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# Geothermal and Clean Energy District Heating System in Xiong'an New Area

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## ABSTRACT

Xiong'an New Area is a state-level new area located about 100 km southwest of Beijing, it is a "millennium strategy" to phase out non-capital functions from Beijing, explore a new model of optimized development in densely-populated areas, and restructure the urban layout in the BTH region. The New Area will cover around 100 square km initially and will be expanded to 200 square km in midterm and about 2,000 square km in the long-term. Geothermal is rich in the whole area of Xiong'an and as clean, renewable and most stable energy will play essential role in energy utilization during development. The comprehensive utilization of "geothermal and alternative clean energy" system is analyzed in order to carry out an optimized approach for Clean District Heating system of Xiong'an which is also a requirement in anti-air pollution strategy. It will present different approaches for both district heating and cooling in the New Area, compare alternative clean energy utilization such as GSHP, geothermal, natural gas and solar and sewage water, etc. Besides technical approach analysis, the comparison of economic viability will also be presented in this study, in order to build a showcase for multiple clean energy utilization for Zero Emission City in future.

## 1. INTRODUCTION

China announced on April 1 of 2017 that it would establish the Xiong'an New Area in Hebei province, as part of the measures to advance the coordinated development of the Beijing-Tianjin-Hebei (BTH) region. This is another new area with national significance after the Shenzhen Special Economic Zone and the Shanghai Pudong New Area, according to a circular issued by the Communist Party of China (CPC) Central Committee and the State Council.

The New Area, about 100 km southwest of downtown Beijing, will span three counties that sit at the center of the triangular area formed by Beijing, Tianjin and Hebei's provincial capital, Shijiazhuang. The move will help phase out non-capital functions from Beijing, explore a new model of optimized development in densely-populated areas, and restructure the urban layout in the BTH region, according to the circular. The New Area will cover around 100 square km initially and will be expanded to 200 square km in mid-term and about 2,000 square km in the long-term.

Xiong'an New Area is aiming to run on 100% new energy where geothermal, together with natural gas, biomass, and solar energy, will be encouraged. The region will see its energy mix optimized, and act as a guide and demonstration hub for clean heating in the north and for existing cities to refine their infrastructure. Meanwhile, the administration has attached significant importance to clean heating in the country's northern regions and will continuously urge local authorities to step up clean heating implementation plans with policy and market guidance (Hebei provincial government, 2018).

## 2. PRINCIPLE OF OVERALL ENERGY PLANNING IN XIONG'AN NEW AREA

The overall planning for energy utilization in New Area is pure clean and renewable energy dominated. Therefore, geothermal, clean electricity and natural gas will be the pillar energy source. The authorized energy planning has not launched yet right now, but according the guidance of overall planning for the New Area, 100% pure clean energy will be harnessed both for electricity, heating and cooling.

There are abundant renewable energy resources in this region, especially geothermal. The experience shows that through decades' development, majority of three counties of the new area are covered by geothermal especially in Xiong County, over 95% of buildings are heated by geothermal and has set up a well-known, zero emission city which replaced coal boiler with geothermal. This success story has been copied in other places as demonstration project all over the country. Therefore, geothermal will be base load energy source in terms of heating and cooling which will be account for around 50% and the rest would be from clean electricity and natural gas.

Clean electricity will be constructed for Xiong'an with main source of wind power plant of northern Hebei province. Natural gas will be supplied by Petro China from the nearby oil and gas field. All will be 100% secured for sustainable development of clean energy supply.

## 3. GEOTHERMAL ENERGY DEVELOPMENT IN XIONG'AN

### 3.1 Geothermal energy in Xiong County

Geothermal resource is rich in Xiong'an New Area which consists of three geothermal fields: Niutuozhen geothermal field, Rongcheng geothermal field, Gaoyang geothermal field. Xiong County covers half of Niutuozhen geothermal field located in the southwestern area, and Anxin County is a part of Gaoyang geothermal field. They are the several dominated faults such as Niudong fault, the Niunan fault, the Rongcheng fault and the Daxing fault, which were created by folding movement from the Late Jurassic to the Cretaceous, during the Himalayan movement. The main geothermal reservoirs are porous Tertiary sandstone and karst-fissured

dolomite bedrock. The evolution of the North China Basin started by vertical crustal movement before the Late Triassic period, followed by mountain building from the Jurassic to Early Tertiary and subsidence during Late Miocene.

