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IRENA Workshop on Integrating Renewable Energy into District Heating and Cooling Systems, 9 March, 2021 (Virtual Meeting)

District Heating & Cooling by Geothermal Energy: New Technology and Application in Karst Geothermal Reservoirs for Industrial-scale Development in China

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Outline

- Introduction to geothermal heating & cooling
- Karst geothermal reservoirs in China
- Karst geothermal reservoir technology
- Xiongxian Model in North China: A case study
- Outlook on future expansions
- Conclusions

What is geothermal heating?

Geothermal heating and cooling can be achieved very easily by exchanging heat between the air and the soil/groundwater, making use of the natural phenomena that the soil temperature remains constant for most of the year at depth with 200 meters from the ground surface. Heat is extracted either from groundwater through convection or from the soil through conduction.

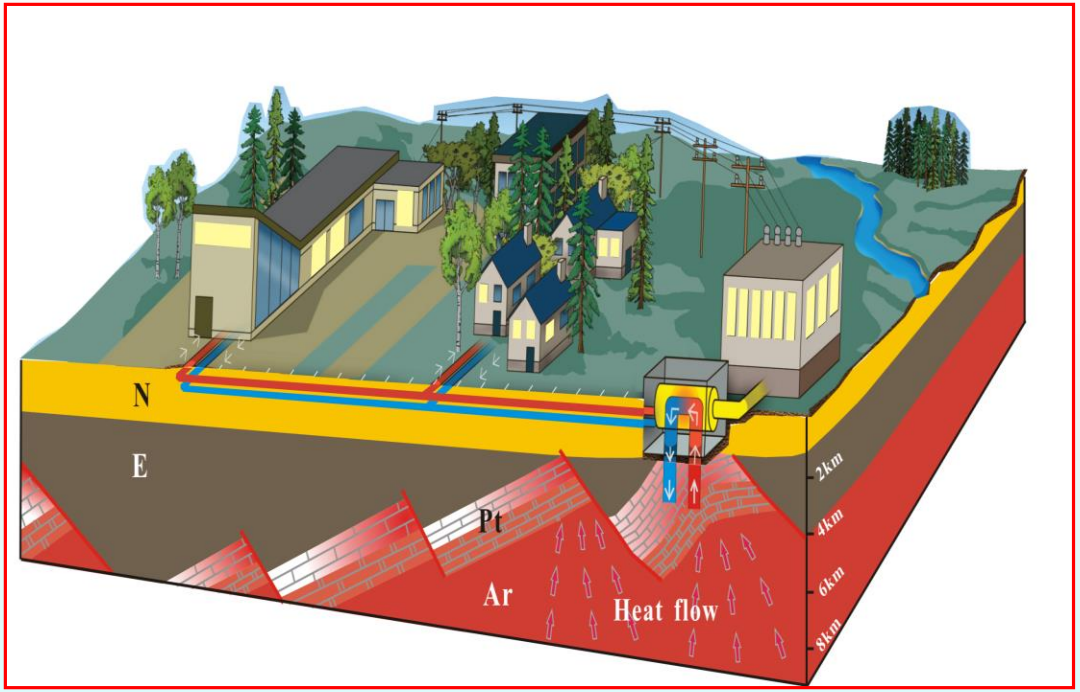
This kind of system is being used to heat/cool millions of square meters per project.

A typical model of geothermal heating using shallow geothermal resources and a heat pump system

What is geothermal heating?

Hot water at about 70 degrees C is pumped out of a production well (red) from an aquifer at a depth about 1500 meters from the ground, piped to a heat exchanger at a thermal plant, where it gives out heat and lowers its temperature to about 35 degrees C, piped to an injection well (green), and flows back to the same aquifer. This is the close loop on the geological side, while the household side is the same as a common system heated by a coal-fired boiler.

This kind of system extracts heat from 200-3000meters, which is supplying millions of square meters per project.



A typical model of geothermal heating in China (Pang et al., 2015)

What is geothermal heating?

A thermal plant is where running water and geothermal water meet and exchange heat. It is composed of piping, water pumps and heat pumps, heat exchanges, etc.
It can be placed underground, which is usually the case in China nowadays.

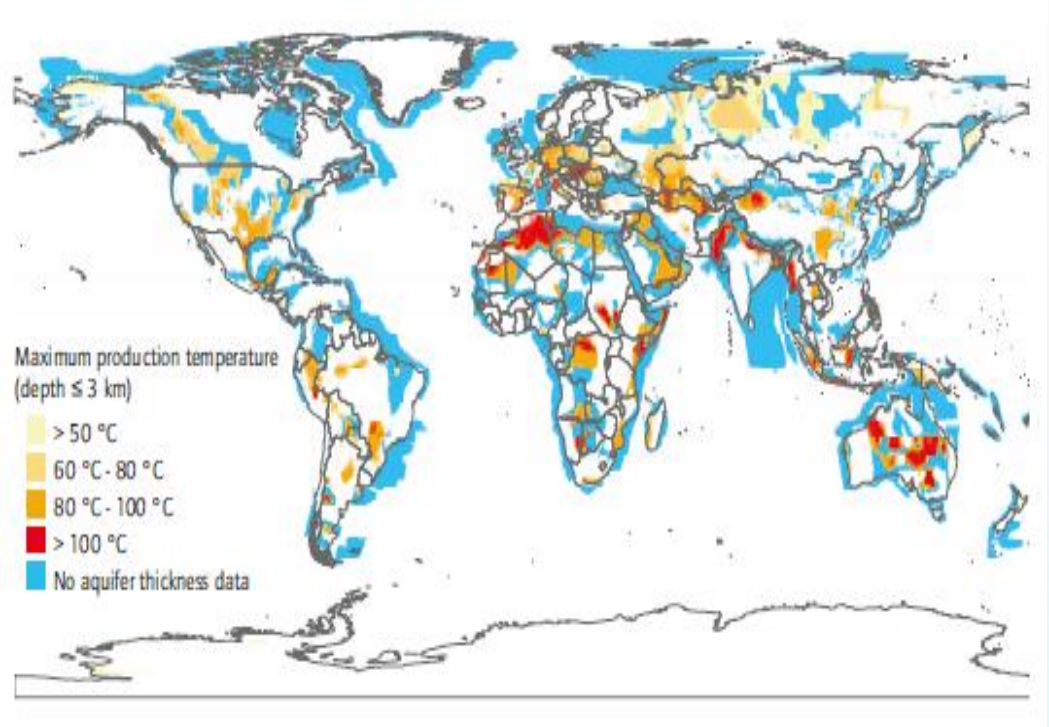
Position of continental China in relation to the major global geothermal belts: suitable for direct utilization

China is located in the east of the Eurasia plate, and for most part of the country out of the major global geothermal belts, where high temperature geothermal systems can be exploited. This is particularly true in the eastern past of the country where population and economy are concentrated.

Geothermal resources are rich in sedimentary basins globally

Similar to many places in the world, geothermal resources are rich in sedimentary basins in China.

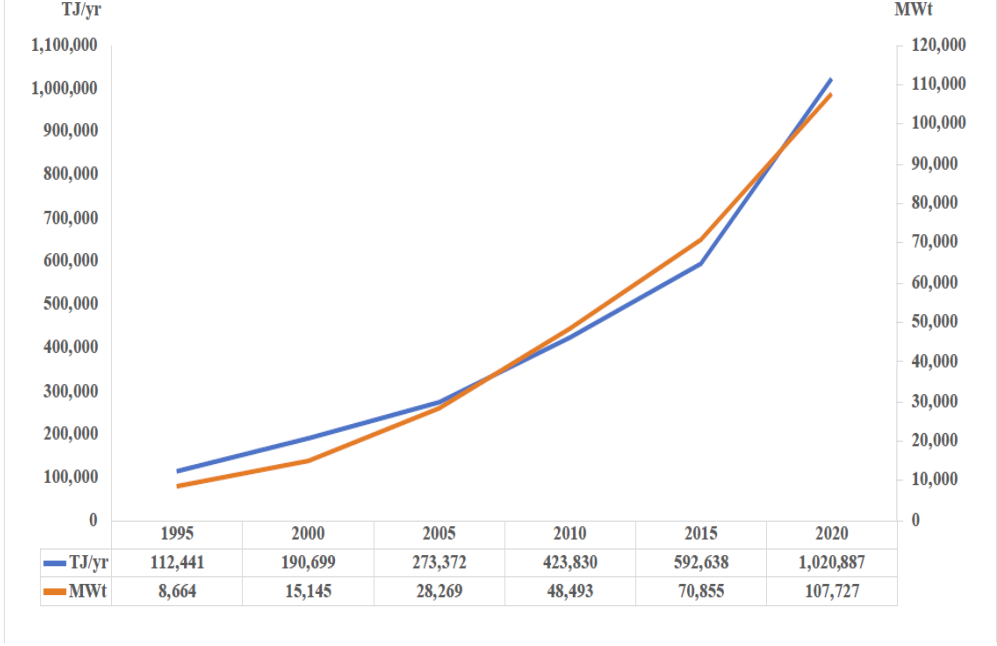
The resources, in the form of hot water usually, are very convenient to use for direct heating and cooling purposes as well, if converted through certain technologies.



