WFP World Food Programme

Control Temperature of Stored Grain Warehouse with Intelligent Photovoltaic Air Conditioning System

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Cloud School

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Demand of Green and Low-Carbon Grain Storage

1 Demand of Green and Low-Carbon Grain Storage

1.1 Green Grain Storage Enhancement Initiative Aligns with "Carbon Peak and Carbon Neutrality" Goals

During the 75th United Nations General Assembly debate, General Secretary Xi Jinping solemnly pledged to "achieve carbon peak by 2030 and carbon neutrality by 2060." According to the National Food and Strategic Reserves Administration's "Action Plan for Enhancing Green Grain Storage," newly constructed warehouses with suitable roof conditions can incorporate rooftop solar photovoltaic panels.

From July 17th to 18th, 2023, the National Conference on Ecological and Environmental Protection was held in Beijing. General Secretary Xi Jinping emphasized the need to actively and prudently promote carbon peak and carbon neutrality...

1 Demand of Green and Low-Carbon Grain Storage

1.2 Green energy-driven solutions are urgently needed for air conditioning and temperature control in grain storage.

Currently, the technology of air conditioning and temperature control in grain storage has been widely applied in China, effectively controlling the temperature in the warehouse and playing an important role in reducing grain loss and ensuring quality. However, over an extended period of use, the issues of high energy consumption and electricity costs remain unresolved. By using solar photovoltaic(PV) power to drive the air conditioning(A/C) system, reducing or eliminating the reliance on the grid, electricity costs can be reduced. While the technology of PV power generation on the roof of grain storage facilities is mature, the problems of high initial investment costs and long return on investment periods have not yet been resolved. This restricts the application of PV power generation on the roof of grain storage facilities.

1 Demand of Green and Low-Carbon Grain Storage

1.2 Green energy-driven solutions are urgently needed for air conditioning and temperature control in grain storage.

Only a small number of grain storage enterprises utilize the rental of their rooftop space for PV power generation, grid connection, electricity compensation, and receive a minimal amount of rent for the roof. The cost-saving and efficiency-improving effects are not very significant, and the return on investment period is long.

The technology for air conditioning and temperature control in grain storage is widely applied

1.3 "Intelligent PV-Based Air Conditioning Temperature Control Technology for Green Storage "

To reduce the energy consumption of air conditioning temperature control in grain storage, it is crucial to make the most of cost-effective and efficient green energy sources. Using solar photovoltaic power to supply electricity for air conditioning temperature control in grain storage holds significant importance in achieving the country's carbon peak and carbon neutrality goals. It also aligns with the enhancement of green grain storage practices and efforts to reduce grain loss.

We have developed the "Intelligent Photovoltaic-Based Air Conditioning Temperature Control Technology for Green Storage ," with the core component of "Intelligent Photovoltaic Air Conditioning Temperature Control System".

1.4 "Intelligent PV A/C Temperature Control System" Introduction

PV Power Generation + Intelligent Drive + PV A/C = A/C Temperature Control

Solar photovoltaic panels generate electricity independently, operating off-grid without relying on the national power grid, providing green energy.

PV Power Generation

Intelligent drive

Prioritize the use of PV electricity, intelligent grid compensation, intelligent control algorithms, and seamlessly switch between photovoltaic and grid power sources.

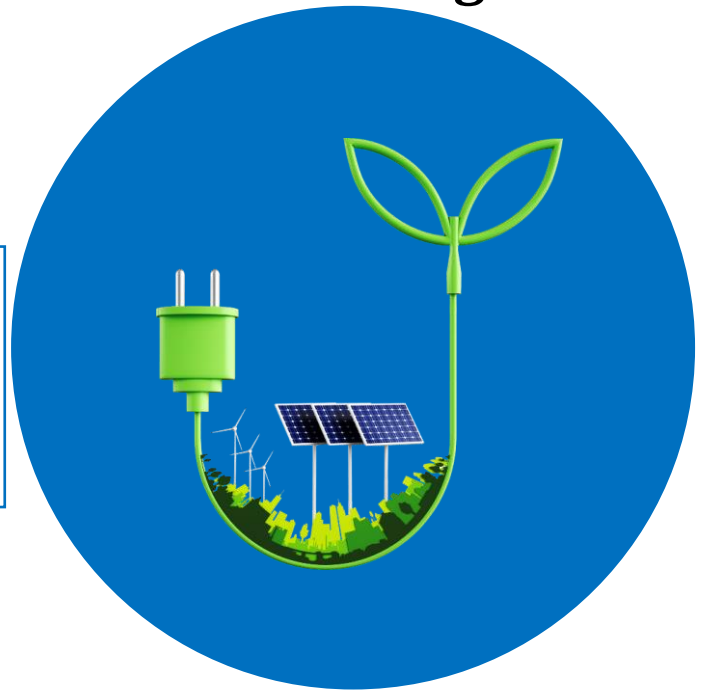
Direct → PVA/C

Inverter → A/C

→ A/C TC

Realize multiple power supply mode switches, such as sunny days, cloudy days, overcast days, and nighttime.

Green Storage



Carbon Peaking / Carbon Neutrality

1.5 Application Case of the Intelligent PV A/C Temperature Control System

Wuhan National Rice Trading Center Co., Ltd.

This addresses the issues of high electricity costs for refrigeration and air conditioning, as well as the high initial investment and long return on investment period for photovoltaic power generation.

It achieves "zero" electricity consumption or low electricity consumption (from the grid) for low-temperature or semi-low-temperature grain storage, contributing to energy conservation, carbon emissions reduction, and environmental protection.

