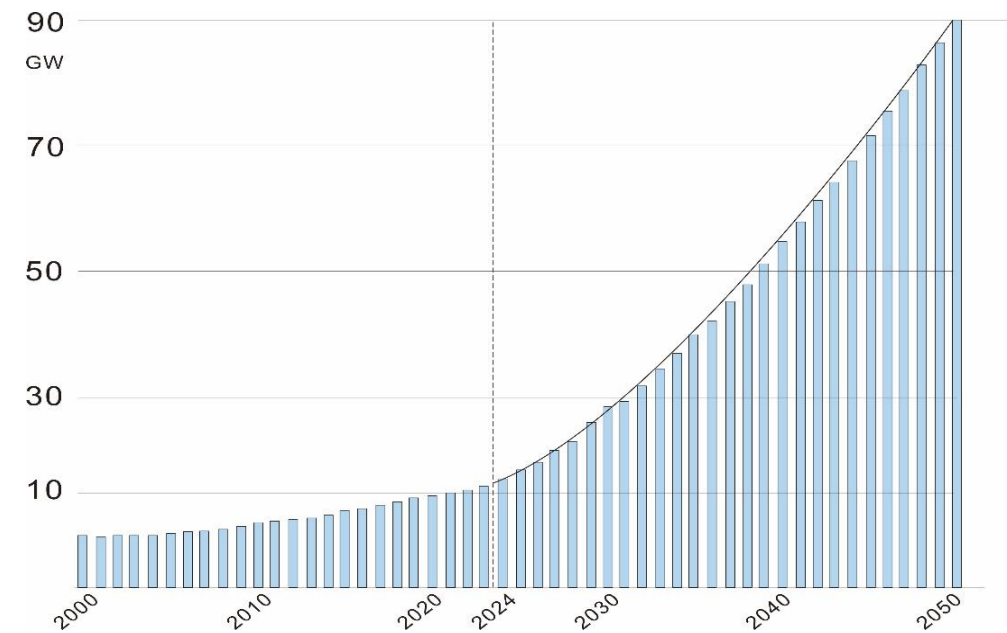


- Global geothermal capacity has grown from approximately 2000 MW in 1980 to **16.26 GW** today.
- The rapid growth of installed geothermal capacity is projected to continue until **2050**, when it is expected to exceed **90 GW**.



Current status of global geothermal capacity and electric generation

Luis C.A.G., 2023 WGC



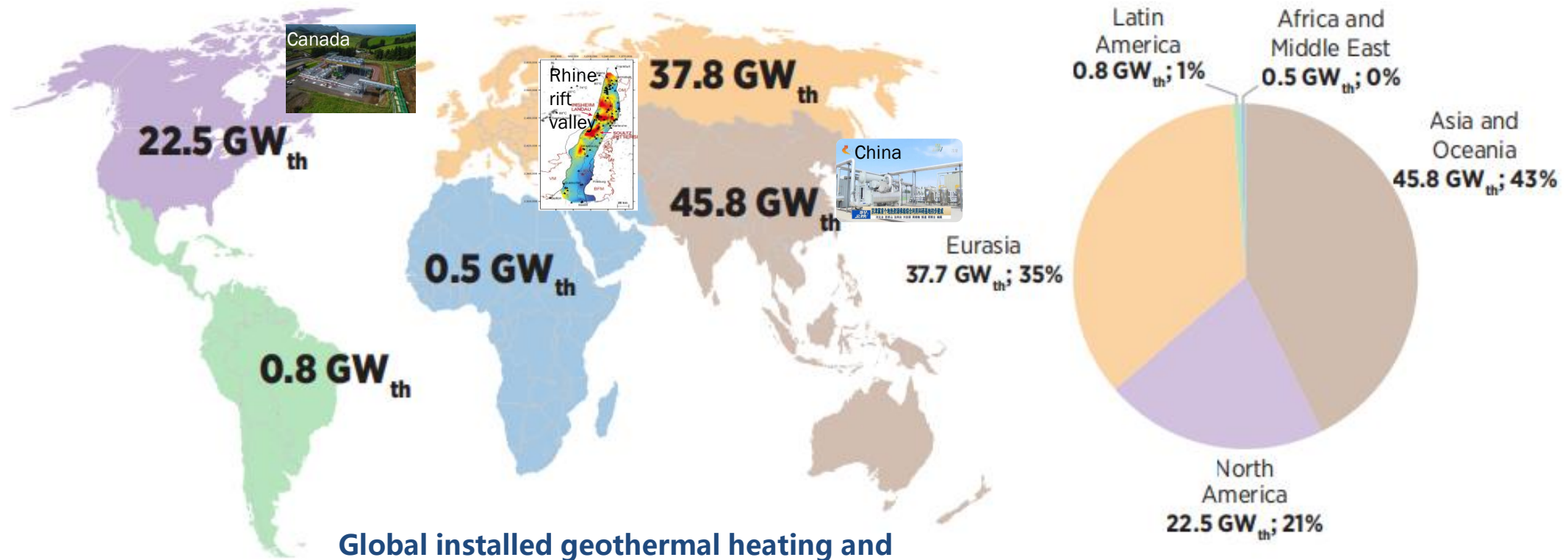
Global Geothermal Installed Capacity Growth Forecast (to 2050)

