Integrated Smart Energy Project that Made Xiaogang Village Modern and Green (Type of project: Low Carbon model Towns)

Applicant: State Power Investment Corporation Limited (SPIC)

Co-Applicant: SPIC's affiliated companies:

Integrated Smart Energy Technology Co., Ltd.,

SPIC's Anhui branch Co.,

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Project name:	Integrated Smart Energy Project that Made Xiaogang Village Modern and Green
Type of project:	Low Carbon model Towns
(Estimated) project completion time:	1. Phase One of the project has been successfully completed in June 2021 2. Phase Two of the project has been started in February 2022 and is planned to be completed by June 2022
Project location:	Xiaogang Village, Fengyang County, Chuzhou City, Anhui Province, China

Preface

1. Project background

In September 2020, Xi Jinping, President of China, announced at the United Nations General Assembly that "China's carbon dioxide emissions will strive to peak by 2030 and achieve carbon neutrality by 2060".

In February 2021, the China's central government issued opinions on comprehensively promoting rural revitalization and accelerating agricultural modernization.

China has one of the oldest civilizations in the world. China's agricultural population accounts for more than 40% of the total population, and the greenhouse gas emissions from agriculture and rural areas account for 15% of the total emissions. Promoting rural low-carbon energy consumption and smart micro-grid to realize energy conservation and carbon reduction is an important way to achieve carbon peak and carbon neutralization in China.

2. Project overview

Starting from Beijing, the capital of China, one may take the high-speed train to the south and in four hours will arrive at Xiaogang Village, Fengyang County, Anhui Province, the village leading China's rural reform.

In 1978, 18 villagers in Xiaogang Village signed the letters of land contract responsibility, which became the prelude to China's rural reform. Today, on Xiaogang Village's 15 square kilometers of land, a total of 4,127 villagers from 923 families are building a modern and green village in China through the integrated smart energy project.

Fig. 1-1 Archways of Xiaogang Village

Fig. 1-2 Residential neighborhoods of Xiaogang village

This project is the first attempt of Xiaogang Village, the "village leading China's rural reform", and State Power Investment Corporation Limited (SPIC), which is the world's largest clean energy power generation enterprise, to achieve rural energy transformation and low carbon emission. It is the first modern and green village integrated smart energy project built by the SPIC, and is also one of the first batch of modern and green village integrated smart energy projects in China.

According to local conditions and local resource endowments, the project provides 100% clean energy sources, 100% clean cooling and heating, and 100% comprehensive utilization of crop straw to this village, whose output value of the village's iconic industries exceeds 100 million yuan. The means of provision of such services include ecological energy such as solar photovoltaic power generation, ground source heat pump, comprehensive utilization of straw biomass, integrated smart facilities such as solar photovoltaic-energy storage-charging sheds, smart street lighting and seats. On this basis, the interconnection and mutual supply with the State Grid are established.

It is worth mentioning that Fengyang County, where Xiaogang village is located, is the hometown and tomb location of the first emperor of the Ming Dynasty in China, the history of which can be traced back to more than 600 years ago. Xiaogang village has abundant wind resources, but considering the custom and tradition of "feng shui", Xiaogang village decided to exclude wind power from integrated smart energy projects.

In addition, the project effectively connects the energy network, government affairs network, and community network through the "Tianshu-1" integrated smart energy management and service platform - a new digital system, and sends the information regarding government affairs, agricultural affairs, business, tourism, health care, and education and training to every family and organization in Xiaogang Village instantaneously and accurately. Since then, China has the first village committee to manage complex governance affairs with powerful digital tools. Every family in the village has lived a modern, green and affluent life on the field of hope.

3. Specific results of the project

Xiaogang village is a pioneer of China's rural reform and an AAAA historical and cultural tourist attraction of China, with an average annual visitor flow of more than 600,000. It is also a rural practical talents training base for the Organization Department of the CPC Central Committee and the Ministry of Agriculture and Rural Affairs, receiving more than 6,000 trainees each year.

(1) The project plans a solar photovoltaic power generation system with a design life of 25 years and a total capacity of 18.7MW(11.25MW has been built in Phase One), located at the intersection of Gaige Avenue and Chuangxin Avenue, two main streets of Xiaogang Village, Majiaba Reservoir, the visitor center, and the roofs of farmers' houses, with an annual electricity generation capacity of 21.774 million kWh. It is interconnected with the State Grid to provide clean power to Xiaogang Village's historical museum, training college, village committee's office, and every household.

(2) The project has built two 120kW DC charger piles with a design life of 10 years in the solar photovoltaic shed of the visitor center. Each charger is equipped with two charging guns and a 100kW / 200kwh energy storage equipment, so as to realize the integration of solar

photovoltaic power generation, energy storage, and charging, to provide sufficient clean energy for the visitor center and charger piles, and to store the extra power generated from solar photovoltaic cells for use at night.

(3) Smart streetlights with such functions as environmental monitoring, security monitoring, regional noise monitoring, emergency police have been built in the neighborhoods, training college, historical museum, and bus stops of tourist attractions; Smart street seats with such functions as resting, mobile phone charging, Wi-Fi, lighting, information release, and emergency call have also been installed. While saving energy, such facilities also help with village affairs management and make tourists' resting easier.

(4) The cooling and heating systems of the historical museum, the village committee's office, and the nursing home has been upgraded. The cooling and heating energy source system is a magnetic levitation ground source heat pump, which provides cooling in summer and heating in winter. The simultaneity usage coefficient of the air conditioning system is 0.9, the cooling load is 450kW, and the heat load is 318kW. With the installation of ground source heat pump system, cooling and heating with clean energy are fully realized, saving about 75% of electricity cost.

(5) Smart agriculture: Ten solar insect killer lamps have been built in the farmland where photovoltaic agriculture is practiced. Solar photovoltaic hydroponics are applied in areas where photovoltaic agriculture is practiced. Solar photovoltaic container plant factory scheme is adopted, in which photovoltaic cells are installed on the top side of containers to provide clean energy for the LED lighting system, air conditioning system, and water system of hydroponic culture.