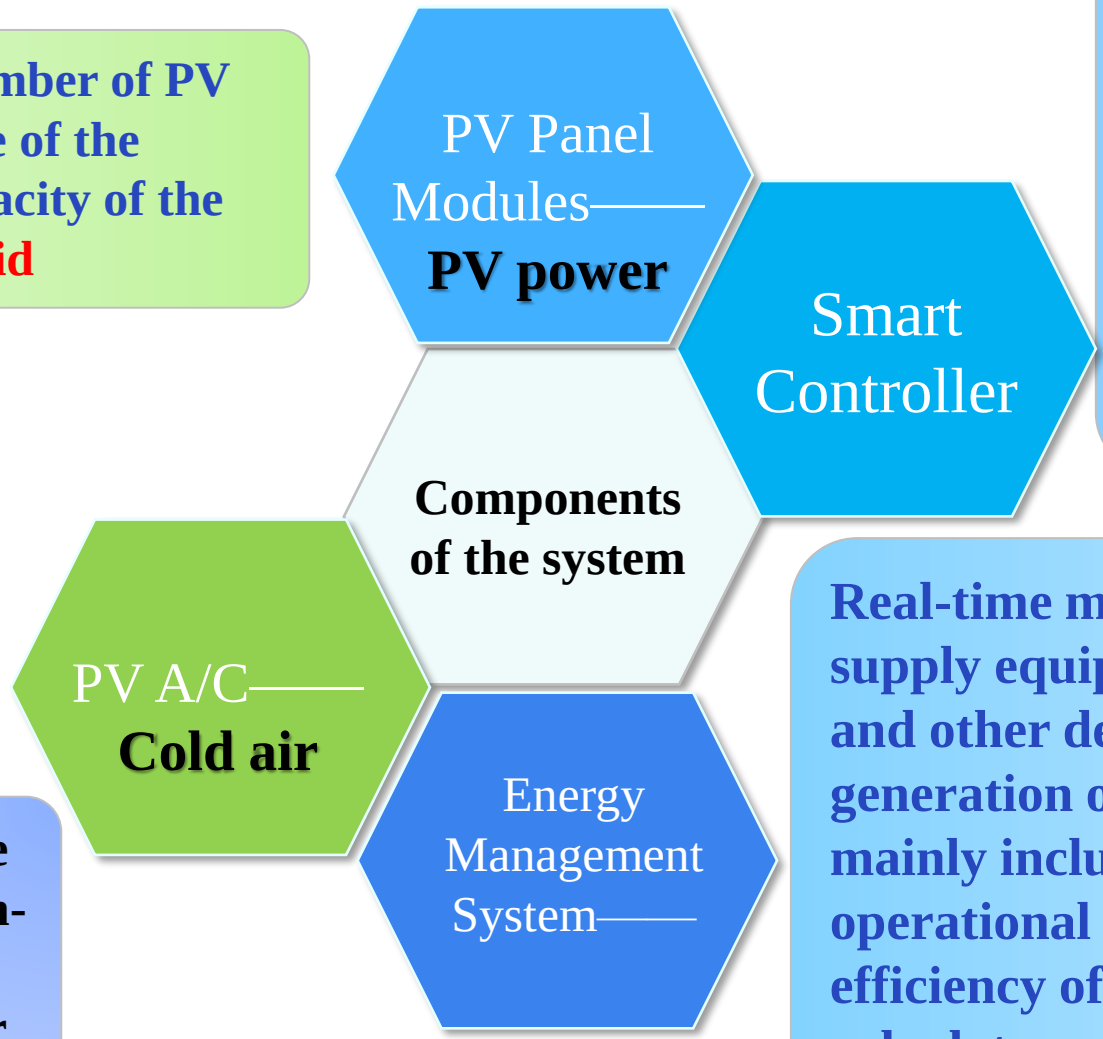
02

Intelligent Photovoltaic Air Conditioning （PV A/C ） System

2 Intelligent PV A/C System

2.1 The System Components

Configure a certain number of PV panels based on the size of the warehouse and the capacity of the A/C system. ——off-grid



Prioritize the use of off-grid independent PV electricity for both types of A/C. PV electricity and grid electricity are connected continuously and compensate each other uninterruptedly, when the weather changes, sunny, semi cloudy, and all cloudy.

The primary source is the PV A/C system, Save . Non-PV A/C can also be used, albeit with slightly higher energy consumption.

Real-time monitoring of intelligent power supply equipment, electricity meters, PV A/C, and other devices allows for the automatic generation of various reports. These reports mainly include power consumption and operational status, ultimately enhancing the efficiency of the system's operation. It also calculates energy savings and carbon reduction effects.

2.2 PV Panel Modules

Based on the size of the warehouse and the capacity of the A/C system, the corresponding number of PV panels should be configured. As an example, for a warehouse with a capacity of 5000 tons, which meets the requirements for low-temperature grain storage, and is equipped with two 6HP PV A/Cs:
Generally, a 6HP PV A/C is equipped with a 6KW PV panel. Therefore, for a single warehouse, it requires 12KW of PV panel modules. This means one warehouse would need 22 pieces of 550W PV panel modules. The area covered by the PV panel modules is approximately 30-50 m^2 and can be arranged in a 2x11 configuration.

The matching of PV A/C tonnage and the configuration of PV panels

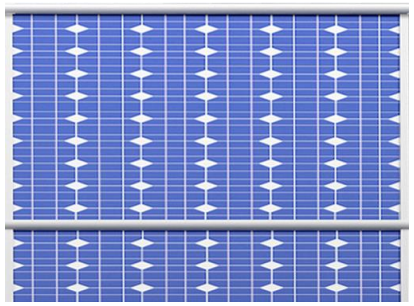
PV AC	3HP	5HP	6HP	8HP	10HP	12HP	16HP
PV Panels	3KW	5KW	6KW	8KW	10KW	12KW	16KW

The matching of non-PV A/C tonnage and the configuration of PV panels

Split AC	3HP	5HP	6HP	8HP	10HP	12HP	16HP
PV Panels	3.6KW	6KW	7.2KW	9.6KW	12KW	14.4KW	19.2KW

2.3 PV A/C

The photovoltaic panels convert sunlight into direct current (DC). After being connected in series or parallel, the DC current is input into the intelligent control system of the photovoltaic air conditioning unit. It is then stabilized to output DC voltage ranging from 260 to 310V. The inverter controller is connected to both the compressor and the fan, directly driving the DC variable-frequency compressor and the DC EC fan.