(IEA, Geothermal Road map 2011)

Global Growth of Direct Utilization of Geothermal Energy 2015-2020 at a higher speed

Direct utilization of geothermal energy for heating and cooling purposes has increased rapidly in the last 5 years, partly due to the demand increase and partly as a consequence of requirement raised for mitigating climate change. Technology improvement has also played a role.



	1995	2000	2005	2010	2015	2020
TJ/yr	112,441	190,699	273,372	423,830	592,638	1,020,887
MWt	8,664	15,145	28,269	48,493	70,855	107,727

Fig.1 The installed direct-use geothermal capacity and annual utilization from 1995-2020.

(Lund et al.,2020)

China still leads the world in 2020:
Direct utilization of geothermal energy for heating & cooling both with or without the application of heat pumps

MWt		TJ/year	
China	(14,160)	China	(197,281)
Turkey	(3,480)	Turkey	(54,413)
Japan	(2,407)	Iceland	(33,590)
Iceland	(2,368)	Japan	(29,958)
Hungary	(952)	New Zealand	(9,729)

Hydrothermal without heat pumps

MWt		TJ/year	
China	(26,450)	China	(246,212)
United States	(20,230)	United States	(145,460)
Sweden	(6,680)	Sweden	(62,400)
Germany	(4,400)	Germany	(23,760)
Finland	(2,300)	Finland	(23,400)

Hydrothermal plus heat pumps

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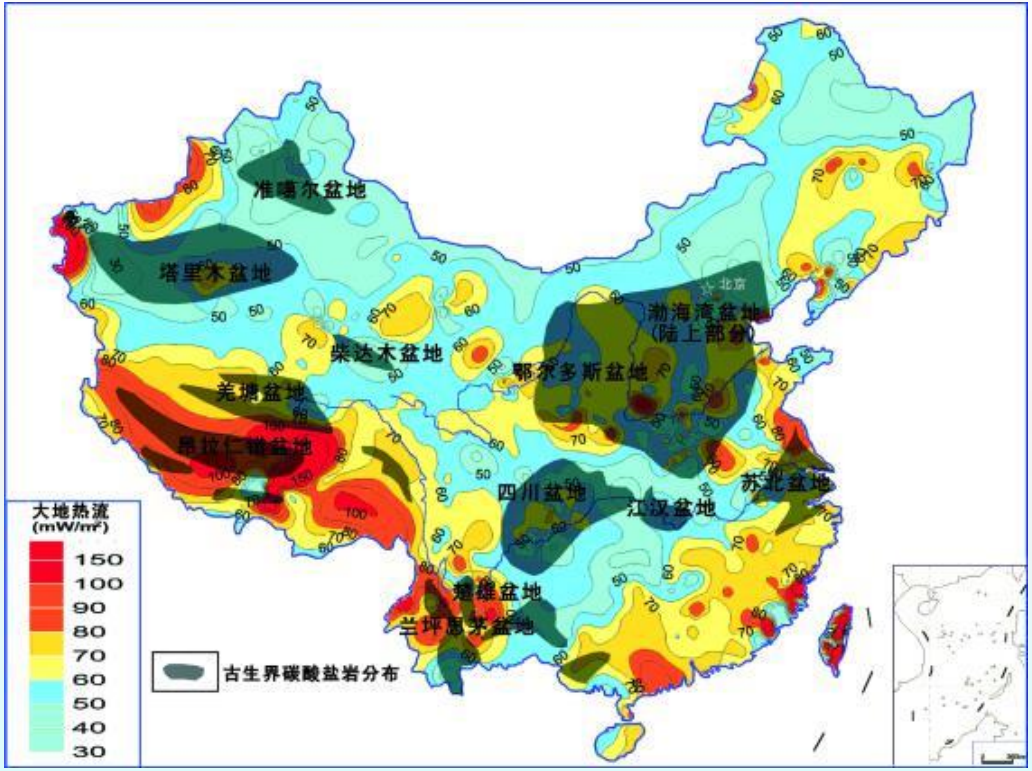
The buried Karst geothermal reservoirs in China

The total area of carbonate rocks in China is more than one-third of land area. Among them, the outcrop area is 900,000km2, buried area is more than 2,500,000km2.

The buried type is very favorable for geothermal development. We have estimated the resources to be up to 500-5000 billion tunes of coal equivalent.



(Pang et al.,2012;2020)

Advantages of Karst geothermal reservoirs: richest medium depth resources for industrial-scale development

- Large flow of water
  - the water yeild of a single well is 3616m3/d in Xuyi, Jiangsu
- Low in salinity

  The condition of recharge and circulation are beneficial, and the value of total dissolved solids are low
- Easy in reinjection
  - The reinjection rate is 180m3/h in Xiongxian, Hebei Province
- Less impact on environment
  - The lower possibility of land subsidence

However, a major difficulty: heterogeniety!

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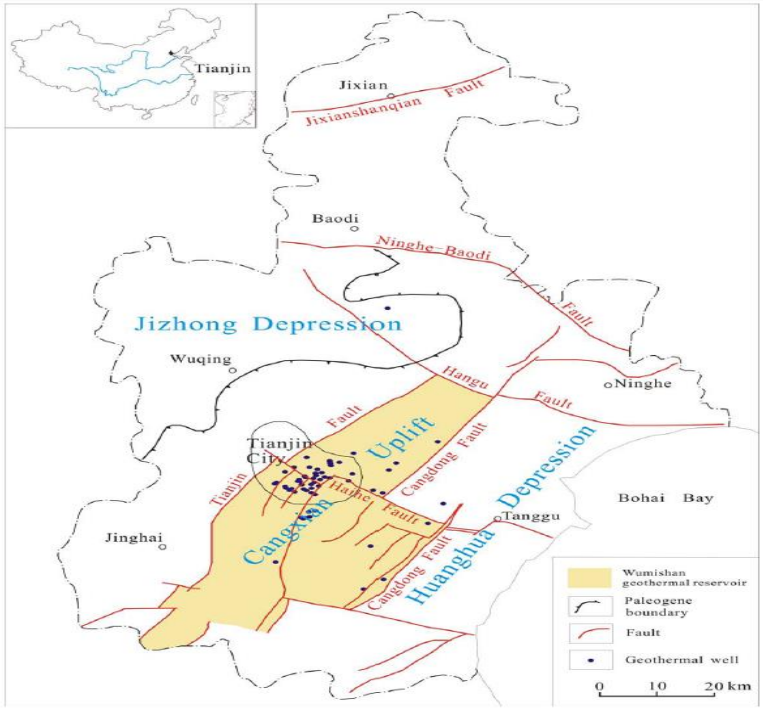
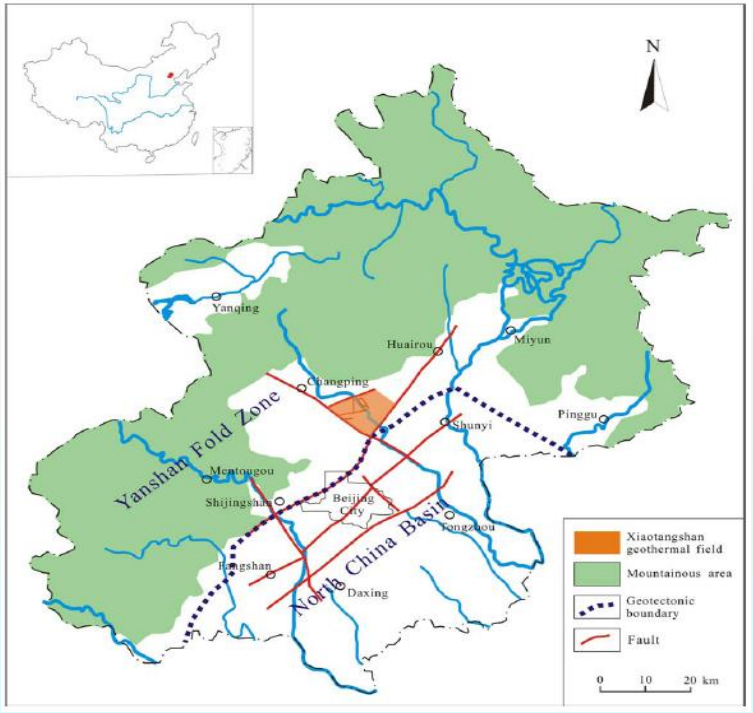
1. Guantifying Sustainability of karst geothermal reservoirs