(6) Smart government affairs: PC-end software/phone APPs are designed, the functions of which include: web portal, document management, transaction management, culture center, knowledge center, system configuration, comprehensive management, supervision, and one-click police reporting. Thus, the modern digital paperless office for the management of village affairs is realized for the first time.

(7) Smart healthcare: One-button medical alert systems, smart watches, and smart cameras are installed in the nursing home, and are connected to the PC-end software/phone APPs, thus realizing remote video consultations with external high-quality doctors, real-time healthcare of the elderly, and a safe and happy life for the elderly in their hometown.

(8) Smart education: Distance education and training is provided, which shares excellent external teachers while training Xiaogang Village's own teachers in kindergartens, primary schools, and junior middle schools.

(9) Smart tourism: Analysis of the whole process of tourism in Xiaogang Village is conducted to provide the best personalized options for tourists on mobile phone APPs.

(10) "Tianshu-1" integrated smart energy management and service platform is created, which integrates energy, government affairs, agriculture, education, health care, and tourism, so as to realize centralized monitoring and management of solar photovoltaic, energy storage, charging piles, cooling and heat load, and within-village power distribution system; and through data sharing and analysis and regional-level performance calculation and analysis within the integrated smart energy project, the integration and dynamic smart management of energy and life in the village can be realized, which raises the comprehensive energy utilization rate of project, reduces carbon emissions, and improves villagers' quality of life and increases tourist

satisfaction.

(11) Gender inclusion is taken into full consideration in the project. Six women have played important roles in the design and construction of the project. As chief engineers, main designers, and main managers of the project, they have completed various kinds of work excellently. In addition, most of the elderly in Xiaogang Village are women, and the smart health care system is helping them live a healthy, long-lived, and happy life, and allows women in Xiaogang village's every family to work in agriculture and business and live their lives more efficiently and effectively.

(12) Xiaogang Village's integrated smart energy project and Fengyang County's smart energy project have been included as a model case into the "low-carbon development and optimization of energy infrastructure in China's small and medium-sized towns" program of the Asian Development Bank (ADB).

4. Overall effects of the project

(1) China's standards and Anhui' provincial standards are that the construction and development of beautiful countryside need to use traditional fuels such as wood, grass, and straw scientifically and gradually reduce such use, promote the use of clean energy such as electricity, solar, wind, biogas, and natural gas, and the proportion of farmers using clean energy should be ≥ 70%. Xiaogang Village integrated smart energy project 100% meets and is superior to the China and Anhui provincial standards for the construction of beautiful countryside.

(2) Through the overall implementation of the project, Xiaogang Village's average annual power generation capacity will reach 21.7774 million kWh, carbon dioxide emission is reduced by 18,315 tons, SO_2 emission is reduced by 480 tons, and NO_x emission is reduced by 240 tons, which has remarkable environmental benefits.

(3) Taking Xiaogang Village's 2020 electricity consumption of 10.56 million kWh as the reference value, through the implementation of the project, 100% clean energy power substitution has been fully realized, and thus, Xiaogang Village has become the first batch of China's low-carbon emission village. The problem of straw treatment since the middle of the past century has also been effectively solved through the comprehensive utilization production line. The clean application of biomass pellet fuel production has helped realize "carbon neutralization" in Xiaogang village.

(4) Through the construction of photovoltaic agricultural and solar photovoltaic facilities on the lands, reservoir and roofs, this project brings an annual income of 50,000 USD to the village collective and villagers. The straw purchase for the comprehensive straw utilization production line increases the village collective's and villagers' annual income by about 350,000 USD. In 2021, the integrated smart energy project brought Xiaogang villagers an annual income increase of 2%, year-on-year, and created dozens of jobs.

(5) With its vision, planning, demonstration, and achievements, Xiaogang Village's modern and green village integrated smart energy project tells how Chinese villages get close to nature in the most appropriate way in modern society, and how Chinese villages maintain their established customs and traditions (such as "feng shui") while coping with development and environmental challenges. Phase One, which took three months to complete, and Phase Two, which is expected to be completed in four months (considering the time needed for inspecting the roofs of each household for the application of solar photovoltaic generation, and

the fact that the straw system is relatively complex and the production cycle is slightly longer) of the Xiaogang Village project are successful cases of the construction of modern and green village in China, and a window for the world to understand the successful protection of ecology and the construction of modern and green in Chinese villages under the challenge of climate change. It is expected that other economies will be inspired by and benefit from the success of Xiaogang village.

5. Next step of planning for the project

The second phase of the Xiaogang village project is planned to expand the solar photovoltaic power generation system at Majiaba Reservoir, farmland for photovoltaic agriculture, and roofs of villagers' houses by about 7.5mw, with about 6 million USD investment and an expected 9% rate of return.

In the next three years, with reference to the Xiaogang Village project model, SPIC will develop modern and green village integrated smart energy projects in 565 counties, and will take "Tianshu-1" as the smart brain to enable low-carbon transformation of rural energy, digital management, affluent and happy life, and modern and green village on the field of hope.

Corresponding points of ESCI scoring mechanism		
Number	Corresponding points of ESCI scoring mechanism	Description of key points
One	**STRATEGY**	
1	Innovativeness	
1.1	Is the innovative concept come from the project itself or other existing programs?	1. Xiaogang Village integrated smart energy project is the first modern and green integrated smart energy project of SPIC, and it is also one of the first batch of integrated smart energy projects of modern and green village in China. 2. The project's smart brain system "Tianshu-1" connects the energy network, government affairs network, and community network, and sends the information regarding government affairs, agricultural affairs, business, tourism, health care, and education and training to Xiaogang Village instantaneously and accurately, becoming China's first software that manage village governance affairs with smart and digital technologies.
1.2	How the innovative policy design encourages financial support and public-private partnership?	1. The local government has provided nearly 600 hectare of idle land to the SPIC for the development of clean energy. 2. Photovoltaic agriculture has attracted the investment from the ChunHe Modern Agriculture Technology Company to plant crops on the land where photovoltaic cells are installed.
1.3	How does the innovative concept catch the trend of future development?	1. Before 2025, the project will be replicated by SPIC to the development and construction projects for villages in 565 counties of China. 2. Asian Development Bank (ADB)’s "low-carbon development model of small and medium-sized towns in China".
2	Inspiration	
2.1	Whether the idea can inspire later/subsequent cases?	The project's smart brain "Tianshu-1" will be used in 565 projects counties by 2025.
2.2	What domain has been enlightened by this policy?	1. The Chinese Central Government’s “Implementation Opinions of on Accelerating the Transformation and Development of Rural Energy and Promoting Rural Revitalization” is a guiding document for the project, which sets the aim as being beneficial for the construction of clean, low-carbon, eco-friendly,