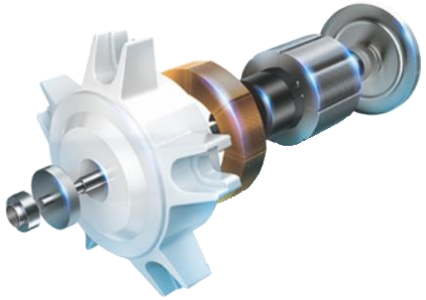
PV Panels
(series/parallel)

Intelligent
Control
System

260~310V
DC

Inverter
Controller

Direct
Drive



DC Variable Frequency
Compressor + DC Fan

2.3.1 Common PV A/C Designs

2.3.2 Common PV A/C Parameter Table - Establishing Standardized Products

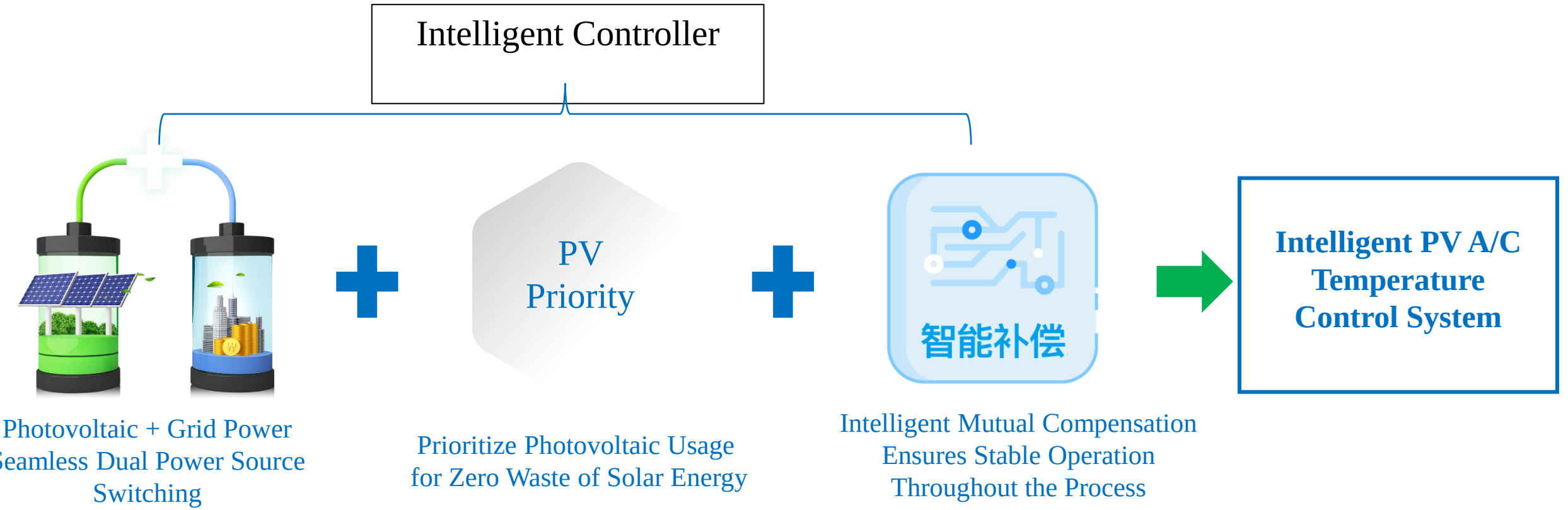
Model	HKY-8.5DL4DAA	HKY-14.2DL4DAA	HKY-16.9DL4DAA	HKY-28.3DL4DAA	HKY-34DL4DAA
PV Panel Configuration	3KW	5KW	6KW	12KW	15KW
PV Controller	3KW	5KW	6KW	12KW	15KW
Rated Cooling Capacity:	8.5kW	14.2kW	16.9kW	28.3kW	34.0kW
Compressor Rated Input Power	2.4kW	3.3kW	3.6kW	6.7kW	7.3kW
Rated Current of the Compressor (Phase Current)	3.95A	5.01A	5.47A	10.18A	11.1A
Maximum Input Power of the Compressor	3.6kW	4.95kW	5.4kW	10.0kW	11.0kW
Maximum Input Current of the Compressor (Phase Current)	5.5A	7.5A	8.2A	15.2A	16.7A
Supply Air Fan Power	0.37kW	0.37kW	0.75kW	1.2kW	1.2kW
Condenser Fan Power	0.15kW	0.30kW	0.30kW	0.35kW	0.35kW
Installed Total Power	3.18kW	3.97kW	4.65kW	8.25kW	8.85kW
Temperature Setting Range	5~30℃	5~30℃	5~30℃	5~30℃	5~30℃
Air Outlet Size	250*250mm	250*250mm	250*250mm	400*400mm	400*400mm
Refrigerant:	R410A	R410A	R410A	R410A	R410A
Noise:	63dB(A)	64dB(A)	65dB(A)	67dB(A)	67dB(A)
Weight:	100kg	120kg	130kg	240kg	260kg

2.4 Intelligent Controller

To address the mismatch between the current used by ordinary grain storage A/C and PV power generation, we have developed an intelligent controller suitable for regular A/C. This resolves the compatibility issue of using PV power for existing A/C, achieving independent off-grid PV power generation with priority supply. **It ensures continuous and uninterrupted mutual compensation between grid electricity and PV power**, significantly enhancing the flexibility of the application. The core technologies include **intelligent compensation algorithms and operation mode switching techniques**.

2.4.1 Intelligent Compensation Algorithm - Seamless Switching between PV and Grid Power Sources

The intelligent compensation algorithm is one of the core technologies of the intelligent controller. It calculates the required operating frequency and output power P0 of the unit based on the set temperature difference. P0 = Ps (PV power generation) + Pa (AC input power). The intelligent controller automatically detects the PV power generation Ps, and the AC input power will be automatically compensated based on the photovoltaic power generation and the unit's output power to prioritize the use of photovoltaic power and ensure the stability of the unit's output power.



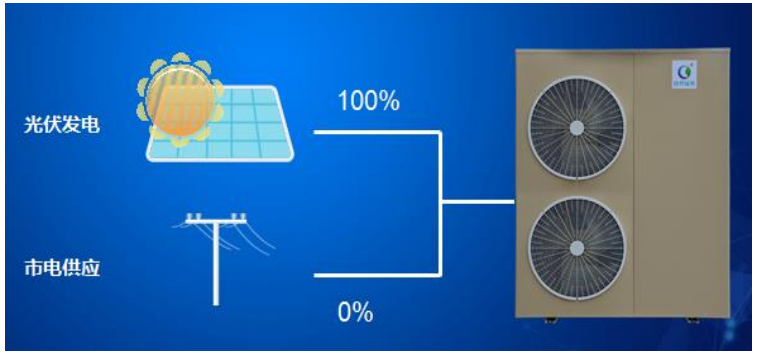
2.4.2 Intelligent Controller Parameter Table - Standardizing Product Formation