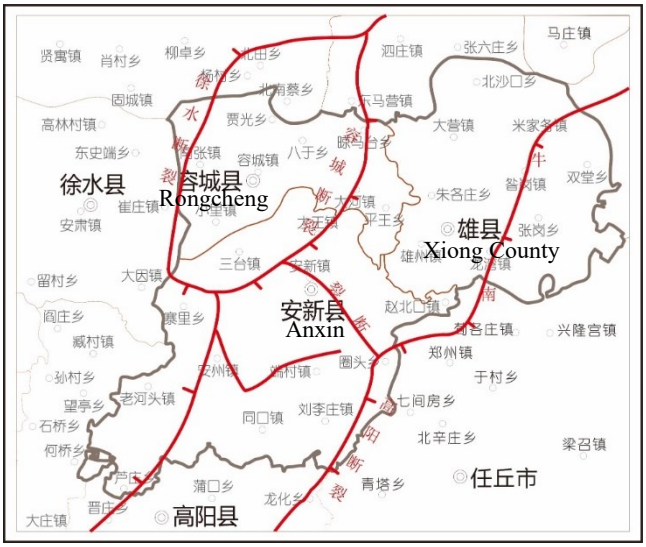


**Figure 1: Geological map of Xiong'an New Area**

The strata of the Xiong'an geothermal system and surroundings include Quaternary and Tertiary formations in Cainozoic, Jixian System and Changcheng System in Proterozoic and Archaeozoic. The following is a description of the strata from new to old.

1) Cainozoic: Quaternary strata spread over the whole territory of Xiong'an. The lithology is clayey silt, mild clay and clay and greyish-white sand. The strata are found in the depth range of 380-470 m. Quaternary strata parallel and unconformable overlies Tertiary strata. The Minghuazhen Formation from Tertiary includes mudstone, sandstone and pebbled sandstone in its upper part, and it includes mudstone and grey sandstone in the lower part. Thickness of the strata at the axis of the Niutuozhen Uplift is about 500-600 m and that of the two wings is up to 1000 m. The upper strata of Minghuazhen Formation spread over Xiong'an. The axis of the Niutuozhen Uplift did not get disposition of lower strata of Minghuazhen Formation but the disposition occurred at the wings and it gets thicker towards the wings. The Guantao Formation, the Dongying Formation, the Shahe Formation and the Kongdian Formation from Tertiary only exist in the Baxian Depression but not in the Xiong County Uplift.

2) Proterozoic: The Jixian System includes the Tieling Formation, the Hongshuizhuang Formation and the Wumishan Formation. Among them Wumishan Formation spreads over most of the Territory of Xiong County and directly underlies Tertiary strata of the Niutuozhen Uplift. It is composed of dolomite and muddy dolomite and the total thickness is 1045-2620 m. The Changcheng System strata underlie the Jixian System strata. The thickness of the Gaoyuzhuang Formation of the Changcheng System is approximately 1000 m. And the rest of the formations in the Changcheng System do not exist in the Niutuozhen Uplift.

3) Archaeozoic: It is composed of gneiss and granulites and underlies the Changcheng System strata and the footwall of the Niudong Fault. The depth is more than 3500 m (Wang, K., 2010).

In total, the geothermal reserve within Xiong'an New Area is $1134 \times 10^8$GJ, the exploitable reserve is $198 \times 10^8$GJ. The main production aquifer for Xiong County and Anxin is Wumishan formation and for Rongcheng which is Gaoyuzhuang formation. The detailed information is shown below:

**Table 1: Geothermal reserve in Xiong'an New Area**

| County | Area（$km^2$） | Reservoir Era | Geothermal reserve | |
|---|---|---|---|---|
| | | | Total reserve（$10^8$GJ） | Exploited reserve（$10^7$GJ） |
| Xiong county | 320.0 | Nm、Pt | 4000.07 | 697.9 |
| Rongcheng | 185.0 | Nm、Pt | 1927.50 | 219.50 |
| Anxin | 695.42 | Nm、Ng、Pn、Pt | 5415.88 | 1065.72 |
| Total | | | 1134.35 | 198.31 |