		livable, and beautiful countryside. 2. It is mentioned in “2021 Instructions on Energy Work” issued by the National Energy Administration that clean heating should be developed in southern China according to local conditions. This is the guiding document for the application of ground source heat pump in the project.
3	Clearness	
	Is there any open and transparent channel of public communication?	1. The general public can get to know the general conditions, progress, and implementation of the Xiaogang village project through SPIC’s WeChat official account. As of February 2022, there are 30,000 hits on the topic. 2. Fengyang Television Station, People's Daily Online, and other important media outlets have very positive reports and comments on the Xiaogang Village project.
	Is there any difference between this policy and other similar policies?	1. The project adapts to local conditions, makes full use of local resource endowments and traditions to carry out personalized development, and has been built Xiaogang village into the first low-carbon village in Anhui Province within three months. 2. Smart brain of "Tianshu-1" is developed to integrate energy, government affairs, agriculture, education, health care, and tourism for integrated management.
Two	**MEASURE**	
4	Practicability	
4.1	Has any effective measure for moving ahead teen made?	1. By 2025, the SPIC will promote low-carbon transformation of rural energy in 565 counties. 2. The smart brain system "Tianshu-1", will be used in all above integrated smart energy projects.
4.2	Is there any numerical goal for reference?	"Tianshu-1" includes 9 functions: energy overview, intelligent prediction, intelligent regulation, intelligent operation, and intelligent maintenance, which can be developed and used in standardized menus.
5	Replicability	
5.1	Could the ideas, methods or techniques hp applied internationally?	1. Environmental adaptability: Rural population accounts for 60% of the world’s total population. APEC economies have abundant solar energy, wind energy, geothermal and other resources. With reference to the successful model of Xiaogang Village, we can make use of renewable resources according to local conditions and implement clean energy substitution. 2. Experience exchange: Along with Xiaogang Village, SPIC is willing to carry out exchange of experiences

		with APEC economies for both sides to achieve success.
6	Cost effectiveness	
6.1	Will it be cost-effective to implement?	The total investment of Phase One and Phase Two of the project is about 15 million USD, and the average internal rate of return is 6%, which meets the investment recovery requirements of SPIC's profit, and has remarkable emission reduction benefits.
6.2	Is there any measurable reduction of emission or energy use? Please describe the measurement method.	1. 18,315 tons of CO_2 emission, 480 tons of SO_2 emission, and 240 tons of NO_x emissions are reduced each year. The electricity consumption of Xiaogang Village in 2020 was 10.56 million kWh, which indicates that Xiaogang village has become a "low-carbon" village where clean energy has completely replaced traditional energy for electricity generation. 2. In the measurement, the standard coal consumption for the average power supply of thermal power plants is set as 307.6g / kWh, and the carbon dioxide emission per unit of thermal power generation is set as about 841g / kWh.
7	Consistency	
7.1	Are adopted measures consistent with energy policy and strategy?	1. In line with the low carbon emission target of the Paris Climate Accords. 2. In line with the APEC's initiative on the development of low-carbon towns. 3. In line with the "Implementation Opinions on Accelerating the Transformation and Development of Rural Energy and Promoting Rural Revitalization (China's National Energy Administration's planning [2021] No. 66). 4. In line with the "Guidelines for the Construction of Beautiful Countryside" (June 2015) issued by the Standardization Administration of China.
7.2	Is there any long-term measure or implementing organization for this project?	In 2021, SPIC established the Integrated Smart Energy Research Center and the Integrated Smart Energy Technology Co., Ltd. to study and implement 4 types and 33 scenarios of integrated smart energy projects: smart towns, centralized buildings, industrial parks, and energy bases, including modern and green village integrated smart energy projects.
Three	**PERFORMANCE**	
8	Completeness	
8.1	Is the achievement scale measurable?	1. Achieved 100% clean energy substitution, 100% comprehensive utilization of crop straw, and 100%

		harmless treatment of garbage and sewage in Xiaogang Village. 2. There is an area of 4,500 m^2 for cooling and heating by ground source heat pump, saving about 75% of electricity cost. 3. "Tianshu-1" has passed the certification examination by the China National Accreditation Service for Conformity Assessment. (CNAS).
8.2	Will it make a considerable success in project goals?	Phase One of the project is completed on time in 2021, and all expected objectives have been achieved. The construction of Phase Two has been started as planned in February 2022, and is expected to be completed in June 2022.
9	Verifiability	
9.1	Is there any data presented to support the project?	1. Awards: excellence award of the China Integrated Smart Energy Industry Association. 2. News reports: People's daily, sohu.com, chinapower.org.cn, and other media reports. 3. Interviews: appreciative comments by the director of the Xiaogang Village Committee
9.2	Is there any supportive measurement or reference for the provided data?	1. Pictures of the award 2. News websites 3. Promotional videos
10	Impact	
10.1	Will it make a significant change in the field of energy efficiency and energy saving?	1. As a clean energy, solar photovoltaic energy has completely replaced fossil energy in the village, realizing 100% clean energy substitution. 2. As a renewable energy, ground source heat pump makes full use of geothermal resources and saves 75% of electricity. 3. The overall carbon dioxide emissions of the project is reduced by 18,315 tons / year.
10.2	Will it impact multiple operational areas or just single specific area?	1. As a reference example, such kind of projects will be implemented for the development of 565 counties in 31 provinces across China. 2. Strategic cooperation has been reached with the Anhui Farming Group Co., Ltd. to jointly build a "double green project" that integrates green energy and green agriculture, and will have 50% of the economy market share in 2033.
11	Inclusiveness	
11.1	Is it gender	1. Six women have played an important role in the

	inclusive	design and construction of the project. As chief engineers, main designers, and main managers of the project, they have completed various kinds of work excellently. 2. Most of the elderly in Xiaogang Village are women, and the smart health care system is helping them live a healthy, long-lived, and happy life, and allows women in Xiaogang village's every family to work in agriculture and business and live their lives more efficiently and effectively.