Luis C.A.G., 2023 WGC; DOE: Pathways to Commercial Liftoff

## 2.3 Geothermal heating and cooling is dominated by Eurasia



- Geothermal heating and cooling installed in the northern hemisphere is more concentrated, Eurasia and Oceania occupy nearly 80% of the global geothermal heating and cooling.



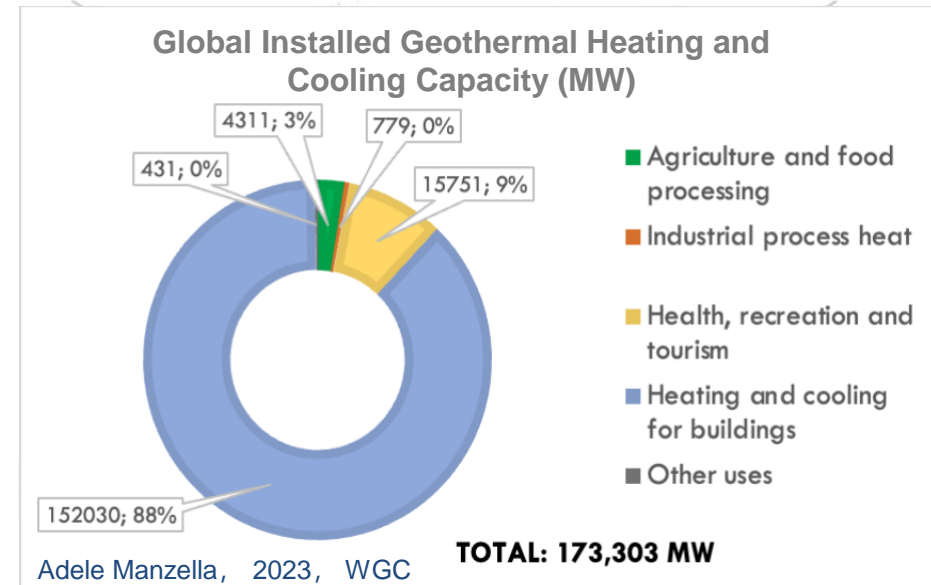
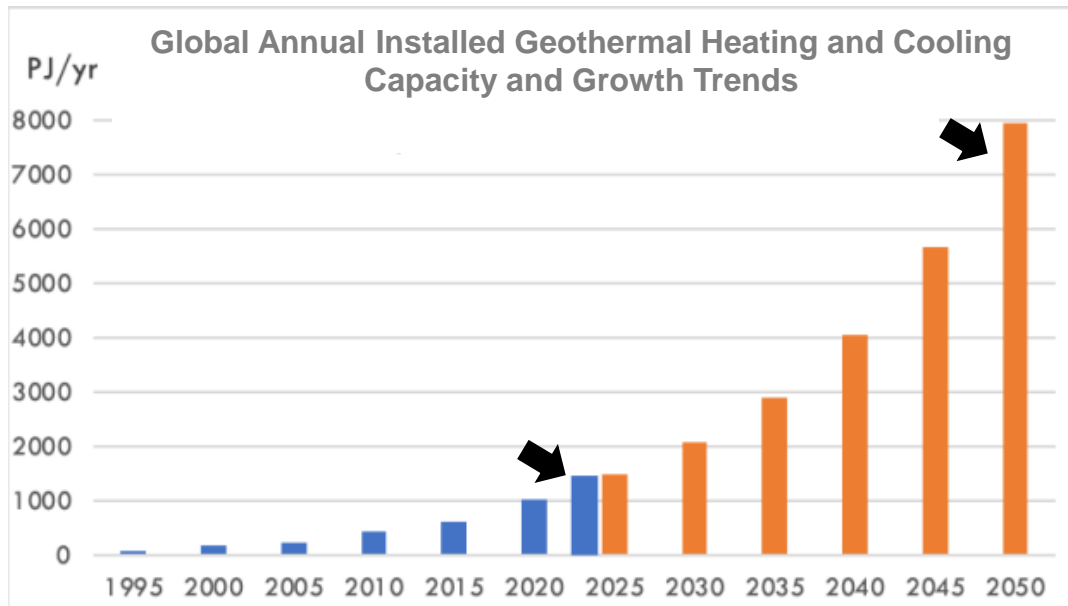
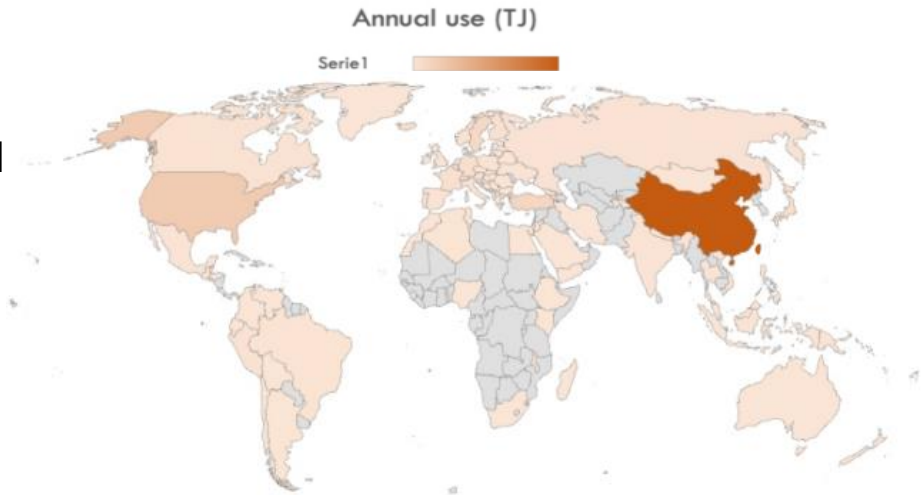
Global installed geothermal heating and cooling capacity in different regions by 2020