### 3.2 Geothermal district heating status in Xiong'an

The overall scaled geothermal district heating started in Xiong County was back to 2009. Since then, it grew rapidly each year and over 90% of buildings in Xiong County have been covered by geothermal by 2014. The concept of "Xiong County Model" was spread all over the country, being copied to regions where geothermal is rich. The essence of the concept is recycling utilization of geothermal with 100% re-injection. Then in 2011, the geothermal district heating projects in Rongcheng also started and up to now it has covered more than half of the buildings in the county before Xiong'an New Area was established. The investor and operator is Sinopec Green Energy Geothermal Development Company which is a joint venture between China and Iceland. The total geothermal district heating area amounted to 7 million $m^2$, and 51 heat centrals and over 120 geothermal wells both production and re-injection.

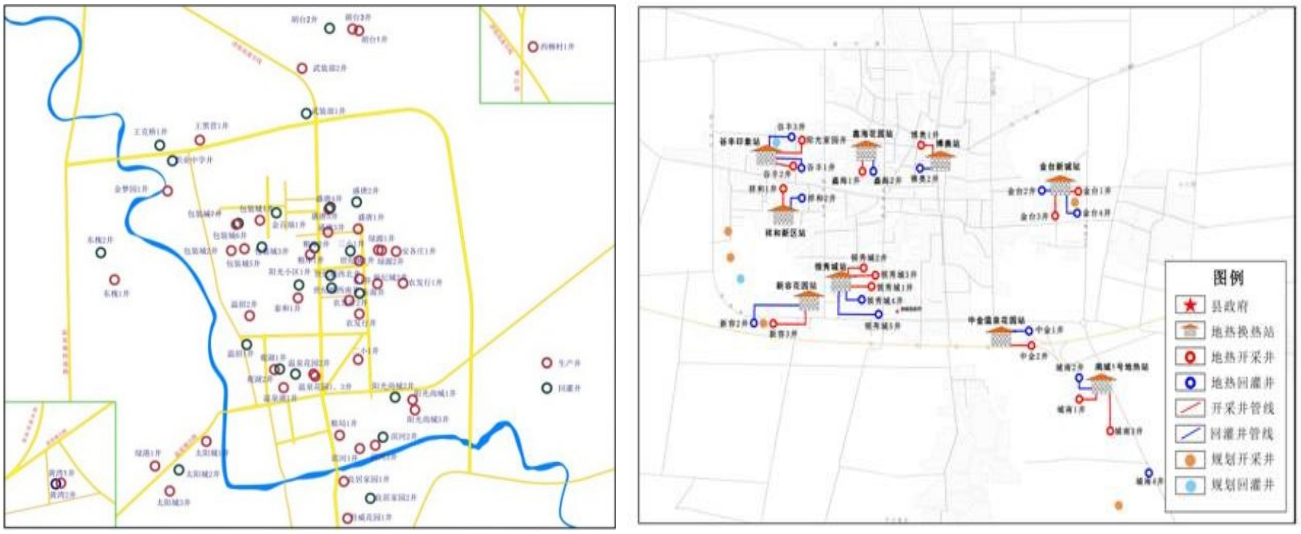


**Figure 2: Geothermal projects distribution in Xiong County and Rongcheng**

"Xiong County Model" is a National Showcase in China by the Chinese National Energy Authority/National Reform and Development Commission (NDRC) and a foundation case for the government's 13th 5-Year Plan for geothermal. The inhabitants of Xiong County enjoy a higher quality of life with cleaner air, better health, less costly heating energy today. It is a zero emission city created by geothermal district heating. Due to the abundant resource of geothermal and success of development, it would provide Xiong'an New area a fundamental base load energy for new and larger construction.