CONTENTS

Ⅰ Technical Program

1. Natural Resources Analysis

Villages and towns are the basic unit of rural social development, and solving the issues relating to agriculture, rural areas and farmers is the key to the sustainable development of Chinese society. The high-quality rural development has become an urgent task for China in the next stage with what China has achieved in recent years, including the vigorous development of the low-carbon economy, continuous introduction of policies for achieving the two carbon-related goals, and the rural revitalization strategy making new grounds. Potentials can be found in developing low-carbon industries such as distributed wind power, photovoltaic, geothermal and biomass energy in rural areas according to local conditions, promoting clean energy, improving rural living conditions, and upgrading rural energy consumption. Such orientations will not only help to realize the low-carbon development of rural economy and transform the traditional energy consumption structure centering around straw and firewood, but also broaden the channels for farmers to increase their income and improve the villagers' sense of gain and happiness. The development of low-carbon villages and towns is vital to creating Modern and green village, and is also an inevitable trend in developing modern rural society.

Based on the resource endowment and current energy consumption situation of Xiaogang Village, as well as the main demands for transforming it into a Modern and green village, this project conducted a thorough research on the natural resources of Xiaogang Village in the initial stage.

1.1 Overview

At present, there are 23 villagers' groups, 923 households, and 4,127 people in Xiaogang Village. It covers an area of 1500 hectare, including 966.7 hectare of arable land.

1.2 Infrastructure

Centralized supply of water, power and natural gas has been achieved in Xiaogang Village.

The domestic water of Xiaogang Village is from the existing water plant in the north, with a designed treatment capacity of 20,000 tons/day, and Randeng Reservoir is the source.

Xiaogang Village is mainly powered by a 10KV transmission line, a branch of the 35KV Xiaoxihe Substation.

Regarding the communication facilities, 5G facilities have been installed on 4G base stations, and 5G signals have covered the village service center, museums and other major areas.

There are about 400 vehicles, all fuel powered, in Xiaogang Village as the distance to the counties and towns are relatively far and the regional charging facilities need further improvement.

There are 13 types of main public and residential buildings, namely Village Service Center, New-era Civility Square, residential area, Household-based Contract Museum, Comrade Shen Hao's Deeds Museum, Xiaogang Cadre Institute, farmhouses, Xiaogang Elderly's Home, Xiaogang Training Center, Xiaogang Visitor Center, clinic, school and passenger station.

1.3 Wind Resources

East wind dominates Xiaogang Village throughout the year at an average speed of 2.7m/s and a direction maintenance rate of 10%. The annual average wind speed at 80m is 5.25m/s, the high altitude wind shear ranges between 0.15 and 0.25, and east-northeast and northeast winds, being the main direction, also provide the most wind energy.

1.4 Photovoltaic (PV) Resources

Most of the annual total solar radiation, being 4639MJ/(m^2•a), in Xiaogang Village is concentrated in the C area, i.e. resource-rich area. The maximum monthly average total radiation extends from May to July, reaching 552.4 MJ/m^2; the minimum is 222.6 MJ/m^2 in December. RW=222.6/552.4=0.403, with a "B" rating, and the stability level is relatively stable.

1.5 Water Resources

With no major river flowing through and around Xiaogang Village, the surface water resources are limited. Xiaoxi River is the only natural water system, with a width of 10-15 meters and the highest water level reaching 21.4 meters above sea level. Randeng Reservoir is the main surface reservoirs around Xiaogang, with a total storage capacity of 47.6 million cubic meters. There is one small (II) reservoir, Majiaba Reservoir, in Xiaogang Village, located in Shima Village, Xiaoxihe Town, Fengyang County, which belongs to the Xiaoxi River system of the Huaihe River Basin. The reservoir has a catchment area of 2.75 km^2.

1.6 Geothermal Resources

Geothermal resources in Anhui Province are mainly distributed in the areas along the rivers, the basin in central Anhui, northwest Anhui, south Anhui and the Dabie Mountain Area. The discovered geothermal fields are mainly of the stratified and strip thermal storage types, and the water is mostly warm or slightly hot. According to the Rock-soil Thermal Response Test Report on the ground-source heat pump project around Xiaogang Village, the soil comprehensive thermal conductivity λ=1.91W/m.K, the underground temperature of buried pipes is 18.8℃, and the heat exchange between buried pipes and soil in summer is about 60W/linear meter, and that in winter is about 50W/linear meter.

Xiaogang Village has a sewage treatment plant adopting the A/O process, which consists of anaerobic and aerobic reactions; the treated water is discharged to the trunk canal of Xiaoxi River, and its quality reaches Level III of Sewage Discharge Standards. The designed daily capacity of the sewage treatment project is 1,500 m^3, and 750 m^3 has been built. The project mainly serves the northern and central area of Xiaogang Village and Shima community, with a network of about 8.7 km of pipes, serving 1.36 km^2.

1.7 Straw Resources

The arable land area is 966.7 hectare. The crops in the village are mainly rice and wheat, and soybeans, corn, peanuts and sweet potatoes are also planted. The crops are harvested twice a year. In recent years, on the basis of planting traditional crops, the plantation scale of cash crops such as black beans, grapes, stevia and vegetables has been expanding. The treatment of straw is mainly burnt in the fields or discarded.

As the straw to grain ratio of rice is smaller compared to wheat, corn and beans, the quantity of straw is small. At present, the straw is mainly from rice, and the straw resources in Xiaogang Village is about 20,000 tons/year.