Model	SUN-175KTL-H0	SUN-110KTL-M0	SUN-60KTL-M0	SUN-12/15KTL-MO
Efficiency				
Maximum Efficiency	99%	98.60%	98.71%	98.60%
Chinese Efficiency	98.30%	98.10%	98.30%	98%
Input				
Maximum Input Voltage	1,100 V	1,100 V	1,100 V	1,100 V
Maximum Input Current per MPPT	26 A	26 A	22 A	26 A
Maximum Short Circuit Current per MPPT	40 A	40 A	30 A	40 A
MPPT Voltage Range	200 V ~ 1,000 V	200 V ~ 1,000 V	200 V~1,000 V	200 V ~ 1000 V
Rated Input Voltage	750 V	600 V	600 V	600 V
Maximum Input Channels	20	20	12	8
Number of MPPTs	10	10	6	4
Output				
Rated Output Power	125,000 W	110,000 W	60,000 W	12,000W/15,000W
Maximum Output Apparent Power	137,500 VA	121,000 VA	66,000 VA	13,200VA/16,500VA
Output Voltage Frequency	50 Hz	50 Hz	50 Hz	50 Hz/60 Hz
Rated Output Current	144.4 A	167.2A	91.2 A	45.6A/60.8A
Maximum Output Current	160.4 A	185.7A	100 A	50.4 A/67.2 A

2.4.3 Intelligent Thermostat - Seamless Mode Switching, Smart Control

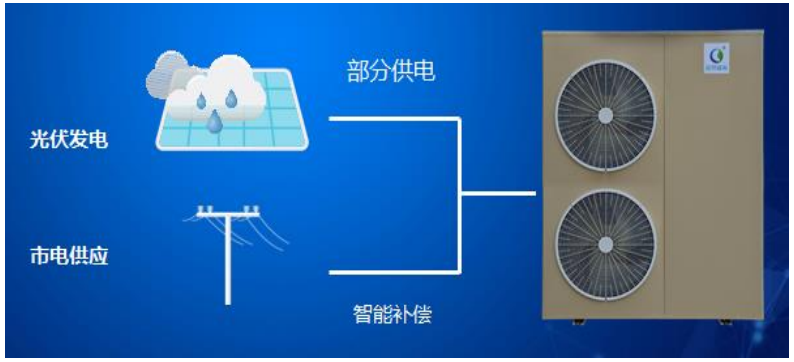
Sunny Day Mode:
Zero Electricity Cost for Cooling/Heating

On a clear and sunny day, the PV system generates enough power to fully meet all the electrical needs of the PV A/C, achieving 'zero electricity cost' for air conditioning cooling.



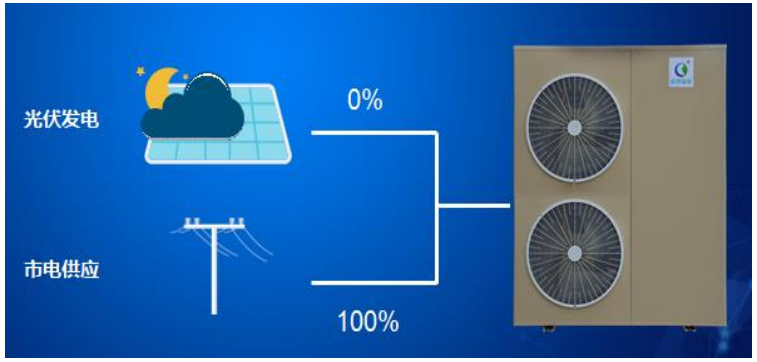
Overcast Day Mode:
Intelligent Compensation for Enhanced Stability

In overcast and rainy weather, when sunlight is insufficient, the photovoltaic system prioritizes providing partial power. The intelligent control system adjusts grid compensation for partial electricity usage, ensuring continuous operation of the photovoltaic A/C.