Downtown Tianjin

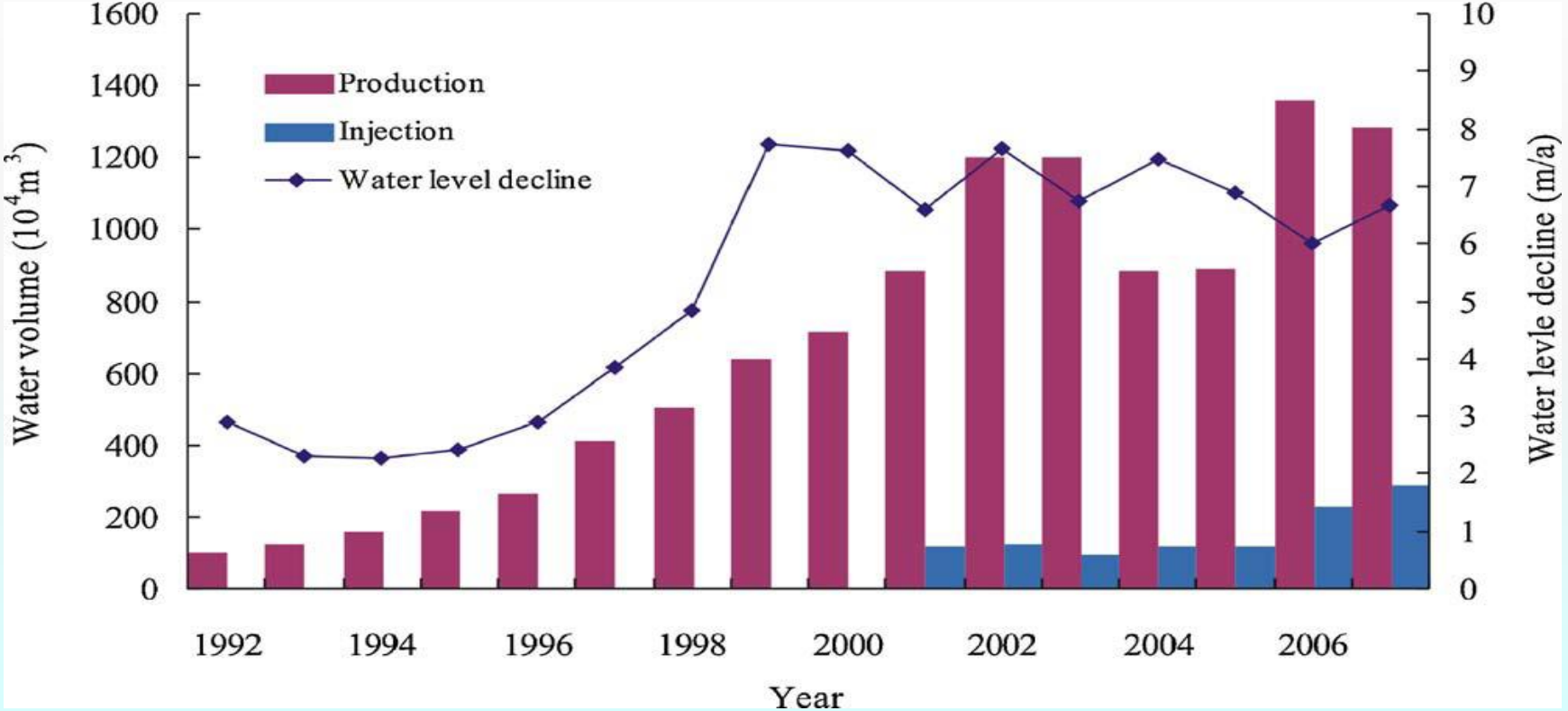


Xiaotangshan in Beijing

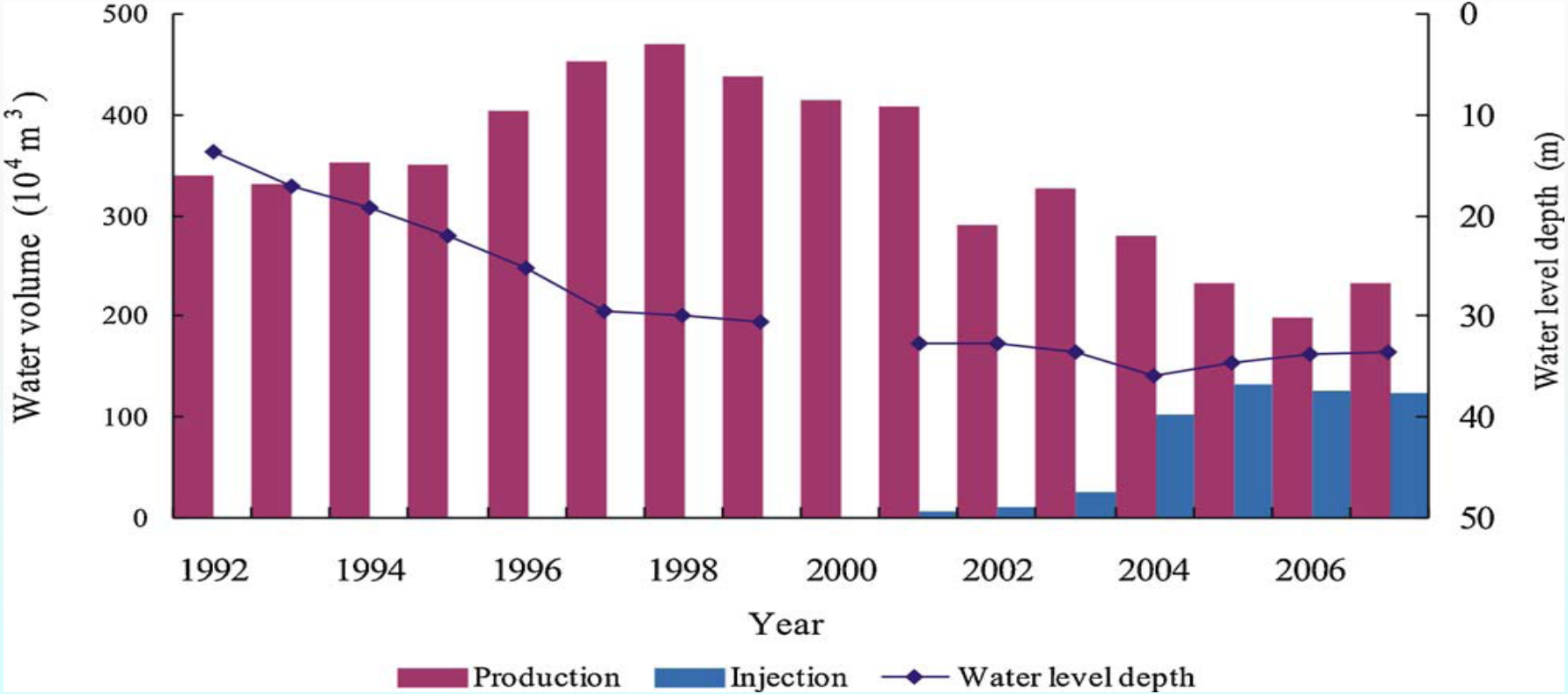


(Duan, et al, 2011,Geothermics)