## 4. GEOTHERMAL AND CLEAN ENERGY INTEGRATION APPROACH IN XIONG'AN

As mentioned previously, Xiong'an New Area was established on April 1st, 2017, it would become a special area of National significance similar to Shanghai Pudong New Area and Shenzhen Special Economic Zone. This new area will house much of China's administrative functions currently in Bejing. The 1st phase will cover 100 $km^2$, then 200 $km^2$ and finally 2000 $km^2$. Energy supply is the key issue for establishing a new city. 100% clean energy utilization is written in the energy master plan. The main idea is to combine and optimize all available clean energy to create a comprehensive system which is called "geothermal and clean energy" integration. Here geothermal refer to not only above mentioned hydro-thermal geothermal but also ground source heat pump which is perfectly providing both heating and cooling mainly for public buildings. Priority shall be given to low and medium geothermal energy, supplemented by shallow geothermal energy with heat pumps and sewage to ensure the New Area to be a green and smart city. Synchronization of Geothermal, electricity and natural gas to build an international geothermal showcase in Xiong'an New Area.

### 4.1 An integration clean energy district heating approach for Rongdong District

The first resettlement and new construction area for Xiong'an will be Rongdong District. It is located to the east of Rongcheng County, with planned land area of 12.28$km^2$, population of about 170,000 and total building area of around 12,000,000$m^2$. It is planned to build a central public service area, 1 neighborhood and 5 communities (Community A, B, C, D, E). It is planned as a demo-project for clean and renewable energy utilization. All the buildings are designed as energy saving building with very low heat loss. Geothermal, clean electricity and natural gas will be taken into account as the main energy source for both heating and cooling. Table 1 as shown below is the basic information for all end user building area.


**Figure 3: Rongdong district general layout**

**Table 1: Rongdong building area information**

| No. | Block | Area | Resettlement area | New Area | Business | Commercial | Education and Medical | Industry | Road | Total | Plot ratio |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 10^3 $m^2$ | 10^3 $m^2$ | 10^3 $m^2$ | 10^3 $m^2$ | 10^3 $m^2$ | 10^3 $m^2$ | 10^3 $m^2$ | 10^3 $m^2$ | 10^3 $m^2$ | % |
| 1 | Neighborhood A | 2,010.0 | 285.0 | 35.0 | 52.0 | 72.0 | 143.0 | 1,102.0 | 262.0 | 1,689.0 | 1.0 |
| 2 | Community D | 2,010.0 | 951.0 | 294.0 | 199.0 | 286.0 | 573.0 | 0.0 | 441.0 | 2,303.0 | 1.5 |
| 3 | Community A | 2,280.0 | 1,046.0 | 329.0 | 216.0 | 315.0 | 644.0 | 72.0 | 497.0 | 2,622.0 | 1.5 |
| 4 | Community B | 1,020.0 | 692.0 | 208.0 | 138.0 | 186.0 | 401.0 | 344.0 | 359.0 | 1,968.0 | 3.0 |
| 5 | Community C | 1,570.0 | 398.0 | 104.0 | 78.0 | 115.0 | 229.0 | 501.0 | 245.0 | 1,424.0 | 1.1 |
| 6 | Community E | 1,640.0 | 735.0 | 216.0 | 147.0 | 215.0 | 430.0 | 286.0 | 373.0 | 2,029.0 | 1.6 |
| 7 | Central Green | 2,370.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | | |
| 8 | Road | 2,790.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2,176.0 | | |
| Total | | 15,690.0 | 4,107.0 | 1,185.0 | 830.0 | 1,188.0 | 2,420.0 | 2,305.0 | 4,352.0 | **12,035.0** | 1.4 |
| Building area ratio % | | | 34.1 | 9.8 | 6.9 | 9.9 | 20.1 | 19.2 | 36.2 | 100.0 | |

The heat load and cooling load as designed is shown below in Table 2. For residential building the heat load code per area is 30W/$m^2$, and for public buildings is 40W/$m^2$, therefore the general heat load code in Rongdong District is estimated as 35W/$m^2$, and for cooling load per square meter is 90W/$m^2$. In total, the heat load is 420MW and the cooling load is 532MW (Yue, 2019).