1.8 Farming Waste Resources

In Xiaogang Village, there are still eight decentralized pig farms with a total of about 1,770 and four poultry farms with a total of about 7,650. According to the Design Requirements of Sewage Storage Facilities for Livestock and Poultry Farming (GB/T 26624-2011), the waste water produced by decentralized farming is about 38m^3/d with the solid excrement treatment process, and about 72m^3/d according to the water flushing process.

2. Technical Route

The Integrated Smart Energy Project that Made Xiaogang Village Modern and Green takes the rural revitalization strategy as an opportunity and rural energy supply as a link. It makes full use of the existing natural resources in the countryside, plans a variety of energy elements based on the planning concept of "environmental protection, low-carbon development, energy conservation and ecological friendliness", and launches integrated smart energy projects through various forms, such as "energy + ecology" and "energy + agriculture". Low-carbon village and ecological protection will be achieved through industrial development, green consumption and energy conservation by exploiting clean energy.

At the same time, big data, cloud computing, and Internet of Things among other smart services are integrated into key areas of Xiaogang Village's government agenda and people's livelihood. Government service network and community network based on the self-developed Tianshu-1 energy network platform are established to realize the "three networks integration". The three networks integrates the energy and agricultural modules, and the platform cooperates with external financial institutions, e-commerce, and cooperatives. Terminal services such as APP are provided for farmers, so that they can communicate with the outside world more conveniently. Such efforts also help to upgrade sales channels, bring industrial products to the countryside and agricultural products to the city, and realize integrated and smart management of energy, village affairs, industries, medical care, and education for every household. Villages are digitalized with smart technologies to transform into socialist beautiful countrysides characterized by high-quality and high-efficiency agriculture, livable and business-friendly rural areas, and rich and affluent farmers in the new era.

2.1 Solar Energy

Solar energy can be used in photovoltaic power generation, solar thermal power generation, solar lighting systems, solar household water heaters, solar regional heating systems, solar air conditioning systems, PV water pumps, etc. At present, PV power generation, solar lighting systems, solar household water heaters, and PV water pumps have been commercialized; solar thermal power generation has moved from technological development to promotion and application; solar regional heating technology has matured and is in the stage of domestic promotion and application; solar transportation and solar air conditioning systems are still in the stage of technological development and project demonstration.

Considering that the vast majority of villagers have installed solar water heaters on their roofs for hot water supply, this project plans to focus on promoting solar power generation systems.

A total of 18.7MWp PV power generation systems will be installed, composed of surface PV modules on the water body of Majiaba Reservoir, PV-agriculture modules in the west side of the intersection of Chuangxin Avenue and Gaige Avenue, and rooftop PV modules of households, with a designed operation period of 25 years. In 2020, the annual electricity consumption of Xiaogang Village was 10.56GWh and Phase I generated about 11.87GWh of power annually. Thus, 100% clean electricity replacement and low-carbon village have been truly realized. The project can save an average of 66,987,200t/a of coal equivalent and reduce 18,315t/a of carbon dioxide emissions per year, which is significantly beneficial to the environment. Being an effective supplement to the regional energy supply, the green-power-generating project is conducive to relieving the pressure of environmental protection of the

power generation industry in the region, propelling the sustainable and rapid development of the regional economy, and contributing remarkable social benefits.

Fig. 2-1 PV-agriculture and water surface solar power generation systems

2.2 Wind Energy

Wind energy is used mainly by converting the kinetic energy of atmospheric motion into other forms of energy. Wind is the horizontal movement of the air and propelled mainly due to the different intensity of solar radiation latitudinally on Earth. Currently, wind is mainly used for power generation.

However, Xiaogang Village is the hometown of Emperor Zhu Yuanzhang, and the county denies wind power projects on the ground that fengshui cannot be destroyed. We respect their suggestions and the local tradition.

2.3 Geothermal Energy

Geothermal energy is used through power generation and thermal utilization. Power generation is not promoted due to its high cost, while the application of ground-source heat pump system has been mature. The ground-source heat pump is a clean renewable energy utilization technology, which is a heating and cooling system using shallow geothermal resources on the Earth's surface (usually less than 400 meters deep) as the heat and cold sources of energy conversion.

Ground-source heat pumps save more than 2/3 of electricity compared with electric boilers, and about 1/2 of energy compared with fuel boilers. Thanks to the stable heat source temperature throughout the year, the cooling and heating coefficient of ground-source heat pumps can reach 3.5~4.4. Compared with traditional air-source heat pumps, their operation cost is 50%~60% of traditional central air conditioning systems.

In this project, the cooling and heating systems of Shen Hao Museum, village committee and nursing home are renovated with ground-source heat pump solutions. A central ground-source heat pump equipment room is set up near Comrade Shen Hao's Deeds Museum. For the air-conditioning system, the simultaneous utilization coefficient is 0.9, the calculated cold loads is 450kW and the calculated heat loads is 318kW. The cooling and heat source system is a set of maglev ground-source heat pump unit, which supplies cool air in summer and heat in winter. After the ground-source heat pump system is installed, Shen Hao Museum, the village committee and the nursing home are cooled down and heated up completely with clean energy, further helping transform Xiaogang Village into a low-carbon village.

Fig. 2-2 Ground-source heat pump system

2.4 Sewage Energy

Water-source heat pump is an air conditioning system utilizing the energy stored in water as a source of heat for energy conversion. The water bodies that can be used include groundwater, rivers, lakes, oceans and the recycled water from sewage treatment plants. Water-source heat pump units operate without any pollution and are a form of using clean and renewable energy.

Water-source heat pump units work by transferring heat from the buildings to the water in summer, extracting the energy from the water source with a relatively constant temperature in the winter, raising the temperature with air or water as the refrigerating medium according to the heat pump principle, and delivering heat to buildings.