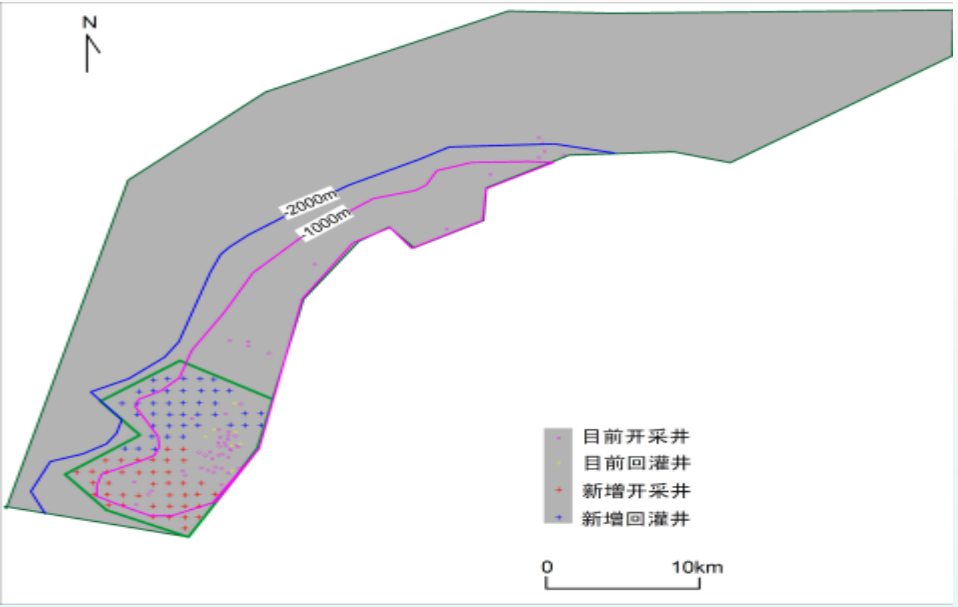
The development history of Karst geothermal reservoir (Wumishan) in Tianjin