**Table 2: Heat load and cooling load Rongdong District**

| No. | Building type and area | | | Heat and cooling load | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Type | Area | Ratio | Heat load per area | Heat load | Ratio | Cooling load per area | Cooling load | Ratio |
| | Type | 10^3 $m^2$ | % | $W/m^2$ | kW | % | $W/m^2$ | kW | % |
| 1 | Resettlement | 4,110 | 34 | 30 | 123,224 | 29 | 0 | 0 | 0 |
| 2 | New Residential | 1,180 | 10 | 30 | 35,540 | 8 | 0 | 0 | 0 |
| 3 | Commercial | 830 | 7 | 30 | 24,904 | 6 | 0 | 0 | 0 |
| 4 | Business | 1,190 | 10 | 40 | 47,531 | 11 | 90 | 106,946 | 20 |
| 5 | Education and Medical | 2,420 | 20 | 40 | 96,781 | 23 | 90 | 217,757 | 41 |
| 6 | Industry | 2,300 | 19 | 40 | 92,200 | 22 | 90 | 207,449 | 39 |
| Total | | 12,040 | 100 | 35 | **420,181** | 100 | 44 | **532,152** | 100 |
| Residential | | 6,120 | | | 183,669 | 44 | | 0 | 0 |
| Public | | 5,910 | | | 236,512 | 56 | | 532,152 | 100 |

### 4.2 Outdoor temperature distribution

The outdoor temperature in this area for recent year is shown below with highest and lowest figures. The designed heating outdoor temperature is -8.3 ℃.

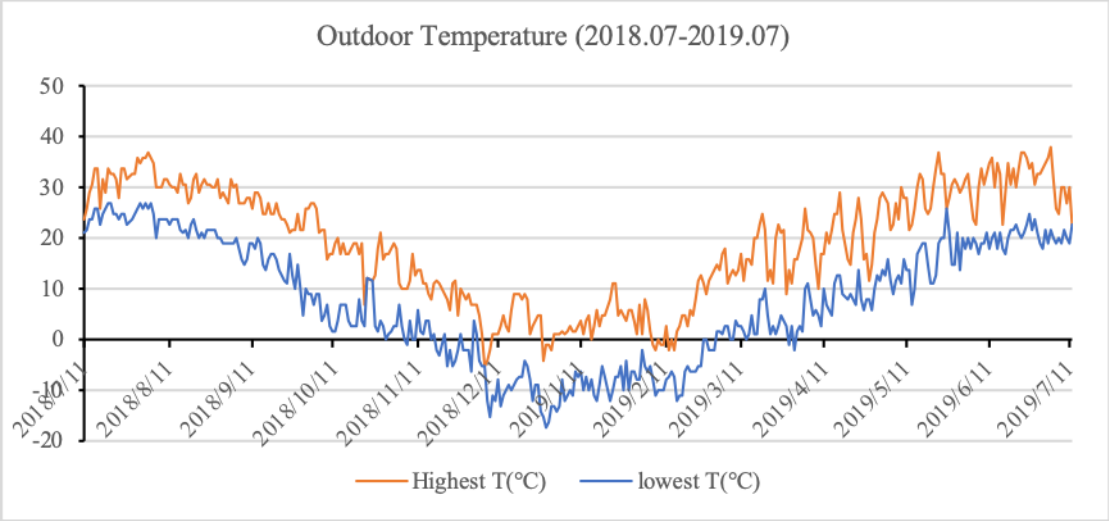


**Figure 4: Outdoor temperature distribution from 2018.07 to 2019.07**

### 4.3 Integration energy system analysis

There are alternative energy sources available in Rongdong District such as geothermal, sewage water, surface water, shallow geothermal, data center waste heat, municipal electricity net, natural gas and solar energy. Comparison of different energy utilization shows that geothermal is the most stable and economic approach for district heating and cooling. But due to the limited area and reasonable development principal, the integration of alternative energy will be considered as the main solution. Natural gas and electricity will be the secured energy source to cover all the area demand.


**Figure 5: Alternative energy source in Rongdong District**

The approach of different energy utilization for district heating and cooling is shown below in Figure 6. It will be integrated in the overall plan and design for the whole district.

