The planning and construction of Distributed Energy System in Qingdao Sino-German Eco-park

Cun Wei\textsuperscript{1, 2}, Gaijing Zhang\textsuperscript{1, 2} and Peipei Song\textsuperscript{3, 4}

\textsuperscript{1}. Shanghai research institute of building sciences, Shanghai, China.
\textsuperscript{2}. 568 Shenfu Rd., Shanghai, China.
\textsuperscript{3}. Management Committee of Qingdao Sino-German Eco-park, Qingdao, China.
\textsuperscript{4}. 2877 Tuanjie Rd., Qingdao, China.

Abstract. This paper introduce the development and characteristics of new energy, Eco-city and Distributed Energy System in China, a case study of Qingdao Sino-German Eco-park, research on practical application about planning and construction of Distributed Energy System in Eco-city. Results show that: we must first do a good job in energy planning, giving full play to their own advantages, and Distributed Energy System based renewable energy resources is a promising option for reducing emissions from electricity generation in Eco-city.

1. Introduction
At present, the construction of urban has entered a period of rapid development with the increase in the number of urban population. As a result, energy consumption and environment damage have become more and more serious. Now, various initiatives have made great efforts to mitigate them. Along with our country’s urbanization process, the energy transformation that takes the new energy as the pivot has become the trend of our country's energy development. With the increasing scale of fossil energy consumption, it is urgent to develop new energy resources and accelerate the transformation of energy. With the new energy as the fulcrum of China’s energy transformation system is accelerating change, and vigorously develops new energy has risen to the national strategic level.

For this reason, the Power Generation and Installed Generation Capacity by new energy in China has been rapid development in past the 10 years, which is shown in Fig.1. The Power Generation refers to the capacity of electricity generation in the actual operation; the Installed Generation Capacity refers to the capacity of electricity generation in full load operation.
In this situation, energy reform and environment protection have become a new challenge of whole human being. Also, the construction of sustainable developmental harmonious society will ulteriorly accelerate the development and innovation of Chinese urban. The increasing concern for Green, ecological, and low carbon in China is driving government to develop and implement.

Alternative practices especially the construction of Eco-city. The concept of Eco-city is proposed in the process of the “man and biosphere” plan, which was launched by the joint Anglican branch organization in 1971. However, there is no real definition about Eco-city in the world, but the understanding about the intension of Eco-city is also continuing to deepen [1].
In addition, President of Xi Jinping is proposed to support the construction of Eco-city for improving overall ecological environment quality and low carbon level in the Thirteenth Five-Year Plan of China. Therefore, the number of national Eco-city approved has reached 18 by the end of 2015 including Qingdao Sino-German Eco-park, Tianjin Sino-Singapore Eco-city, etc. [2]. The distribution of national Eco-city is shown in fig.2, in which I simply list these Eco-city approved by Housing and Urban-Rural Development.

2. Development of Distributed Energy in China

By the end of 2014, the Installed Generation Capacity of renewable energy resources has reached 133400Mw, soared by nearly 28% compared with last year, according for 7.9 %of national electricity generation. The installed generation capacity from wind power has reached 95810Mw, according for 27% of global wind power generation, which has exceed other countries all over the world. Similarly, with the rapid growth rate of solar power generation all over the world, the installed generation capacity from solar power reached 26520Mw and ranked second only to the Germany. The Installed Generation Capacity of solar power in most provinces of China at the end of 2014 is shown fig.3.

![Figure 3. Solar power generation capacity in most provinces of China at the end of 2014](image)

The centration and distribution deployment modes of renewable energy utilization are the most common measures all over the world. But the nature situation of wind and solar in china determines that the wind power generation by distribution is dominated and the solar power generation by their combination.

Future, we should do it as best as we can about exert the advantage of renewable energy, strengthen the development of renewable power generation and the optimization of layout and promote the efficiency of resources transition. Overall objectives of China have been proposed in the “Strategic action plan for energy development (2014-2020)“, the Installed Generation Capacity by wind power will reach 0.2 billion Kw, the Installed Generation Capacity by solar power will reach 0.1 billion Kw.