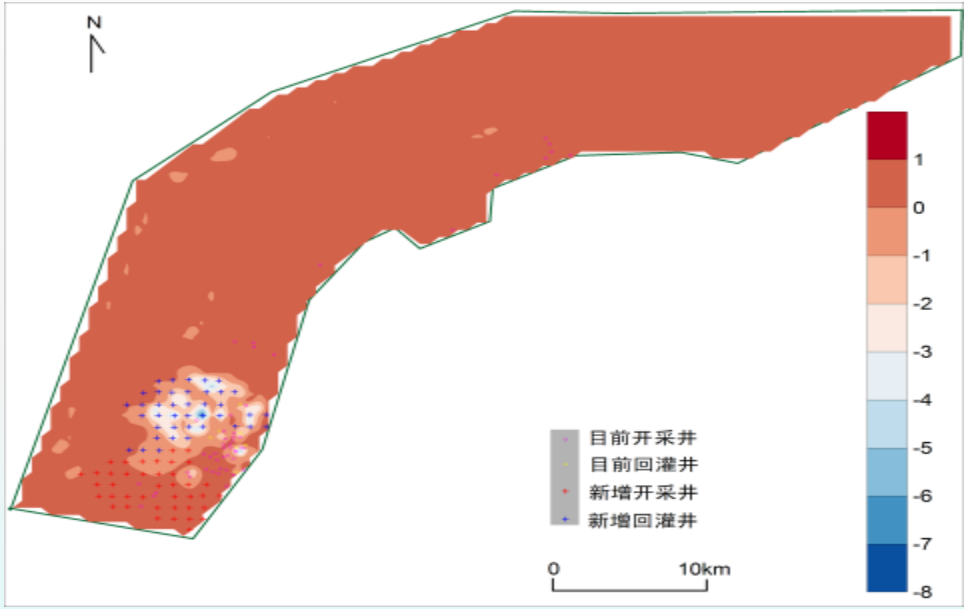


Production history of Xiaotangshan karstic geothermal reservoir in Beijing



2. Optimal production model

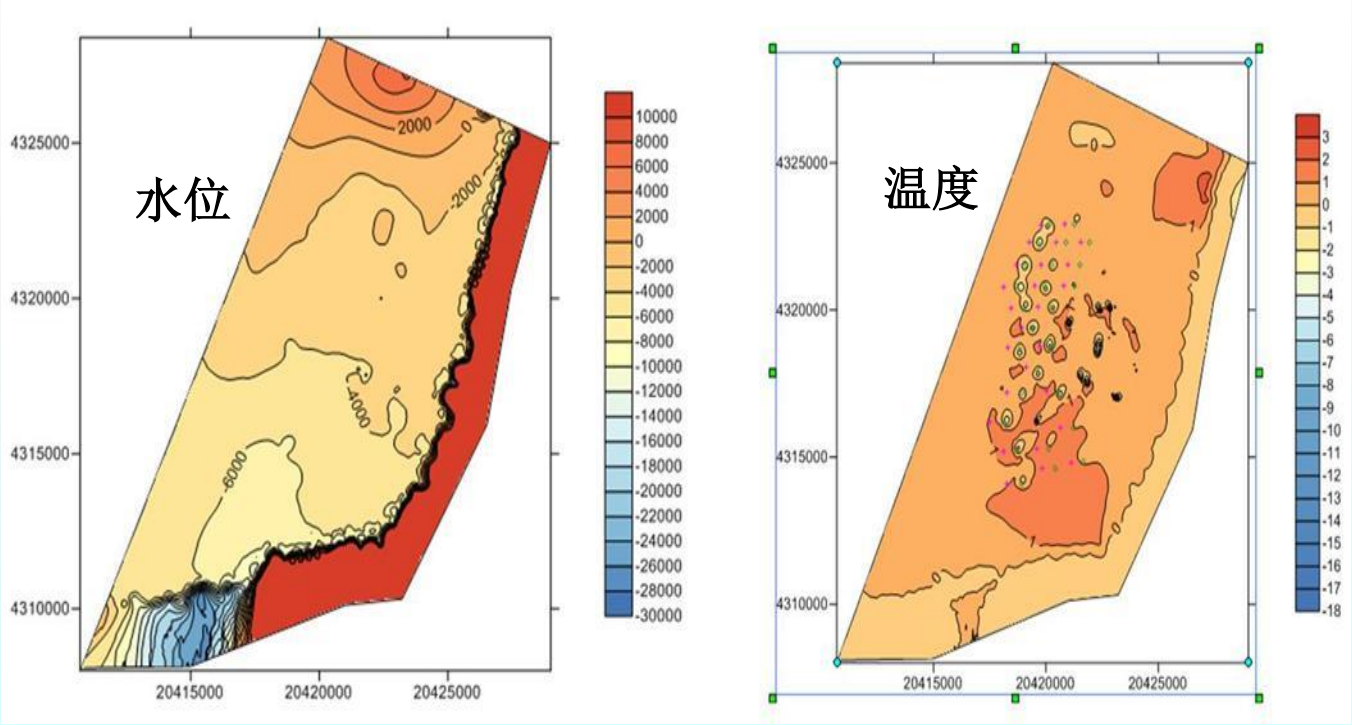




Separated production and doublet reinjection model

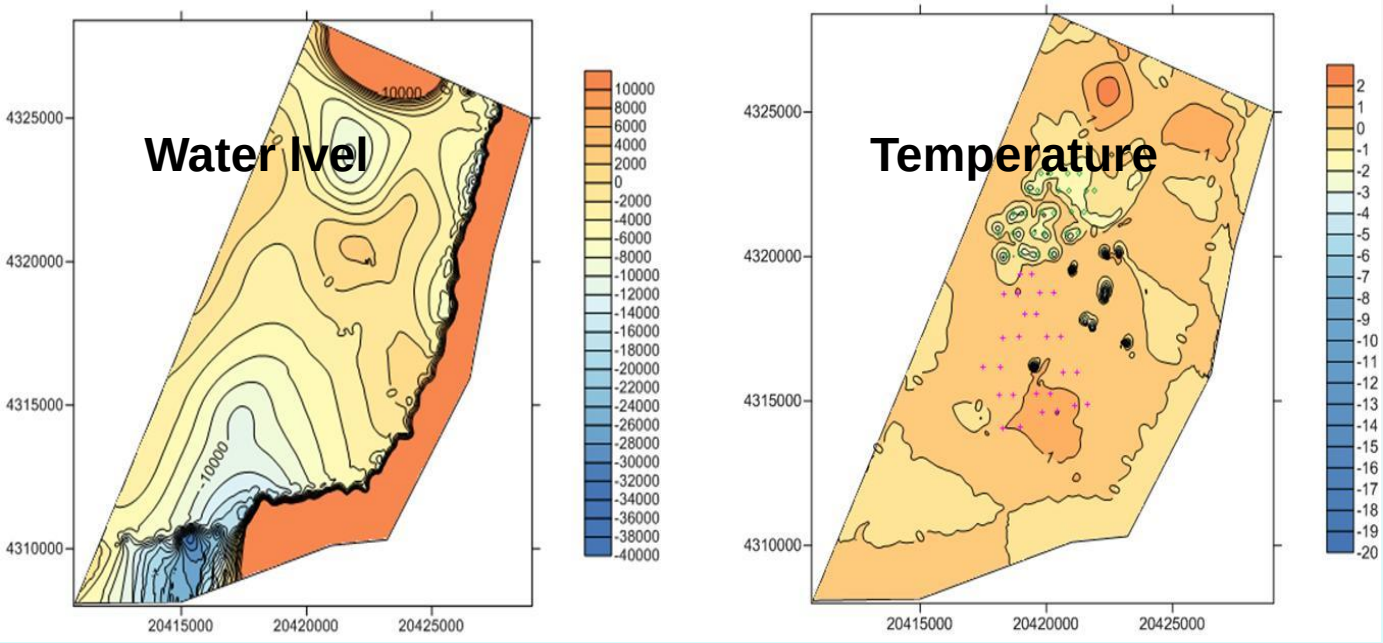
Sustainable development

Doublett：After operation for ten years, geothermal has dropped



Sustainable development

Separated Production/injection： after 10 years of opperation, temperature field has changed but less.



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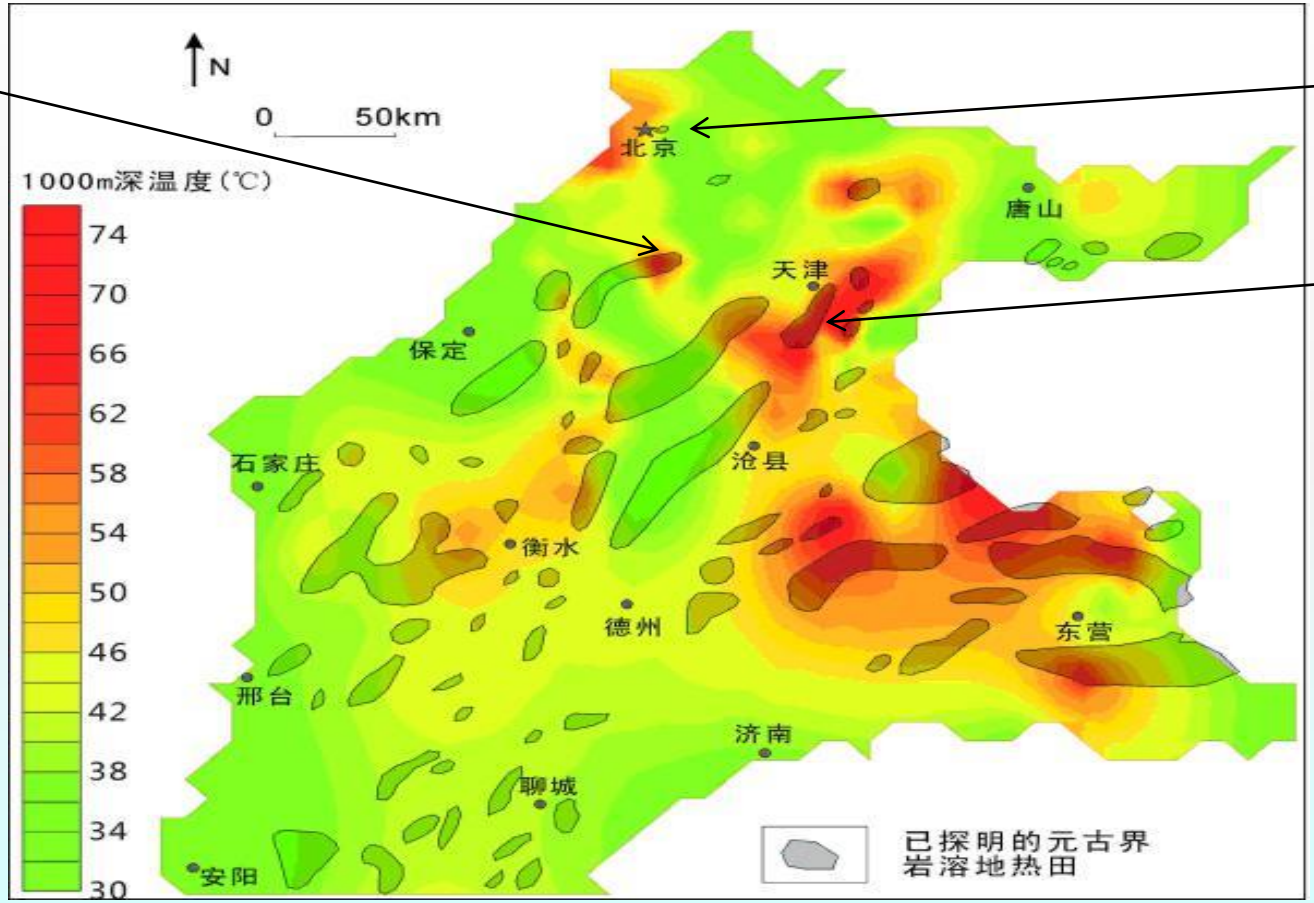
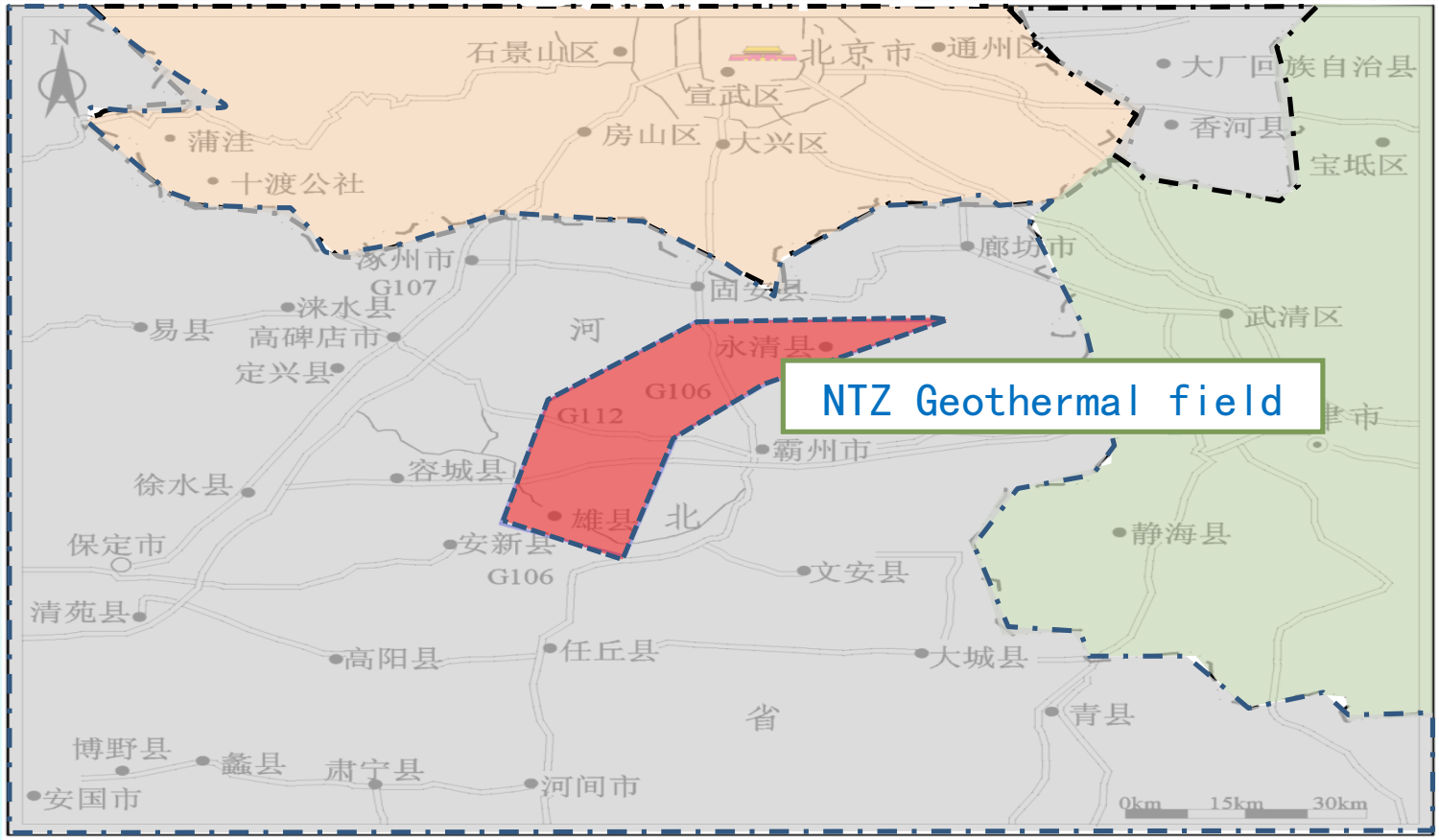
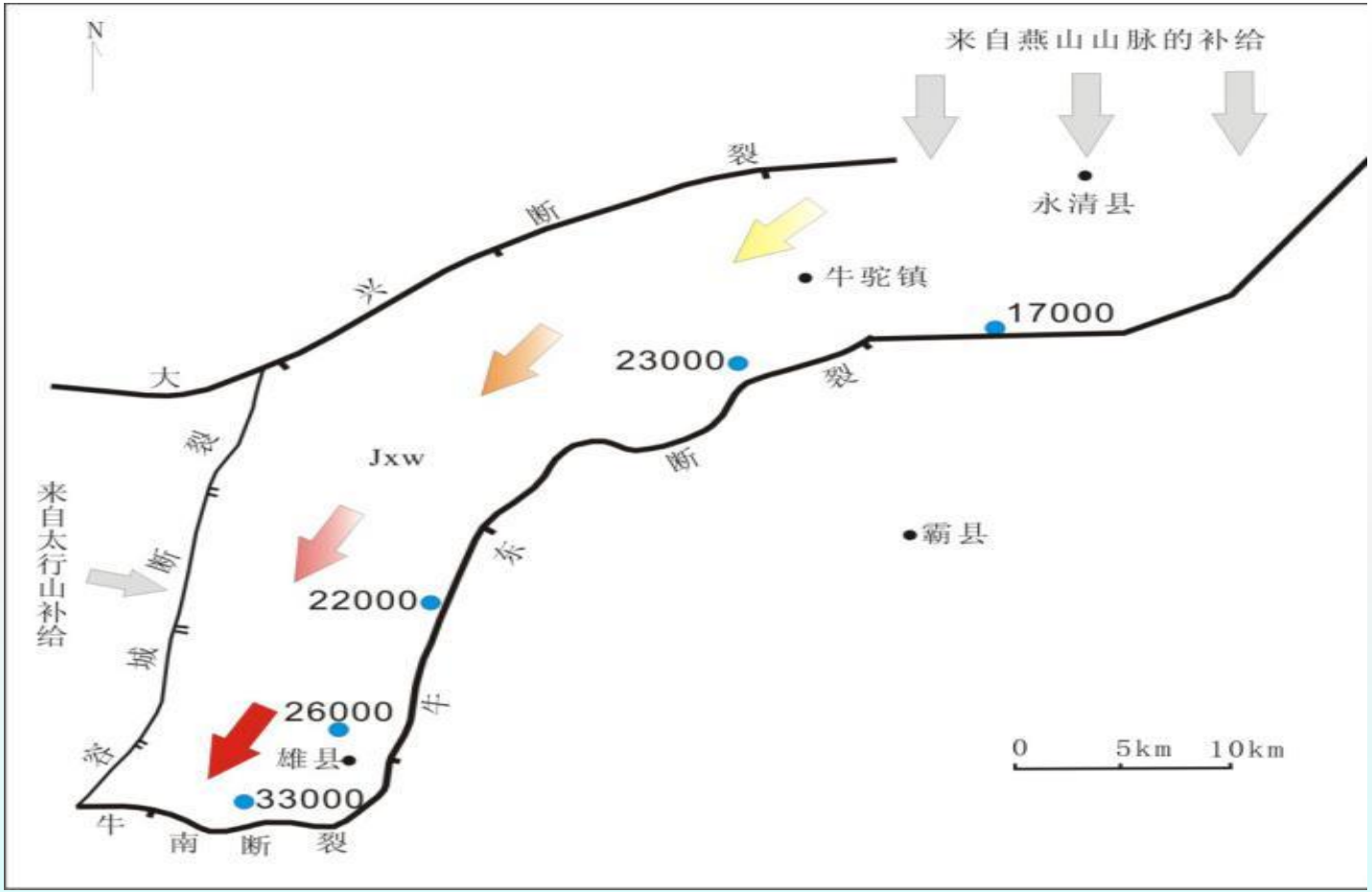
karst geothermal reservoirs in north China