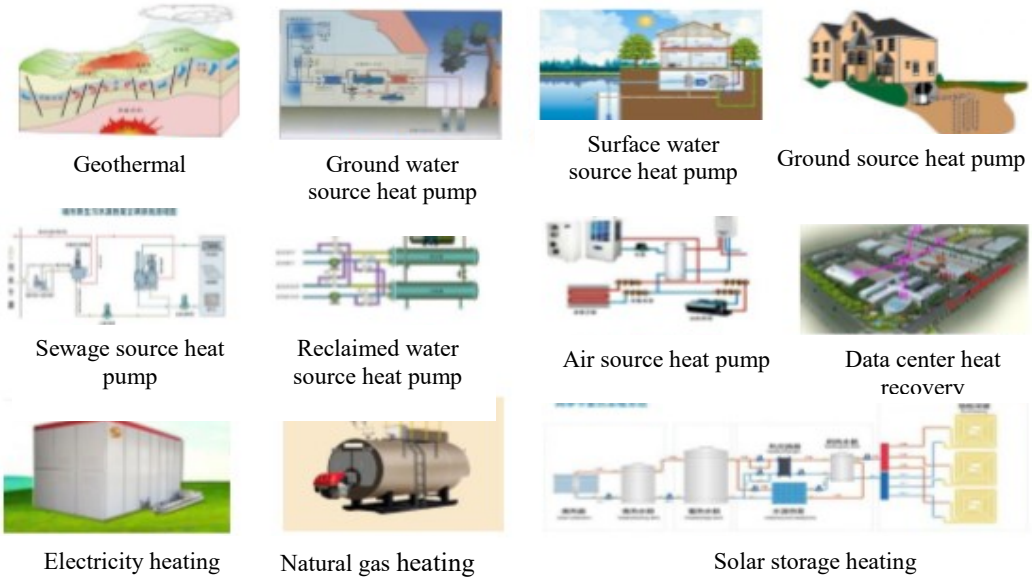


**Figure 6: Alternative energy utilization principal approach**

Geothermal as the base load energy will be the priority choice in Xiong'an. According to the geothermal resource assessment report for Rongcheng County, the total exploited resource is $17.40\times10^8$GJ for total area of 193.4km$^2$. and for Rongdong District it is $1.10\times10^8$GJ for 12.28km$^2$, and annually exploited resource is $1.10\times10^6$GJ， equals to $3.75\times10^4$ t coal equivalent. Based on the existing well data and geophysical exploration assessment, the production of each geothermal well is roughly 120 m$^3$/h, with wellhead temperature of 57-60 ℃. Assuming re-injection temperature as 25 ℃, then each well with heat pump can supply heat of 5.2MW. If divided by average heat load per square meter, each well can cover about 148,571m$^2$. Based on reasonable distance between wells of 500m, it can be drilled 43 geothermal wells in total in Rongdong District with 25 production wells and 18 re-injection wells. Therefore, geothermal can provide total heat of 130MW, which accounts for 31% of the total heat load for the whole district. The rest of the heat load would be mainly covered by natural gas and electricity. For public building district cooling, the majority will be

supplied by shallow geothermal ground source heat pump supplemented by electricity chillers.