Sources: Lund and Toth, 2021

## 2.4 World geothermal heating and cooling installations expected to grow rapidly



- ❑ The 2023 statistics for global installed geothermal heating and cooling capacity is **173.3 GW**. China is the top country in the world in terms of total installed capacity.
- ❑ Global annual heating and cooling in 2050 is expected to be 5.3 times that of 2023.



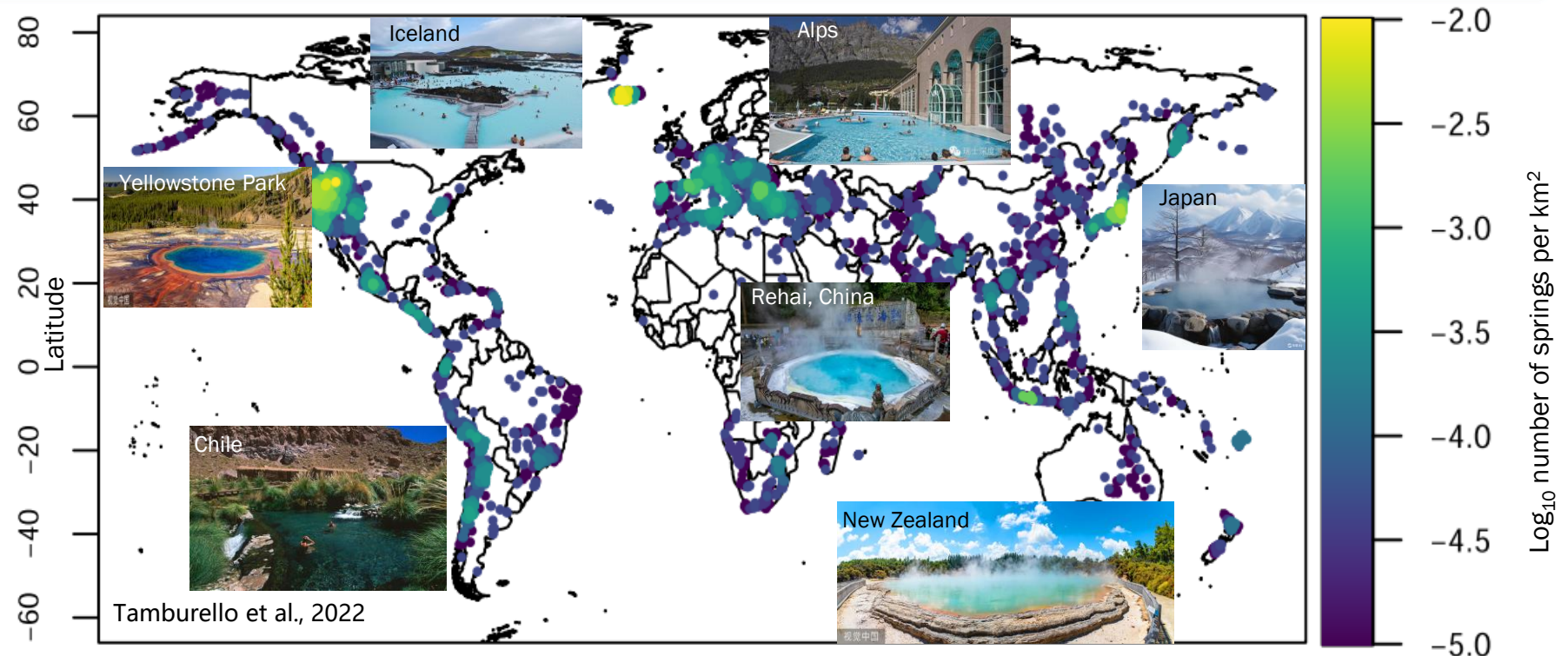


## 2.5 Geothermal tourism and health care industry is widely distributed globally, consistent with the distribution of hydrothermal resources



- ❑ Spa and health care is a globally popular hot spring tourism item, which has considerable industrial economic value to the tourism industry in the world.