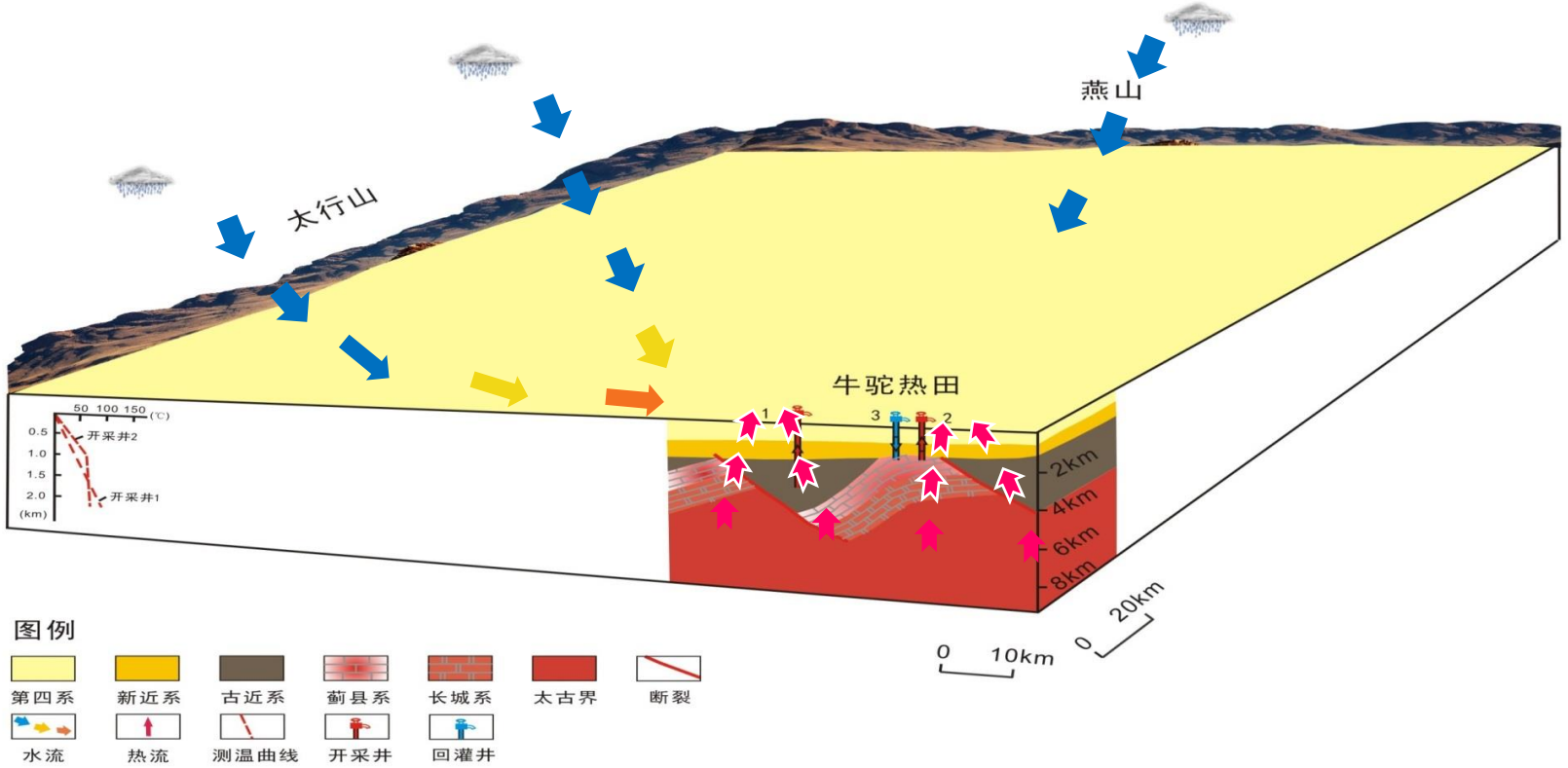
Niutuozhen geothermal field in Hebei Province