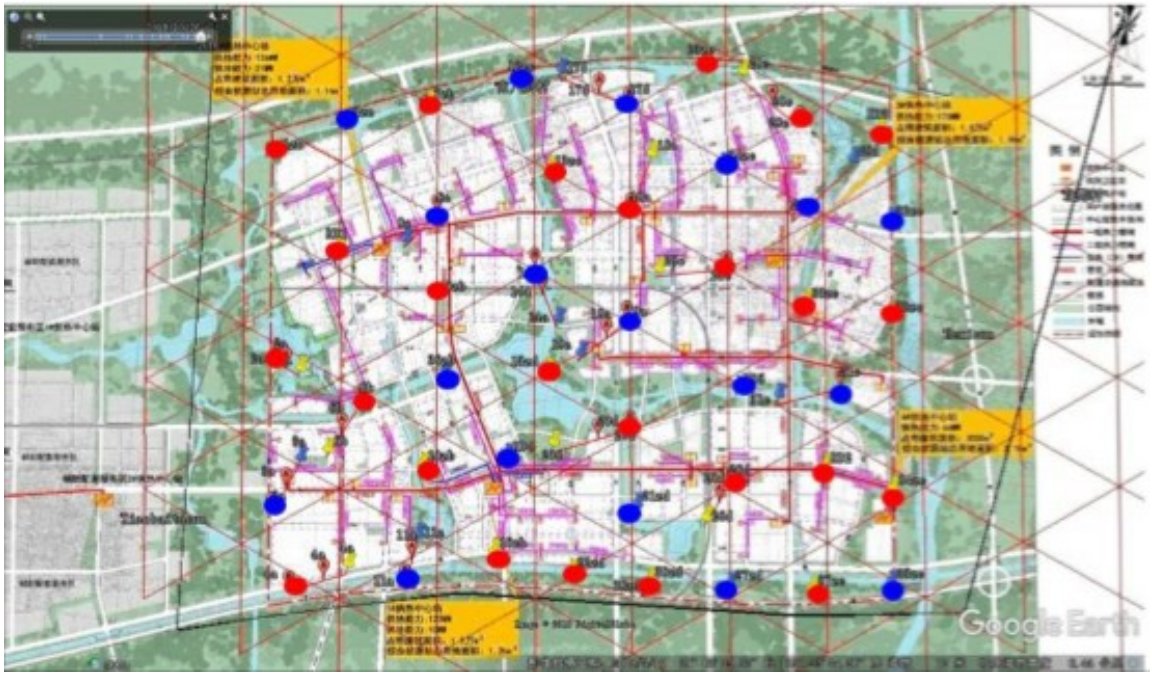

**Figure 7: Geothermal well distribution layout in Rongdong**

General integration of geothermal, electricity and natural gas is shown in Figure 8. Hydro-thermal geothermal will cover 31% of the total heat load. The central green land with area of 2.37 million $m^2$ will be the perfect location ground source heat pump system. It will totally provide 303MW heating capacity and 398MW cooling capacity assuming 80% of the green land is available for drilling boreholes for GSHP system. Therefore, the heat load can be covered by both geothermal and GSHP and majority of cooling load. The rest cooling load will be covered by chillers. Natural gas CCHP as a secured energy source to maintain the rest and extra capacity. Other energy source such as sewage water, air source heat pump, and solar storage solutions will be considered as decentralized heat center for scattered end users.