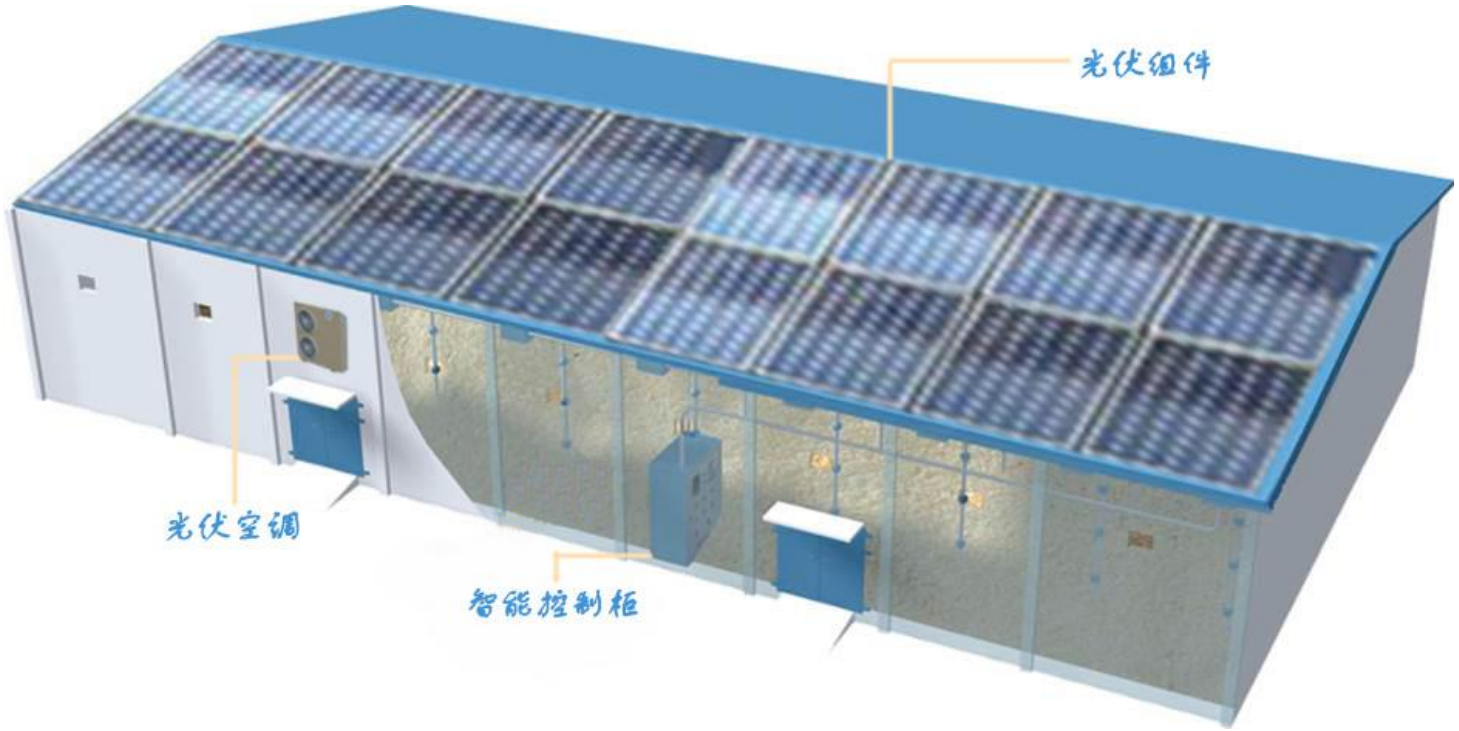


Night Mode:
Direct Power Supply from the Grid

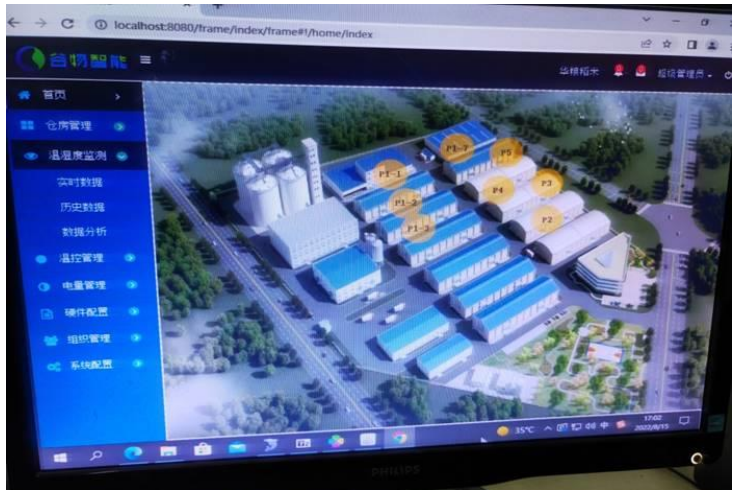
During the night, when the PV system is not generating power, the entire power supply is compensated by the grid, allowing the PV A/C to continue running.



2.5 Energy Management System



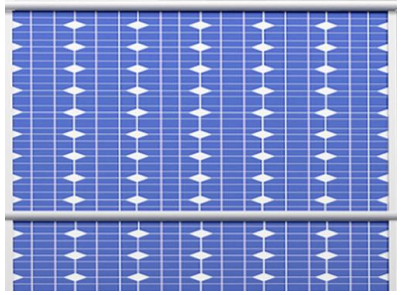
The Energy Management System is used to monitor the real-time operation of devices such as the intelligent control cabinet, electricity meters, and PV A/Cs. It automatically generates various reports, including power consumption reports and air conditioning operation status, to enhance operational efficiency. Additionally, it calculates energy savings and emission reductions.



Mobile App - View Anytime, All in Your Hands

2.6 Intelligent PV A/C Temperature Control System vs. Traditional PV Power Generation System

Traditional PV Power Generation System



PV Panels

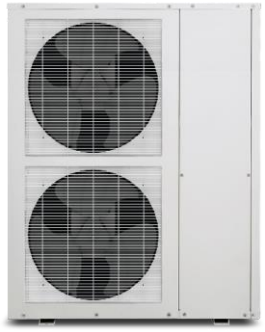
Inverter loss is approximately 10%

Inverter

\+

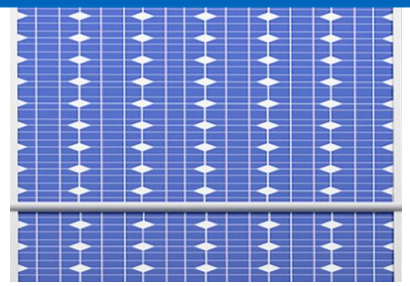
AC/Rectification/DC/Loss approximately 10%

Grid Connection



A/C Main Unit

Intelligent PV A/C Temperature Control System



PV Panels

PV A/C

By reducing the number of inverters and grid connection equipment, we aim to significantly reduce equipment investment costs for users. This can lead to an investment reduction of over tenfold, resulting in a 10% to 20% increase in energy savings from PV power generation. Additionally, installation becomes more convenient.