- ❑ It can be used as a natural scenic spot and water recreation site, driving the upgrading of the real estate industry and exporting the brand of therapeutic bathing and hot spring food culture.

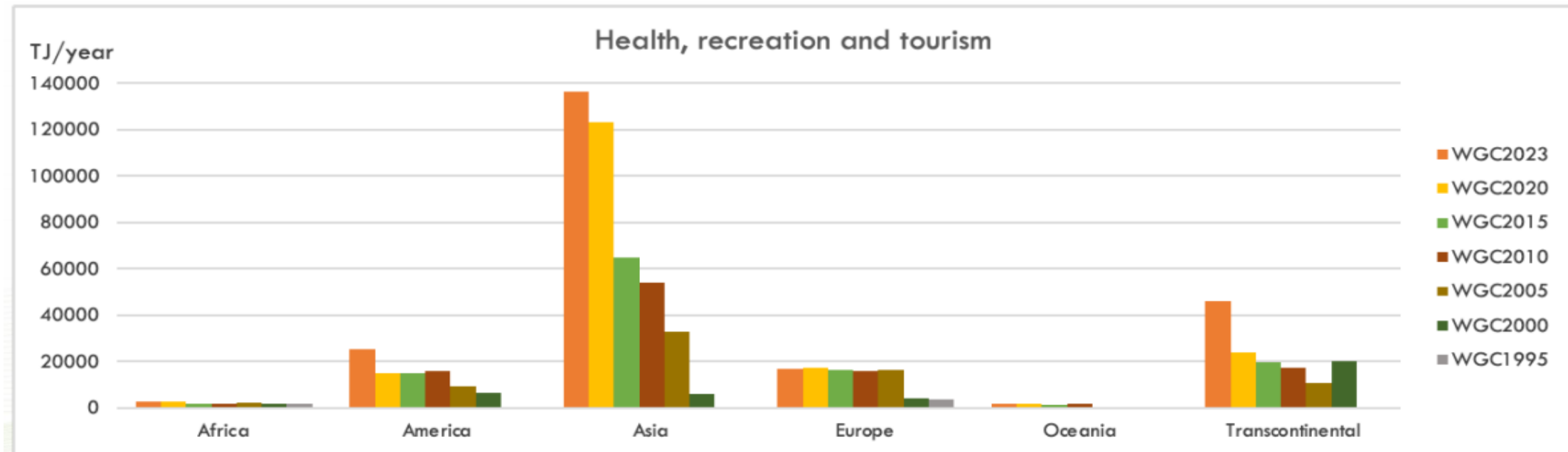
- ❑ Natural landscapes
- ❑ Favorable mineral compositions
- ❑ Water recreation
- ❑ Bathing culture
- ❑ Real estate upgrade
- ❑ Hot spring food



## 2.6 Geothermal tourism emerging markets developing rapidly, becoming new economic growth points



- ❑ There are more than 72,000 spa facilities worldwide, and the spa-related health care and tourism market was estimated at \$1353 billion in 2007 statistics (P.E Cooper and M. Cooper, 2009).
- ❑ According to the World Geothermal Congress 2023, from 1995 to 2023, the scale of geothermal tourism and recreation is growing rapidly in Asia, Latin America and other regions, and slowly in Europe and other developed regions.