Water-source heat pump technology features obvious advantages over heating systems based on boilers and air-source heat pumps. Water-source heat pumps save more than 2/3 of electricity than electric boilers and more than 1/2 of energy than fuel boilers. Thanks to the stable heat source temperature throughout the year, the cooling and heating coefficient of water-source heat pumps can reach 3.5~4.4. Compared with traditional air-source heat pumps, their operation cost is 50%~60% of traditional central air conditioning systems.

In the long term, the project plans to establish a water-source heat pump system with a capacity of about 200kW in the sewage treatment plant and provide cooling and heating services to Household-based Contract Museum.

2.5 Energy Storage

Energy storage technology is applied by adding a process of storing electricity based on the traditional power generation model, making the original system, which is almost completely rigid, become flexible. The safety, reliability, economic efficiency and flexibility of the power grid will be greatly improved.

The project has proposed to use container-type lithium battery for the storage facility. According to the PV power generation capacity, one set of battery with a capacity of 100kW/200kWh will be arranged at the side of the visitor center to ensure the energy consumption of the chargers. A charging-discharging scheme is adopted as the battery， which is charged during the day when PV modules generate power and discharged at night for the chargers.

Fig. 2-3 Integrated PV power generation and storage system

2.6 Biogas Energy

In areas with farming as the pillar industry, where manure and raw materials are abundant, biogas utilization is rapidly developing. Straw-to-biogas technology transforms crop straw into clean, efficient and convenient ecological energy sources.

The breeding scale of Baodi Breeding Pig Technology Co., Ltd. in Xiaogang Village is 100,000 pigs per year, and a biogas power generation system has been built. In the long term, it is planned to upgrade the biogas system and consider the development of biogas for villagers' own use.

2.7 Straw Utilization

Progress has been made in using straw, which is mainly for fertilizer production, as fuel and feed, and using straw as raw material and base material are supplemental means. Judging from consumption capacity, using straw as raw material, base material and feed are far from solving the problem of open burning of straw, while using it as fuel and fertilizer are the two ways with the greatest potential. Traditional solid fuels are made from crushing, grinding, drying and compressing biomass as the raw material. Black biomass pellet fuels are coal-like fuels made from crushing, grinding and then pyrolysing and carbonizing biomass at a low temperature. The volume density and energy density of solid fuel are increased after compression, which, to a certain extent, address the problem of straw storage and transportation. Traditional solid fuel production process is mature, and the market trading mechanism is well-structured. Black biomass pellets with good hydrophobicity and high energy density are easy to grind and feature better fuel properties.

The project plans to build a black biomass pellet production plant with an annual capacity of 15,000 tons and a straw processing capacity of 4T/h. With high quality and slightly higher fuel cost, black pellet fuels are more cost effective than natural gas. For heating, black pellets can replace coal stoves in urban areas (to be shutdown), natural gas (high price) and cooking and heating with bulk coal in rural areas. Black pellets enjoy a bright prospect in distributed clean heating in the context of peak carbon emissions and carbon neutrality.

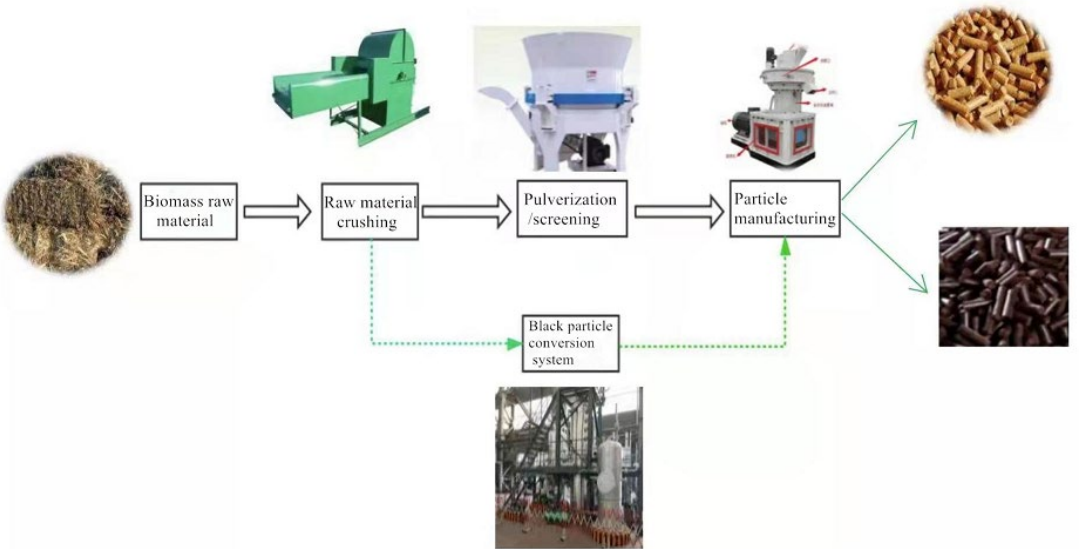

Fig. 2-4 Straw-to-pellet system

2.8 Smart Energy

The development of Tianshu-1 integrated smart energy control and service platform system helps to realize centralized monitoring and management of PV modules, energy storage facilities, charging piles, heating and cooling loads and village's power distribution system in different locations. Enabled by data sharing and analysis in the integrated smart energy project, this system has achieved smart, integrated, remote and visualized management of energy. Through regional performance calculation and analysis, it realizes overall integration and flexible management of energy in the village, improves the comprehensive energy utilization rate and reduces carbon emissions.