Comparison and Analysis Table with Traditional PV Power Generation System

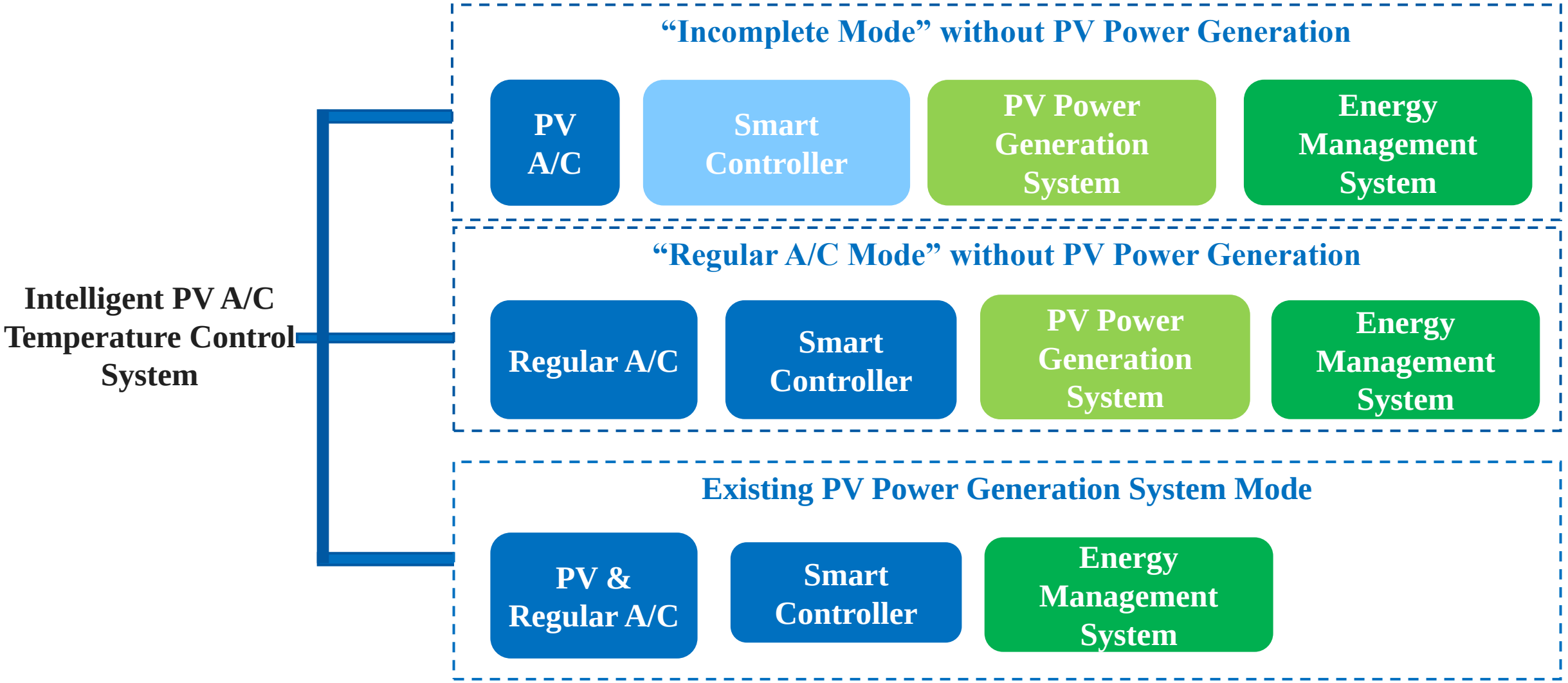
Intelligent PV A/C Temperature Control System	Traditional PV Power Generation System
Fully self-sufficient, no need for grid connection application.	Self-consumption with excess power declaration to the grid
Prioritize using solar power, intelligently supplement with grid electricity.	Feed the surplus solar energy back to the grid, then use grid electricity
Reduce the number of inverters and grid connection equipment.	Grid connection requires inverters and distribution cabinets
Powered by DC, more efficient with solar energy by over 20% compared to regular air conditioners.	Losses: Inverter approximately 10% + AC/DC/DC conversion approximately 10%
No grid connection or registration required, making installation more convenient	Requires registration, and grid connection installation is complex
For a flat warehouse with a capacity of 5000 tons, only 30-50 square meters of PV panels are needed, with an investment cost of about 60,000 yuan	For a flat warehouse with a capacity of 5000 tons, the investment cost for covering it with PV panels is approximately 500,000 yuan.
The system investment cost can be recovered through saving on air conditioning electricity bills within 3 years. The investment is low and the payback period is short	Selling PV power to the grid, with a investment payback period of 10 years.
Each PV panel weighs about 27.2kg. Installing 22 panels per warehouse, the total weight of PV components for a single warehouse is 598.4kg. This is lightweight, ensuring high safety, and does not require rechecking.	The additional weight of the PV system, including the module weight of approximately 6 tons, constitutes a constant load. It is necessary to engage professionals from the relevant departments to reevaluate the roof's load-bearing capacity to ensure its safety.

VS

Analysis of Economic, Social, and Environmental Benefits

3 Analysis of Economic, Social, and Environmental Benefits

3.1 Application Modes



3.2 Economic Benefit Analysis

The Intelligent PV A/C Temperature Control System can cater to different needs including new construction projects, existing regular air conditioning systems, and existing PV power generation systems. It involves configuring PV air conditioning units, intelligent controllers, PV power generation systems, and energy management systems accordingly.

Taking a flat warehouse with a capacity of 5000 tons that meets the requirements for low-temperature grain storage as an example:

3.2.1 Investment Estimate for "Complete Mode" Application of Intelligent Photovoltaic Air Conditioning Temperature Control System:

Calculating based on 2 units of 6HP air conditioners for a single warehouse, the installed capacity for photovoltaic power generation requires 12KW. At a cost of 4 yuan per watt, the investment cost for the photovoltaic power generation system is approximately 48,000 yuan.

The investment cost for 2 units of 6HP photovoltaic air conditioners is 66,000 yuan.

The total investment cost for a single warehouse's intelligent photovoltaic air conditioning temperature control system is 114,000 yuan.

3.2.2 "Regular Air Conditioning Mode":

Calculating based on 2 units of 6HP AC air conditioners for a single warehouse, the installed capacity for photovoltaic power generation requires 14.4KW. At a cost of 4 yuan per watt, the investment cost for the photovoltaic power generation system is approximately 57,600 yuan. The investment cost for one 15KW intelligent controller is 6,000 yuan. The total investment cost for a single warehouse is 63,600 yuan.

3.2.3 "Existing Photovoltaic Power Generation System Mode":

The investment cost for a photovoltaic grid-connected system is over 180,000 yuan. Calculating based on 2 units of 6HP photovoltaic air conditioners for a single warehouse, the investment cost for two 6HP photovoltaic air conditioners is 66,000 yuan. The unit price of a photovoltaic air conditioner is 3,000 yuan more expensive than a regular air conditioner.

3.2.4 Calculation of Photovoltaic Power Generation System Investment Payback Period:

The investment cost for the photovoltaic power generation system can be recovered through saving on air conditioning electricity bills over its 25-year lifespan.

In the case of using the photovoltaic air conditioning in "Photovoltaic Air Conditioning Mode", the investment payback period is 48,000/17,300=2.8 years, making a profit for 22 years!

In the case of using "Regular Air Conditioning Mode", the investment payback period is 63,600/17,300=3.7 years, making a profit for 21 years!

In the case of using "Existing Photovoltaic Power Generation System Mode" and selling electricity back to the grid, the photovoltaic investment payback period is 180,000/17,300=10.4 years, making a profit for 14 years!

The Intelligent Photovoltaic Air Conditioning Temperature Control System requires less investment and has a shorter payback period.

3.3 Social and Environmental Benefit Analysis

If this technological achievement is applied, it is projected that through the utilization of PV power generation technology, the project will provide year-round electrical energy for the mechanical refrigeration of storage facilities. This will result in a clean energy source, achieving a state of "self-sufficiency" for low-temperature or semi-low-temperature grain storage. It will maintain quality, reduce losses, lower costs, and increase profits, attaining the high standard of low-temperature and semi-low-temperature grain storage with low carbon emissions and high energy efficiency. This will ensure the safety of grain storage and food security.