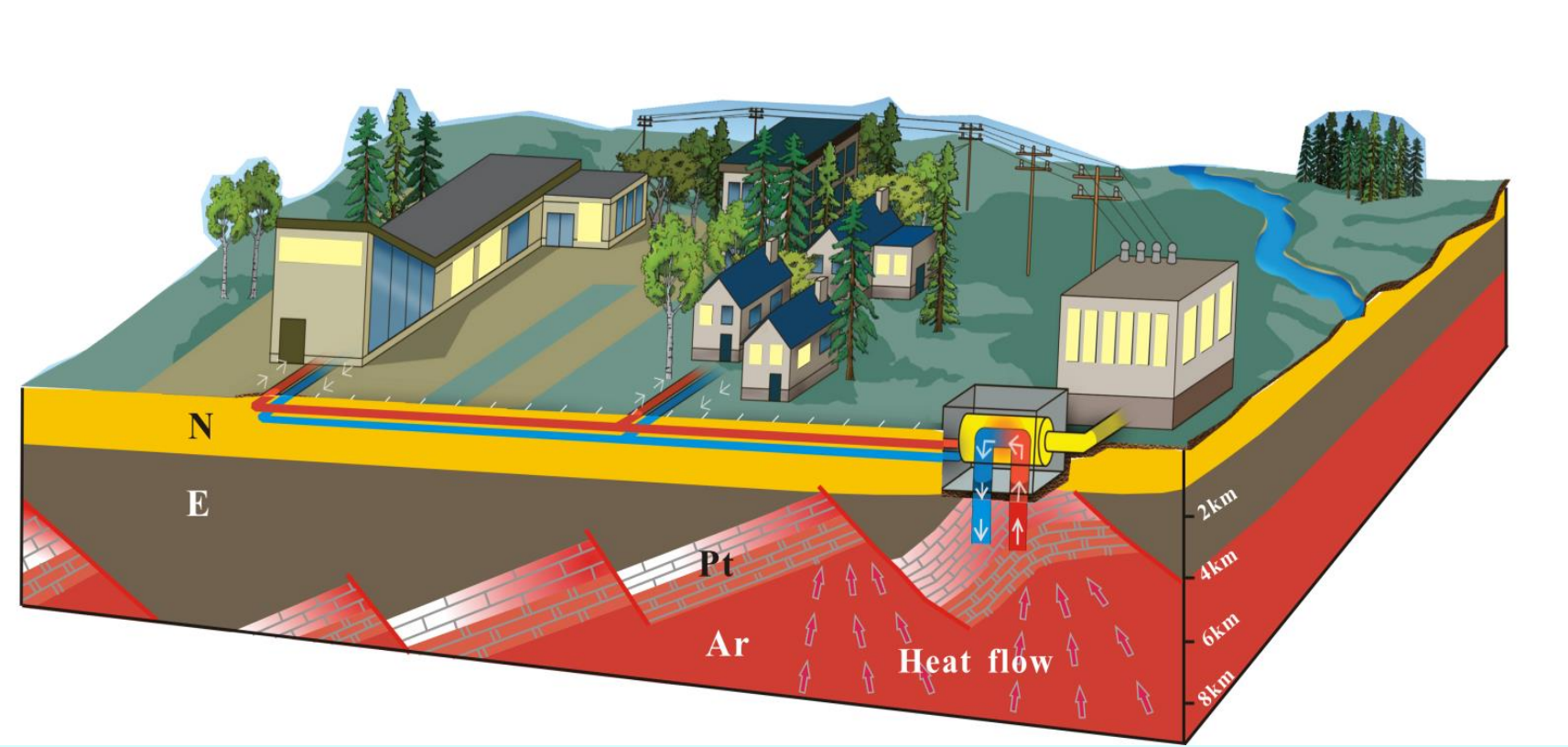


The geothermal water flowpath

A Two-Element Thermal Accumulation Model



Xiongxian Model

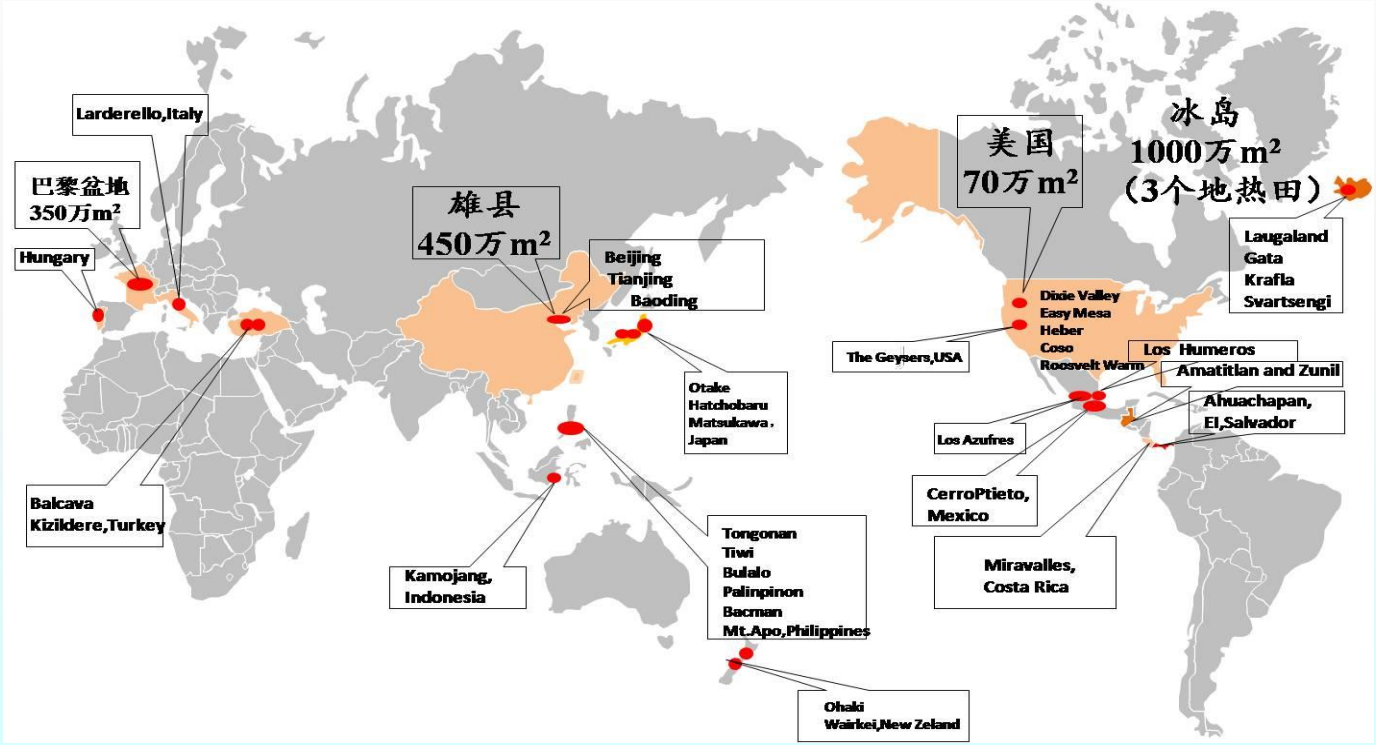


The Successful Xiongxian Model: zero emission city

雄县模式

雄县位于保定市东部平原，西南距保定市54km，北距北京市108km，东距天津市100km，全县总面积524km^2。雄县是华北乃至全国地热资源最为丰富的地区之一，地热田总面积260km^2，国际地热协会理事、中科院地球物理研究所庞忠和研究员将其命名为“华北大型岩溶热储”，是2006年中国矿业联合会授予河北省的第一个“中国温泉之乡”。其地热资源开发利用模式具有很好的典型性和示范作用。