Based on big data analysis and supply-demand capacity prediction, the cloud platform can realize real-time energy consumption analysis, energy-side output prediction, demand-side consumption prediction, energy supply and consumption guarantee, smart analysis and decision making, user-side feedback, interactive management of energy supply and use, etc. Energy overview interface shows the overall energy structure and operation data of Xiaogang Village in three-dimensional diagrams, curve charts, and flow diagram among others. Multi-energy flow monitoring consists of comprehensive monitoring, power monitoring, heating and cooling monitoring, charging station monitoring, etc. Comprehensive monitoring interface displays various energy-related information of Xiaogang Village, including daily load curves of electricity, cooling and heating supplies, energy efficiency of electricity, cooling and heating equipment and alarming. Electricity monitoring interface displays the current electricity consumption of the whole village and various load information by building floor. Heating and cooling supply monitoring interface displays information on the operation, suspension and malfunction of heating and cooling equipment, including the current heating and cooling load on each floor of each building, histogram of the predicted and actual values of load, etc. Smart demand-side energy consumption prediction provides forecast of future load for multi-energy flow dispatching, including power, heating and cooling loads in the region, and specifically day-ahead load prediction, short-term load prediction and ultra-short-term load prediction. Demand-side energy consumption prediction is based on historical and meteorological data and considers real-time conditions. By accumulating a large amount of users' energy consumption

data through demand-side management, it is possible to conduct big data analysis with the users' big data information, upgrade the models of users' equipment and behavior with customized improvements, and improve the accuracy of energy consumption prediction by identifying real-time user data.

Based on the above output and load predictions and the limitation of equipment operation, smart and dynamic supply-demand matching can be performed to further gain an real-time energy dispatching strategy through the calculation. According to the actual controllable situation of the existing equipment, the automatic dispatching of ground-source heat pump units and air-cooled units can be realized, including automatic start/stop of equipment and automatic setting of water outlet temperature, etc.

Fig. 2-5 Tianshu-1 system

2.9 Smart Government Service

PC/APP software is designed, with functions including portal website, official document management, government affairs management, cultural center, knowledge center, system configuration, comprehensive management, inspection and supervision, one-key alarming, etc., to modernize the village committee with smart offices. Official document management function can achieve the e-management of document including sending and receiving, processing, approving, drafting, formating, and stamping, as well as the functions of statistical summary, inquiries, and archiving. Regarding mobile applications, the OA system can be used in Android, Apple, PAD and other terminals, so that issues can be processed on mobile devices. The notice and announcement function enables the issuing of notices and announcements to the village council, villagers, etc. accordingly, and users can check whether the people concerned have received or read the related document. The meeting management function features meeting notice issuance, participation scope determination, participation receipt sending, pre-meeting reminders, meeting minutes, meeting statistics, etc. The daily management function includes the management of village affairs and other applications on the list.

Fig. 2-6 Smart government service system

2.10 Smart Community

It mainly includes smart healthcare (health testing system for the elderly in nursing homes), smart agriculture (energy agriculture+, PV-hydroponics system, etc.), and smart tourism facilities (smart streetlight bench, smart image, multimedia, etc.).

Smart healthcare: The elderly nursing home is upgraded with smart functions, including providing smart devices such as smart bracelets, one-key alarming and desktop robots to realize automatic alarms by collecting real-time physiological big data, thus protecting the life and safety of the elderly.

Fig. 2-7 Smart healthcare system

Smart agriculture: The design focuses on PV pest control lights and PV-hydroponics system, mainly connecting clean energy such as solar power generation, modern agricultural farming and breeding, and efficient protected agriculture. PV power generation system will help to achieve the clean use of energy while supporting agricultural development.

Ten solar pest control lights are installed in the integrated PV-agriculture farmland. The

lights are special devices taking into account the phototropism of insects and emit trapping light source at a specific spectral range sensitive to insects. It prevents and control insects and insect-borne diseases by reducing the index of disease and insect through trapping and effectively killing insects.

A PV-hydroponics system is deployed in the integrated PV-agriculture area, using the PV container plant factory solution. Hydroponic plants are planted inside the container, with PV modules installed on the top to power the internal lighting system, air conditioning system and water system. Two containers are arranged in a unique architectural style to form a plant factory. Smart control in a closed environment provides the light, temperature, water, air, and fertilizer required for the full growth cycle of any plant, and it is not affected by the external natural environment. Its characteristics include: high flexibility, fast movement, convenient transportation, and swift installation are enabled by the lightweight and helicopter-lifting design of vehicle-mounted standard containers according to military and industrial standards; the average monthly output of fresh vegetables is 400 kg; more than 30 kinds of vegetables can be grown; the new control system and environmental control system enable smart control of temperature, humidity, light, CO_2, nutrient solution PH/EC, fresh air, etc.; it can adapt to an ambient temperature of -30℃-40℃; thermal insulation and heat preservation are outstanding and a great amount of energy and water can be saved; centralized monitoring and management are enabled by LAN and Internet; data storage and backup management are conducted automatically, and functions of graded password permission setting and SMS warning are provided.

Fig. 2-8 Smart agriculture system

Smart tourism facilities: Smart streetlight and smart bench systems are installed in communities, cadre institute, Household-based Contract Museum, Shen Hao Museum, attraction sites, stations, etc. to strengthen village management, enhance resting comfort and save energy. Integrating WIFI base stations, cameras, infrared sensors, electronic displays, 5G base stations, etc., the smart streetlight system is an information carrier and entrance of the energy station, realizing the functions of environmental protection monitoring, security monitoring, regional noise monitoring, emergency alarm, etc. The smart solar bench integrates functions of resting, cell phone charging, WIFI, lighting, information release, emergency call, etc. As an essential part of smart village and smart energy system, smart streetlights and smart benches promote the implementation of “smart energy” and “smart village” in energy, lighting and information and communication and tourism.

Two 120kW DC chargers, each equipped with two chargers ports and 100kW/200kWh

energy storage capability, are installed in the PV carport of the visitor center. The facilities can meet the charging needs of local tourists and electric vehicles such as tourism electric buses, and are designed to operate for 10 years. The charging piles feature functions of human-machine interaction (quantitative charging, pre-set charging, fixed quantity charging, automatic charging light), inquiry (account balance, charging time, etc.), metering, card payment, communication, safety protection, etc.

Fig. 2-9 Smart tourism facilities

Ⅱ Model and Benefit Analysis

1. Development and Service Model

The Integrated Smart Energy Project that Made Xiaogang Village Modern and Green provides examples based on strict implementation of the China rural revitalization strategy and solves the obstacles in developing beautiful villages by taking advantage of the group's advantages in clean energy industry. The project helps to promote the high-quality development model integrating rural industries and villagers' energy consumption habits, and achieve a win-win situation of integrated smart energy industry development and beautiful village construction.