Based on calculations, it is estimated that there will be an annual electricity savings of 73,000 kW·h per year. This translates to a reduction of approximately 1 ton of standard coal per ton of grain per year. Considering a grain storage scale of 200,000 tons, this results in a yearly reduction of 200,000 tons of burned standard coal. This has an equivalent effect of reducing carbon dioxide emissions by 535,000 tons, sulfur dioxide by 92 tons, and nitrogen oxides by 131.5 tons. This is comparable to the area of afforestation of 1,450 hectares, demonstrating significant energy-saving and emission-reducing effects. It also contributes to China's efforts in achieving its "dual carbon" goals.

Introduction to Practical Warehouse Applications

4 Introduction to Practical Warehouse Applications

In accordance with the requirements outlined in the "Notice on Issuing the Key Points of National Standardization Work for 2022" (NISTC Dispatch [2022] No. 8) by the National Standardization Management Committee, and the "Notice on Publishing the List of Pilot Units for Green Standardization of Grain Storage" (NFGA Standards [2022] No. 17) issued by the National Food and Strategic Reserves Administration, and considering the actual situation of grain storage in the warehouses of Wuhan National Rice Trading Center Co., Ltd., as well as the practical needs for grain storage safety, we have initiated the three-year pilot project on "Standardization of Grain Warehouse with Photovoltaic Intelligent Temperature Control for Green Grain Storage."

4.1 Project Progress and Methodology

The project construction was completed on August 14, 2022, and it was further improved and upgraded based on the operational data results of 2022. It has been running smoothly since May 15, 2023.

Currently, Wuhan National Rice Trading Center Co., Ltd. subsidiary (Hanchuan Huali Warehouse Area) has implemented the following systems:

1 warehouse utilizing the "Complete Mode" of the Intelligent Photovoltaic Air Conditioning Temperature Control System.

2 warehouses using the "Standard Air Conditioning Mode" of the Intelligent Photovoltaic Air Conditioning Temperature Control System.

1 warehouse employing the conventional grid-powered air conditioning temperature control mode for comparison, serving as a control warehouse. This warehouse stores rice.

4.2 The Energy Management System Records Project Data

According to the project implementation plan and detailed rules, a complete system experiment will be conducted from June to late September 2023. The collected grain condition data and energy consumption data will be gathered and organized to draw conclusions and revise related standards.

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4.3 The preliminary results of the operation up to now

4.3.1 The grid replacement rate of PV power generation

The grid replacement rates are as follows:
"PV A/C Mode": 50%-65% (July)
"Normal A/C Mode": 30%-50% (July)
It was observed that during certain sunny periods in July, the replacement rate reached 100%.

4.3.2 The energy savings and benefits generated are significant

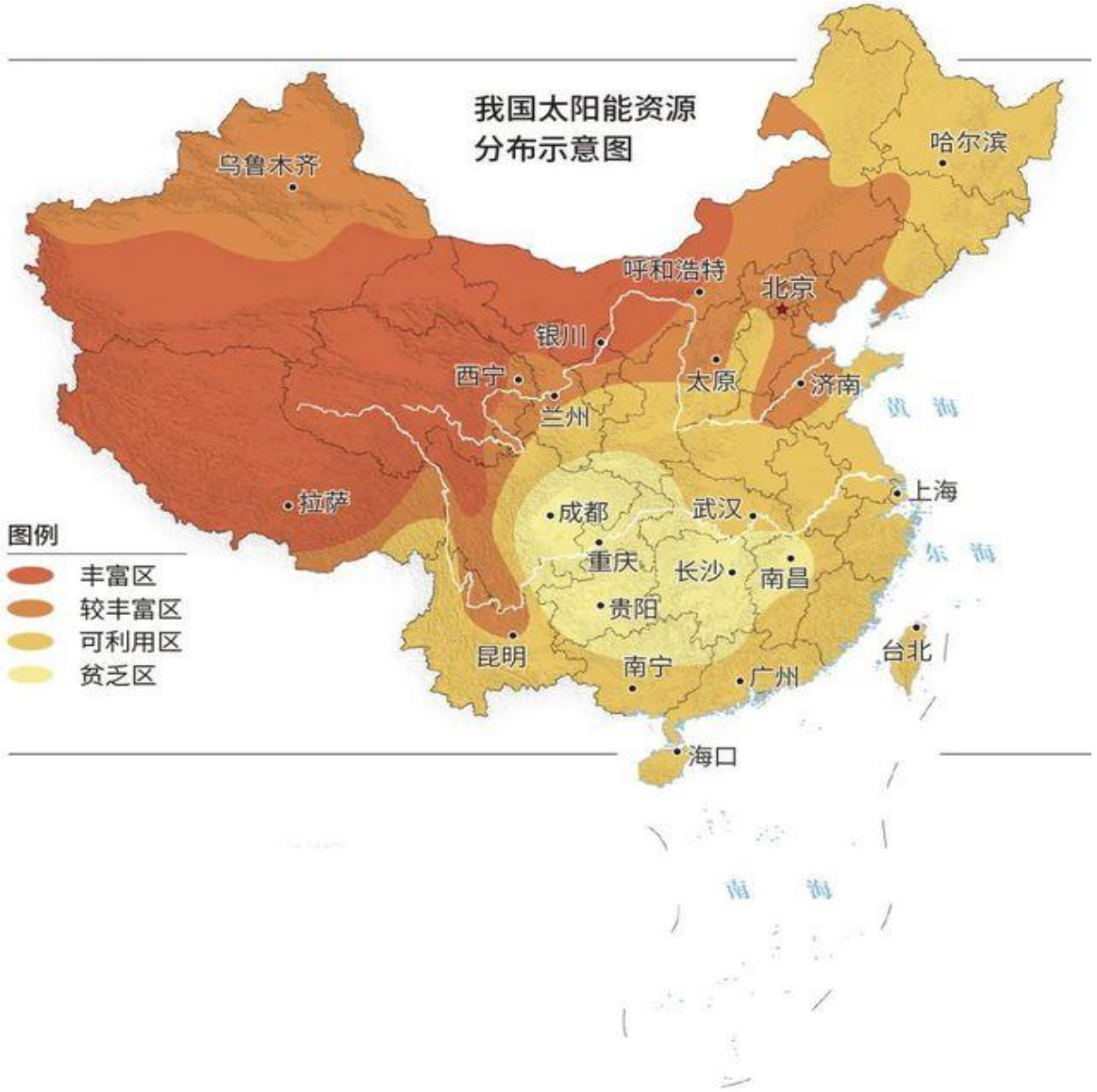
In July, the reference warehouse's air conditioning electricity consumption was 5122.7 kWh.