3. The Planning and construction of Distributed Energy System in Qingdao Sino-German Eco-park
Distributed Energy System (DES) refers to local or small-scale energy supply system of independent in order to provide energy for users nearby, including solar power generation, wind power generation, ground-source heat pump and so on in China. DES as a highly efficient energy utilization system is more and more valued by the state and enterprises at home and broad [3-6], which can play an essential role in providing energy with substantial environmental and other benefits especially in Eco-city. This paper introduces a national Eco-city of China, which adopt DES to provide the required energy.

3.1. Introduction of Qingdao Sino-German Eco-park

In order to promote the development of green ecological, German Ministry of economics and technology and the Chinese Ministry of Commerce jointly signed “The Memorandum on the establishment of Qingdao Sino-German Eco-park (QSGE)” during the German Chancellor Angela Merkel's visit to China in July 2010. QSGE is the focus of cooperation projects between China and German, which is also the first joint construction project in the field of Eco-city in China. In addition, President Jia Qinglin, Premier Li Keqiang, Vice Premier Wen Jiabao also mentioned the project of QSGE during the visit to Germany in 2011. The construction of QSGE mainly form parts of the ecological planning, green building, low carbon industry and green management, which involve a total of more than ten aspects, such as index system, green planning system, energy utilization, green municipal, green construction, environmental protection, intelligent development, low carbon industry, urban management, green consulting and so on.

So far, QSGP has received a large number of honorary titles including "National Low Carbon City (Town) pilot", "The First Comprehensive Standard of demonstration park", "National Green Manufacturing International Innovation Park", "The wisdom of the city pilot", "National Eco-city", "New Energy Demonstration Park", Etc. At present, it is still in the stage of construction, the first phase of the planning land area of 11.56 square kilometers. The planning rendering of QSGP is shown in fig.4.

![Figure 4. The planning rendering of Qingdao Sino-German Eco-park](image-url)
The construction and development of DES in Eco-city depends on the following aspects: first, we should make full consideration about energy consumption and environmental destruction combined with cost estimation and energy technology types in the region while beginning to build the Eco-city, in order to determine the most applicable technology. Secondly, According to the analysis of technologies selected compile the energy planning combined with the size of the region and carry out district construction procedures. In addition, Energy efficiency, the reasonable matching of different energy in the process of using, the circulation and mutual transformation among various energy types from the overall point also should be considered while combine the energy planning. Based on the above content, and following the design idea of high energy and high use, low energy and low use, peak clipping and filling valley, Complementary guarantee, the DES of QSGE are being set up, which also make the most of renewable and clean energy. What's more, all kinds of energy and resources are allocated reasonably, through the establishment of the recycling system of fossil energy and renewable energy, the combination of centralized and distributed, and the combination of mixing system and independent system, in order to optimize the transmission and distribution system. At the same time, the DES of QSGE also enhances the design of the entire energy supply system fully from the links of production, storage and transportation, application and Regeneration, which not only meet the needs of cold, heat, steam, hot water and some electric load, but also improve the economic indicators of energy utilization, mitigate the impact on the surrounding environment, the DES in QSGP is shown in fig.5.[7]
The link of energy production: Using the model of many to single to supply energy, the power, steam, heat water and heat are introduced into the regional distributed energy station. What’s more, the power is composed of wind power, solar power and grid. Thus, there is sufficient capacity to provide energy to sub distributed energy and satisfy the requirements of the endpoint.

The link of energy storage and transportation: The station of L/CNG is constructed in QSGP, and the device of storage for cold, heat and power also is constructed in sub distributed energy station. Hence, it not only can play a role of peak saving and valley filling for both electric network and gas network, but also can assure the demand of peak energy while running. As a result, there is a great contribution to reducing the size of the entire energy system and reducing the cost of running in the future.