1.1 Seize the market. Supported by the Greenland Action, the new energy and integrated smart energy market in rural areas will be taken, with the regional market as the orientation and rural resource endowment, energy consumption and government management as the entry points.

1.2 TO C model. Part of the project's clean energy is directly supplied to farmers and village enterprises. With the intermediate TO B avoided, rural areas gain power directly from the source, thus enjoying affordable green and low-carbon energy.

1.3 Village construction driven by new energy. A new energy base of a certain scale will be built to provide clean energy on the one hand and obtain revenue on the other. Part of the revenue will be used to finance the rural revitalization to achieve a win-win and balanced situation for the enterprise and the village. For example, Xiaogang Village with a population of more than 4,000 can build a 30MW new energy power station, while making efforts to transform into a beautiful village characterized by smart energy, smart governance, smart community and other smart functions to realize the requirements of enterprise on yields.

1.4 Integration. The group will launch projects in more than 540 counties before 2025. With counties, industrial parks, and village as the development units, multiple integrated

decentralized wind power, distributed PV and other small and medium-sized new energy projects will be conducted. This integrated development approach will help to give full play to the advantages of large-scale, professional and regional development, reduce project investment and enhance returns.

1.5 Integration of three networks. Based on distributed and decentralized new energy projects, an energy network connecting every household will be established. With villages as the units, the data from the government network, energy network and community network will be integrated, thereby converting the data into economic activities and benefits.

2. Economic Benefits

The total investment of this project is about USD 15 million, and 20% of the engineering and construction investment is used as the capital fund, with the internal rate of return of the capital fund being 6%. In order to gain higher yield in the future, the overall yield of the project will be enhanced in terms of policy revenue and additional revenue. The policy revenue includes green certificate revenue (will be applied as the Energy Bureau will release the green certificate policy), and direct distributed power sales revenue (green power is directly supplied to village enterprises to improve the LCOE). The additional revenue includes advertising revenue (advertisement services are provided considering the functions and styles of smart streetlights, smart benches, household energy storage facilities and other equipment), and site revenue (farmland renting and joint crop sales are available on integrated PV-agriculture land).

3. Environmental and Social Benefits

Based on the practices of the Integrated Smart Energy Project that Made Xiaogang Village Modern and Green, the achievements of poverty alleviation are consolidated with the green and smart energy projects and support given to developing specialized local industries. The project also helps to solve the problem facing industrial revitalization, promote the integrated development of “green power + rural revitalization + ecology”, transform Xiaogang into an ecological, smart and happy village, and eventually realize the goal of making Xiaogang a beautiful village characterized by “strong agriculture, beautiful countryside, affluent farmers and prosperous industries”.

Ecological Xiaogang: Actions should be taken to make full use of the existing resources in Xiaogang Village, maintain local characteristics, develop a variety of energy sources and realize integrated and smart management. Renewable resources such as solar energy, ground- and water-source heat and agricultural and forestry waste are used to provide clean energy to the village. Such efforts will help to realize the achievement of 100% comprehensive utilization of straw, 100% harmless treatment of sewage and garbage, and 100% clean energy consumption.

Smart Xiaogang: The integrated smart energy control enabled by Tianshu-1 and integrated smart management provided by the service platform integrate smart elements such as big data, cloud computing and Internet of Things into such key areas as government affairs and people’s livelihood in Xiaogang Village. Government service network and community network based on the energy network platform are established to realize the “three networks integration”. The self-developed Tianshu-1 includes 49 applications in nine categories and has passed the CNAS certification. Achieving the coupling and optimal allocation of energy, it is a hub of energy source, grid, load and storage and a hub that integrates the three networks. Tianshu Cloud is

connected with related high-quality platforms to realize the interconnection of energy network, government service network and community network, strengthen the information utilization in village affairs, education, medical care, pension, tourism and business, and solve the rural demand for digitalizing the village. Elderly care in rural areas is a difficult problem faced by China. In this project, we have developed a smart elderly care module, added smart functions to nursing homes, and provided smart devices such as smart bracelets, one-key alarming, desktop robots, etc. to collect big data in real time, thus protecting the health of the elderly. The three networks integrates the energy and agricultural modules, and the platform cooperates with external financial institutions, e-commerce, and cooperatives. Terminal services such as APP are provided for farmers, so that they can communicate with the outside world more conveniently. Such efforts also help to upgrade sales channels, bring industrial products to the countryside and agricultural products to the city.

Happy Xiaogang: Green and low-carbon energy utilization is achieved; green energy cultural corridor is built to increase tourism scenes and improve tourism quality; village collectives and villagers participate in project development by providing resources such as land, roofs, and straw; “energy + agriculture” projects are carried out, and large-scale and industrialized development of PV-hydroponics farming is achieved through the integrated PV-agriculture model; the comprehensive utilization chain of straw is expanded, and there are plans to develop charcoal-based fertilizer production; the electrification and unmanned transformation of agricultural machinery are promoted to modernize agricultural production with technologies. A long-term mechanism to increase capital and generate income is established to provide employment opportunities for villagers and effectively improve their sense of gain and happiness.

Regarding the Integrated Smart Energy Project that Made Xiaogang Village Modern and Green, after completion, it will generate about 21.7774GWh of electricity annually on average and reduce CO2 emission by 18,315 tons, SO2 by 480 tons and NOX by 240 tons. As Xiaogang Village consumed 10.56GW of electricity in 2020, the village will realize the full replacement of clean power to transform into a low-carbon village. The comprehensive straw processing line can effectively solve the problem of straw treatment in Xiaogang Village. At the same time, carbon neutrality can be achieved through the preparation and application of biomass pellet fuel. Integrated PV-agriculture modules, water surface PV modules and rooftop PV modules can bring an annual rental income of USD 50,000 to the village collective and villagers. The annual straw purchase by the comprehensive straw processing line can increase the income of the village collective and villagers by about USD 350,000, which can effectively improve the villagers' sense of happiness and gain.