For the warehouse in "PV A/C Mode", the electricity consumption was 2479 kWh, resulting in savings of 2643.7 kWh. At a rate of 0.57 yuan per kWh, this is worth 1506.9 yuan.

For the warehouse in "Normal A/C Mode", the electricity consumption was 3140.2 kWh, resulting in savings of 1982.5 kWh. This is worth 1130.0 yuan.。

4.4 The carbon reduction benefits

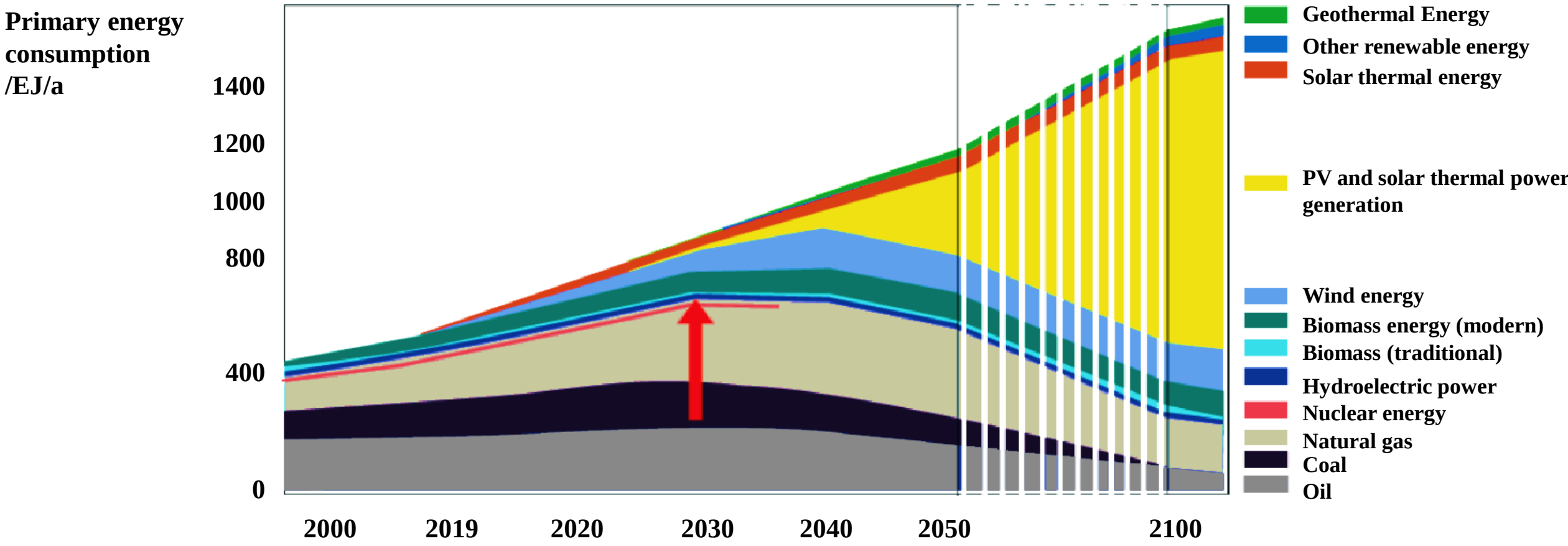
The "complete mode" warehouse can reduce 2635.8 kg of CO2 emissions, saving 1057.5 kg of standard coal. This leads to a reduction in pollutants including 719 kg of carbon dust, 79.3 kg of SO2, and 39.7 kg of nitrogen oxides (NOx). This is equivalent to adding 45.7 acres of forest. The energy-saving and emission-reducing effects are significant and contribute to China's efforts in achieving its "Dual Carbon" goals



Prospects and Outlook

5 Prospects and Outlook

5.1 The market outlook for photovoltaic power generation is highly promising.



5.2 The high demand for energy and the high cost of green storage

The energy consumption costs of key technologies for green grain storage				
No.	Project Name	Energy consumption per ton of grain (kWh/per ton)	Running costs (Yuan/per ton)	Percentage(%)
1	Low-temperature (or semi-low-temperature) grain storage.	8~20	8~20	14~20
1)	Smart Cold Storage Ventilation	0.5~1.5	0.5~1.5	1
2)	Smart Circulation Temperature Control	0.5~1.5	0.5~1.5	1
3)	Smart Air Conditioning Temperature Control	2~6.5	2~6.5	4.5
4)	Intelligent Grain Cooling Temperature Control	5~10	5~10	7
2	Intelligent Nitrogen Gas-controlled Grain Storage	0.5~2	0.5~2	1~2
3	Efficient Dust-free Grain In and Out	0.5~2	0.5~2	1~2
4	Green Preservation of Dry Grains	60~122	60~122	80~85
	Total	69~144	69~144	

Energy demand

The green and high-quality preservation of grain, low-temperature and quasi-low-temperature storage, nitrogen gas-controlled storage, and dust-free storage and retrieval account for more than 90% of the energy consumption. This leads to a significant increase in the electricity consumption of grain depots, placing a greater burden on enterprises and posing significant challenges to energy supply and the implementation of green storage. It is one of the bottlenecks restricting the implementation of green storage.

5.3 Expanding the Application of PV Technology in Grain Depots through Energy Storage

Application of Emergency Power Supplies and Portable Mobile Power Sources in Grain Warehouses

Small-scale energy storage systems have already been applied in grain warehouses. They have low costs and are convenient.。

The large-scale energy storage systems are currently relatively expensive, but with future technological developments, the costs are expected to decrease. They can be used for various technological equipment in the entire warehouse, including grain loading and unloading, nitrogen insecticidal treatment, and grain cooling with grain chillers.

Base station power supply

Size：49*48.5*14cn
Weight：45Kg

Product Model:	3U
Capacity:	3000WH
Power:	3000W
Output voltage:	220V 50Hz / 110V 60Hz


适用工厂、机关、医院、战备等多种场所

The application of charging piles in granaries

The surplus solar energy can be used to establish a solar PV charging station system.

WFP World Food Programme

2 ZERO HUNGER

Thank You !

WFP-China SSC Knowledge Sharing Platform

Cloud School

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