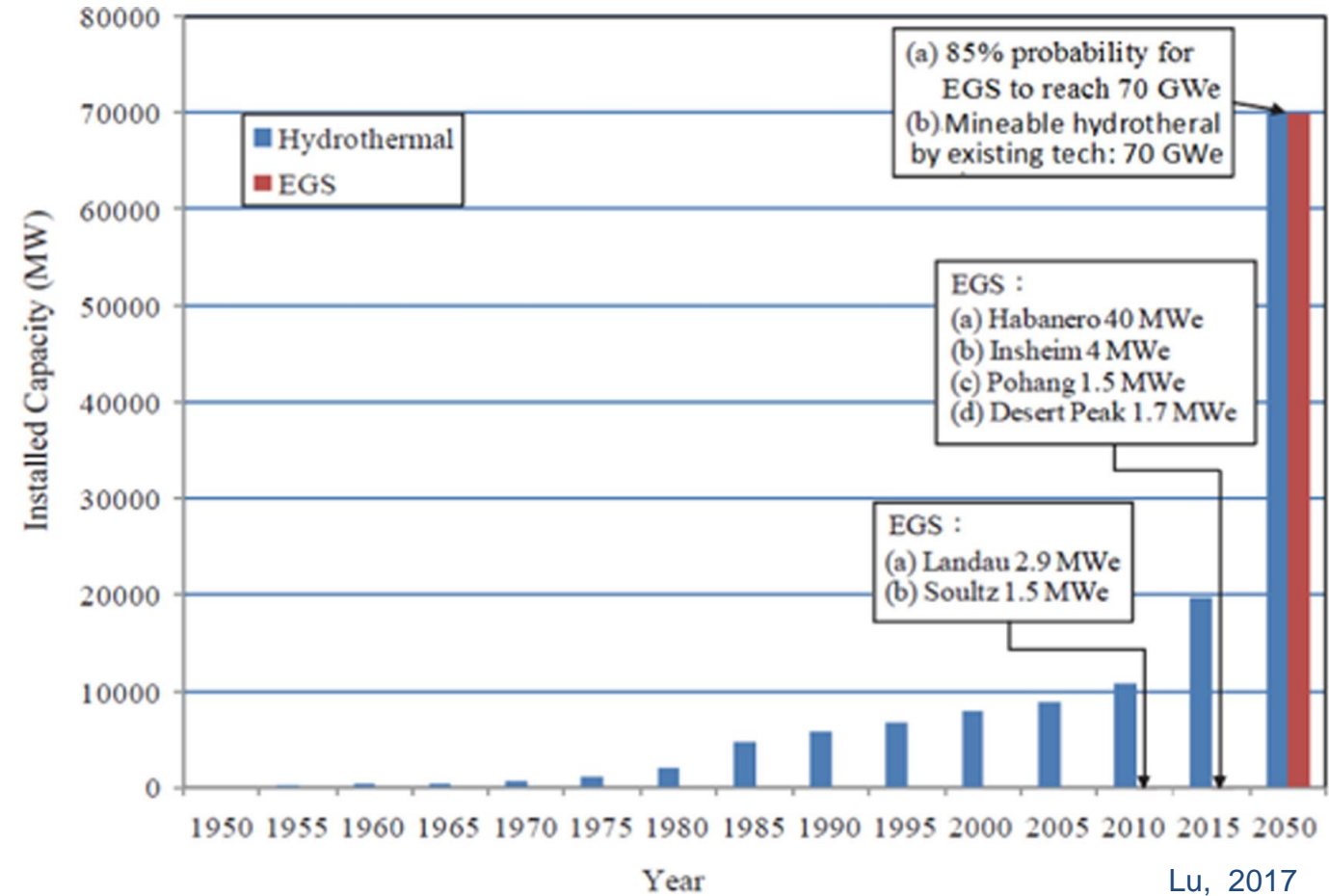


### 3. Global EGS development and utilization is expected to reach 70 GWe by 2050



## Enhanced Geothermal System Forecast

EGS technology is developing rapidly. It is estimated that the global EGS development and utilization could reach 70 GWe by 2050, on par with hydrothermal power generation.





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