The link of energy application: At the side of energy supply, it use the method of mutual complement each other in time and space. In other word, we can transport energy form residential areas where demanded seldom energy to commercial and industrial areas where demanded much more energy in the daytime, by contrast in the evening. Meanwhile, for lowering the temperature of the heating medium and improving comfortable quality, Floor Radiant Heating is used in the building. Besides, taking the method of full day monitoring without interruption, the mathematical simulation and analysis of the data were carried out, and then guide the production of energy in the link of energy production. What’s more, it must be strictly enforced in the process of design or other national codes during construction.

The link of energy regeneration: It can play a vital role in the recovery of waste heat and energy conservation, by means of recovering the waste heat resource from the regional distributed energy station, sub distributed energy stations and industries. Usually, the recovery of waste heat with low grade needs to increase its temperature or grade before supply to the building or plant by setting the circulating water heat pump system. In addition, it is essential to take effective classification and treatment of resident garbage and wastewater in the link of energy regeneration, which will be used to drive the biomass power generation as raw material and provide organic fertilizer for the nearby farmland.

3.3. The part of renewable in the Distributed Energy System of QSGP

Due to a rich solar energy, wind energy and geothermic in QSGP, renewable and clean energy form the chief institutions of the DES. In solar energy, annual total solar radiation is 5040MJ/m², the average annual sunshine hours for 2550 hours. In wind energy, as next to the sea, the annual average wind speed is 5.3m/s, the effective wind energy density is 240.3W/m³, the effective wind energy average time is 6485 hours every year. In geothermic, sand and stone are the most important part of geology, 0~30 meters is weathered granite, 30~120 meters is sand and stone that comprehensive coefficient of thermal conductivity is 1.464W/m, and the average specific heat capacity is 1.847×10⁴J/m³. Therefore, it has a great advantage in the use of renewable energy in QSGP [8].

According to the Planning of Renewable in QSGP, the renewable energy accounted for the proportion of the total energy consumption of the park plan to reach 15%. In order to achieve the goal, Management Committee of Qingdao Sino-German Eco-park has adopted a series of measures such as solar water heater integrated with building, Building-integrated photovoltaic, Ground-source Heat Pump, Wind power, Biomass-Energy and so on. Detailed instructions as shown in Table 1:
Table 1. The major technologies employed and the predicting of annual supply of renewable

| Name                        | Major technologies employed                                                                 | Predicted supply | Proportion |
|-----------------------------|----------------------------------------------------------------------------------------------|------------------|------------|
| Building-integrated solar water heater | More than 90% hot water is provided by the solar hot water system in residential building; More than 50% hot water is provided by the solar hot water system in public building; etc. | 4490.0 tce       | 1.70%      |
| Building-integrated photovoltaic | Use of building-integrated photovoltaic in industrial building; Use the solar energy photovoltaic street lamp; etc. | 3433.8 tce       | 1.30%      |
| Ground-source heat pump     | Large-scale promotion of ground-source heat pump system; etc.                                 | 1848.0 tce       | 0.70%      |
| Wind power                 | The introduction of wind power plant of Zhua Ma Shan; Use the wind power street lamps, etc.   | 29055.0 tce      | 11.0%      |
| Biomass-energy             | Construction waste treatment gasification station; using bio gas to generate electricity; etc. | 1057.0 tce       | 0.40%      |
| Total                      | —                                                                                            | 39883.8 tce      | 15%        |

Based on renewable energy resource, the construction of DES in QSGP has a super advantage compared with the traditional energy systems in terms of energy saving and emission reduction. After preliminary calculation, it can reduce 506 thousand tons of CO\(_2\), 5.8 thousand tons of SO\(_2\), 4.0 thousand tons of NO\(_x\), 2.11 thousand tons of dust and so on.

3.4. Investment estimate

The cost of the total investment of the DES in QSGP majorly includes one regional distributed energy station with large scale, nine regional distributed energy station with small scale, six sub distributed energy stations, one operation management center, and transmission and distribution network. Each distributed energy station is made up of factory building, substation room, guards, control equipment, etc.