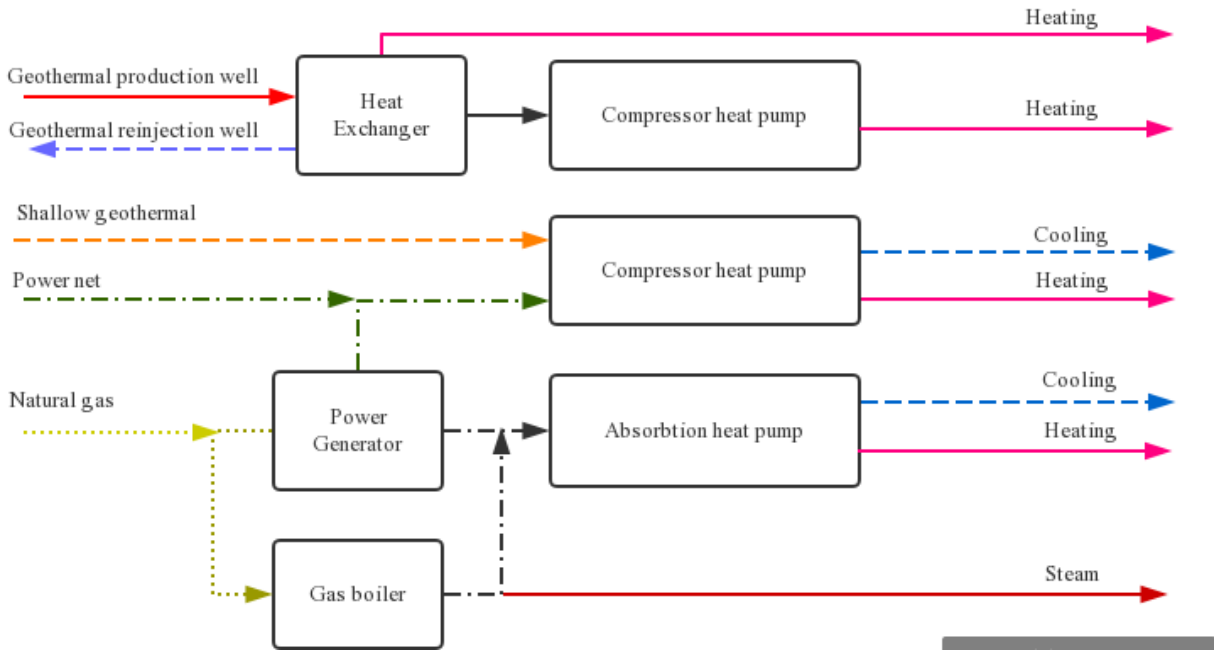


**Figure 8: Integration of alternative energy for district heating and cooling**

### 4.4 Economic analysis

Based on the integration approach and rough calculation, the total investment cost and O&M cost is estimated for a general economic

feasibility analysis. The total investment cost is about 2.9 billion yuan. For O&M cost, the lowest is geothermal district heating, then ground source heat pump system and the highest cost is from the natural gas CCHP system. For cooling system, ground source heat pump is the lowest, followed by chiller and Gas CCHP. Since Rongdong District is still on the planning and design stage, the calculation is relatively rough estimate. But based on the available clean and green energy in this region, the recommended energy utilization system is as mentioned above.

**Table 3: Economic estimate for the integration system**

| No. | System Type | Investment cost (yuan) | O&M cost (yuan/$m^2$) | |
|---|---|---|---|---|
| | | | Heating | Cooling |
| 1 | Geothermal district heating | 501,428,571 | 9 | |
| 2 | GSHP | 1,425,000,000 | 13 | 14 |
| 3 | Gas CCHP | 540,000,000 | 30 | 32 |
| 4 | Chiller | 119,111,111 | | 25 |
| 5 | Main Pipeline network | 340,000,000 | | |
| 6 | Total | 2,925,539,683 | | |

## 5. CONCLUSIONS AND RECOMMENDATIONS

There are abundant geothermal resources in Rongdong District, which would be the best base load energy for district heating system. Preliminary planning includes 43 wells, in which 25 would be production wells and 18 would be re-injection wells, providing 120MW heat in total. Each well produces 120$m^3$/h with wellhead temperature about 60℃.

The integration of geothermal and ground source heat pump, natural gas CCHP and other clean energy utilization is the main solution with the aiming of building zero emission city and combination of centralized and decentralized heating station is recommended for project implementation.

Energy saving buildings are strongly recommended in this new district design and construction. It is suggested to promote passive building and zero energy consumption buildings. It is a fundamental solution for optimizing energy system and reducing the energy consumption.

The main pipeline network is designed as a circle to guarantee heating safety for each Heat Central. For residential buildings, geothermal district heating, ground source heat pump and gas CCHP will be the main heating solution. Individual cooling system is recommended to use for each end user. For public buildings, ground source heat pump, gas CCHP and chillers will cover all the cooling load. Other waste heat, such as from the sewage system and data center would be supplemental energy source integrated into the system.

The estimated investment cost is about 2.9 billion yuan, and the total O&M cost is about 300 million yuan. To maintain the profitability of the operation, the heating and cooling tariff should be refer to Beijing standard and governmental subsidies.

The AI SCADA system is recommended to implement in future heating and cooling system. The monitoring geothermal reservoir is essential for assess the sustainability of resource development. According to end user's heating and cooling demand, the habit to carry out tailored operation and control scheme is important to improve the energy utilization efficiency.

A macroscopic research on clean energy policy and planning is recommended to facilitate the sustainable energy development of Xiong'an New Area.

Rongdong District would be a demo a pilot area for implementing pure clean energy development in Xiong'an New Area aiming for building up zero emission city. Therefore, the whole chain of the energy system should be comprehensively planned, designed and operated.

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