Xiongxian is the largest if total area heated and number of suppliers are judged at field scale



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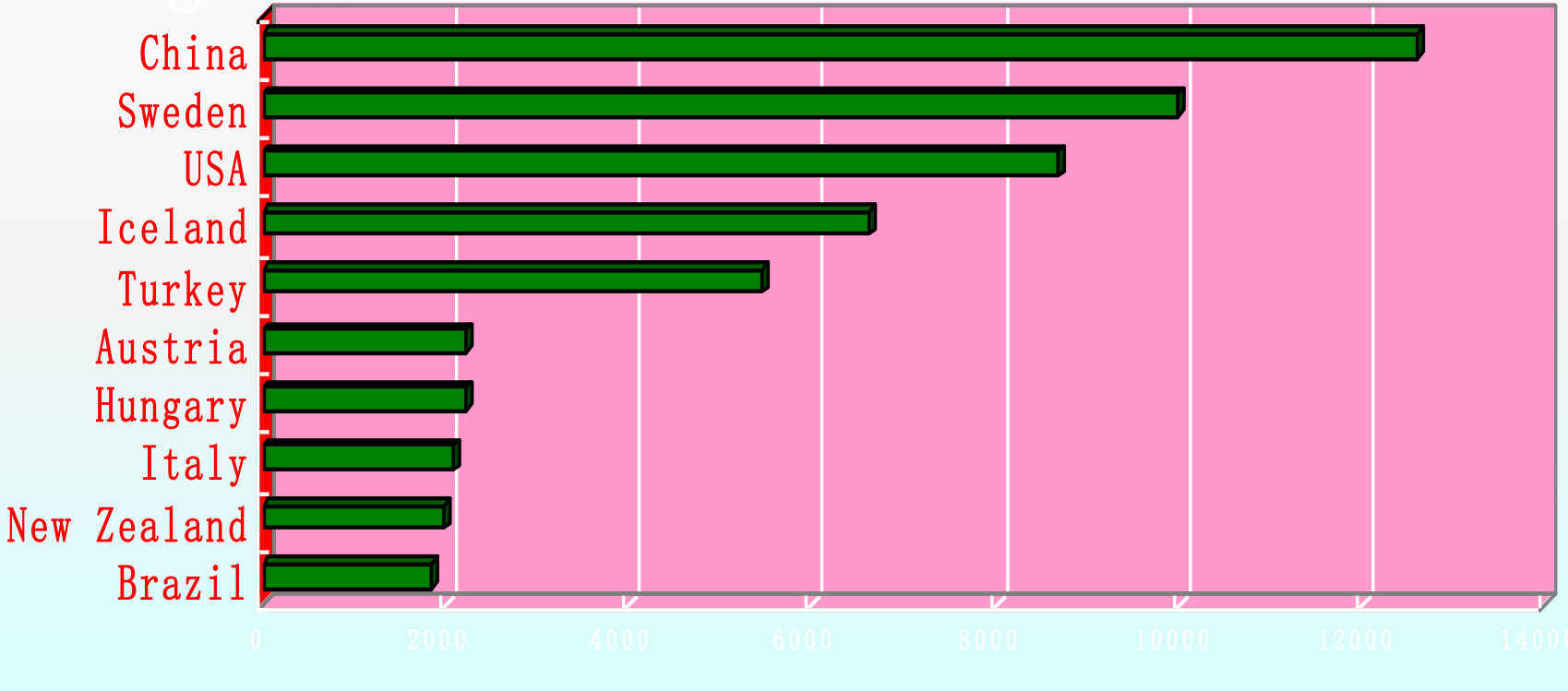
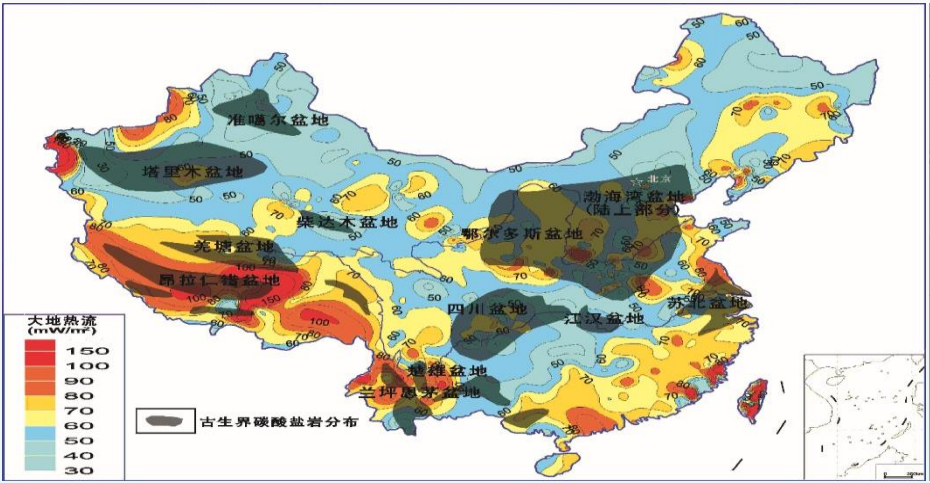
China: the largest user of earth's heat

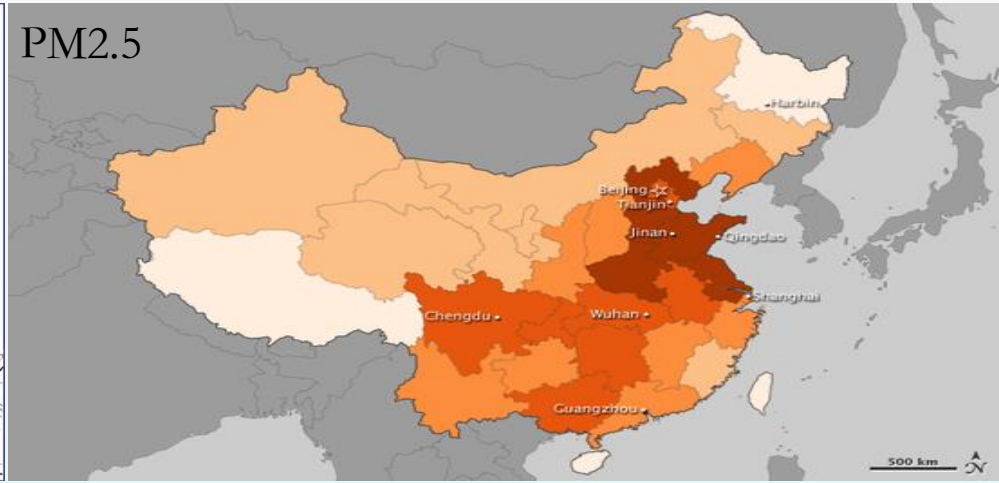
largest geothermal direct user



Geothermal spacing heating to mitigate air pollution and climate change



Pang et al. 2012



来源 NASA

More Zero Emission Cities

Reykjavik Iceland

Xiong County, Hebei (Xiongan)

Xianyang, Shaanxi

Shenghe, Shandong

Wugong, Shaanxi

Rongcheng, Hebei
(Xiongan)

Shijiazhuang, Hebei

Bazhou, Hebei

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Conclusions

- Karst geothermal reservoirs are widely distributed in sedimentary basins in China which are good reservoirs due to their favourable properties.
- The level of sustainability depends on reinjection. Large scale utilization may benefit from the new technologies.
- Successful model projects with new technologies laid better foundation for future work. More expansion can be expected.

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to
The World Geothermal Congress 2023 !