We determined the cost of major equipment based on the experience, equipment price standard and quotation of equipment manufacturers while estimating the initial investment. The calculation methods of the construction engineering cost are based on the price per subdivision according to its own characteristics and local similar engineering. Based on relevant quotas and budget index, we estimated the cost of installation and combined with local market conditions adjust the price. Detailed costs as shown in Table 2:
Table 2. Estimation of the gross investment about the construction of DES [9]

| Code | The name of cost                        | Investment (Thousand dollars) | Code | The name of cost                        | Investment (Thousand dollars) |
|------|----------------------------------------|------------------------------|------|----------------------------------------|------------------------------|
| 1    | Regional distributed energy station    | 40107.69                     | 13   | Intelligent meters                     | 8461.54                     |
| 2    | Sub distributed energy station         | 53378.46                     | 14   | Intelligent control system             | 6615.38                     |
| 3    | Local distributed energy station       | 46476.92                     | 15   | Energy supervising system              | 1815.38                     |
| 4    | Auxiliary equipment                    | 6993.85                      | 16   | Energy optimization system             | 2307.69                     |
| 5    | Engineering installation               | 8287.69                      | 17   | Energy regulation system               | 3846.15                     |
| 6    | CNG storage station                    | 1538.46                      | 18   | Energy trading system                  | 1846.15                     |
| 7    | LNG storage station                    | 5230.77                      | 19   | Public service system                  | 2307.69                     |
| 8    | Gas fueling station                    | 3384.62                      | 20   | Energy cloud computing service system  | 1153.85                     |
| 9    | Solar water system                     | 12307.69                     | 21   | Transmission and distribution network  | 46153.85                    |
| 10   | Photovoltaic system                    | 23076.92                     | 22   | Construction project                   | 7444.62                     |
| 11   | charging station                       | 953.85                       | 23   | Land use                                | 8649.23                     |
| 12   | Recycling and utilization system       | 3076.92                      |      | Total                                  | 295415.38                   |

4. Conclusion
The planning and construction of Distributed Energy System in QSGP is one of the best successful cases in China. It is worthy of promoting, because the characteristics of high energy utilization, environmental protection and energy conservation.

It is important to take efforts to reduce energy consumption and carbon emission. On the one hand, we must first do a good job in energy planning, giving full play to their own advantages, and Distributed Energy System based renewable energy resources is a promising option for reducing emissions from electricity generation in Eco-city. On the other hand, we should conscientiously implement all planning and policies for promoting energy consumption and carbon emission.

Acknowledgments
This work was financially supported by the National Key Technology R&D Program during the 13th Five-Year Plan Period (2017YFC0702303-03).
References
[1] ShunSheng Wang, ChuanChang Gao. Study about planning and Construction of urban Based on Eco-city Theory. *Applied Mechanics Materials*, Vols71-78(2011) pp220-223.
[2] Xun Li, Bing Li. Development status and trend of green ecological city. China Green Building 2016. *Chinese Society for Urban Studies*, 2016. (In Chinese)
[3] Wang Y L, Shi D, Fan L S, et al. Application and Development of Distributed Energy Systems in China 2015. (In Chinese)
[4] Yang Y W, Yang R F, Ren J X, et al. Analysis of Influences of Residential Energy Prices Change on Development of Residential Distributed Energy System, *Applied Mechanics & Materials*, 2012, 209-211:1852-1857.
[5] Zhou Z, Liu P, Zhang J Y, et al. Evaluating the Impact of Carbon Taxes on the Optimal Design of Distributed Energy Systems. *Advanced Materials Research*, 2012.
[6] Chengzhang Zhu. Measures to Prevent Long-term Oversupplies of Electricity and Natural Gas. *SINO-GLOBAL ENERGY*, 2015. (In Chinese)
[7] Xilai Hu, Distributed Energy Resource Planning in Urban Ecological Characteristic of the Construction Park. Tianjin. The University of Tianjin. (In Chinese)
[8] The Green Planning of Qingdao Sino-German Eco-city. The company of Shanghai research institute of building sciences, 2014. (In Chinese)
[9] The Energy Planning of Qingdao Sino-German Eco-city. The company of ENN group, 2012. (In Chinese)