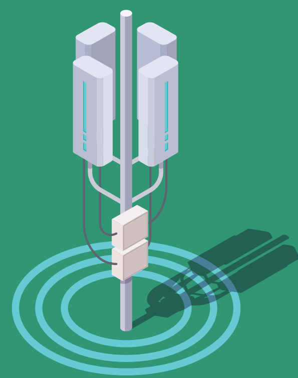
Site Power Low Carbon Target Network

White Paper

HUAWEI

Contents



Figures and Tables

01 Eternal Pursuit of Harmony Between Man and Nature

• Coexisting with Nature

The theory of "unity of man and nature" is a traditional Chinese philosophy, which advocates that human beings are an integral part of nature and should live in harmony with nature.

As a member of the ecological system, human beings, together with other species, form the life system of the earth.

Nature provides all resources needed for human survival and development. However, exploiting these natural heritage incites many problems, among which global warming is one of the most prominent.

• Excessive carbon emissions have led to rising globe temperature, posing a great threat to us.

Extreme climate events and geological disasters become more frequent and wide-ranging. The summer of 2022 witnessed heat waves swept multiple countries in Europe and Asia. The soaring temperatures brought fires, droughts, decreasing water levels, insufficient power supply, accelerated melting of glaciers, and floods. The natural environment has become ever more fragile, and climate change is now a global challenge.

Research has found that greenhouse gases such as carbon dioxide (CO_2) generated by human activities are the main cause of global warming, which in turn causes extreme climate changes and undermines ecological balance. At present, we are still heavily depending on fossil fuels such as oil, coal, and natural gas, which account for more than 80% in the global energy system. Industrial development has proliferated energy demands and carbon emissions. Statistics show that global annual carbon emissions have swollen from 6 Gt by 1950 to 37 Gt by now.

To cope with climate change and global warming, 178 parties worldwide signed the Paris Agreement at the 21st United Nations Climate Change Conference in 2015 and promised to keep the rise in mean global temperature to below 2°C above pre-industrial levels and try to limit the temperature rise within 1.5°C. Some parties have successively launched goals to achieve carbon neutrality. Different industries have begun to inspect their carbon footprints and developed carbon reduction plans and targets.

• Digitalization is an important decarbonization mean. Communication is the cornerstone of digitalization.

In the process to curtail carbon emissions, ICT infrastructure, as the digital foundation of various industries, is playing an increasingly important role. ICT enables other industries to move towards low-carbonization through networked, digital, and intelligent technologies. It can also help modernize government regulation and public services, drive the shift to greener models of living and working, and ultimately facilitate green socioeconomic development.

Though ICT technologies can help decarbonize other sectors, the ICT industry is responsible for 2% of the world's total carbon emissions. It is estimated that the ICT industry will produce 1.3 Gt carbon emissions by 2030, despite the fact that the industry will cut carbon emissions of other sectors by 20% and bring more than US$1.1 trillion revenues.

• The communication sector is one of the main carbon emitters.

As ICT technologies usher in a digital and intelligent era, ICT carriers are facing surges in network traffic and energy consumption. According to the forecasts, digital services will bring 13 times more traffic by 2030 than by 2020, which means more power is required.

According to public statistics, the energy used by the ICT industry will account for 5% of the final energy consumption of the society by 2035, and 60%+ of energy in the ICT industry is consumed by telecom sites. Take China as an example. It is estimated that by 2035, the total power consumption of data centers and 5G sites will be about three times that of 2020, accounting for 5% to 7% of the total power consumption of the society. Even though carbon reduction and energy saving technologies are introduced, the carbon emissions of data centers will still increase by 103% compared with 2020, and the figure for 5G is 321%.

It is conceivable that low-carbon renewable energy and higher energy efficiency are required in the ICT industry to achieve carbon reduction and carbon neutrality goals.

As the main carbon dioxide emitters, telecom sites will be the first to slim down in terms of energy consumption.

02 Status Quo of Energy Saving and Carbon Reduction for Telecom Sites

2.1 Carbon Reduction

2.1.1 Gigantic and Ever-Increasing Site Quantity

In the 5G era, the number of global wireless base stations is substantial and ever-growing. As more countries deploy 5G and industry scenarios accelerate, 5G construction will continue to grow rapidly.

By the end of 2021, the number of 5G base stations worldwide has reached 2 million. The number will reach 8 million by 2026, an increase of nearly 400% compared with 2022. It is estimated that by the end of 2022, the number of 5G base stations in China will reach 2.1 million, accounting for 29.8% of the total number of wireless base stations. Compared with 2021, 600,000 more 5G base stations are built. By 2026, the number of 5G base stations will reach 4 million, with an average annual growth rate of about 50%.

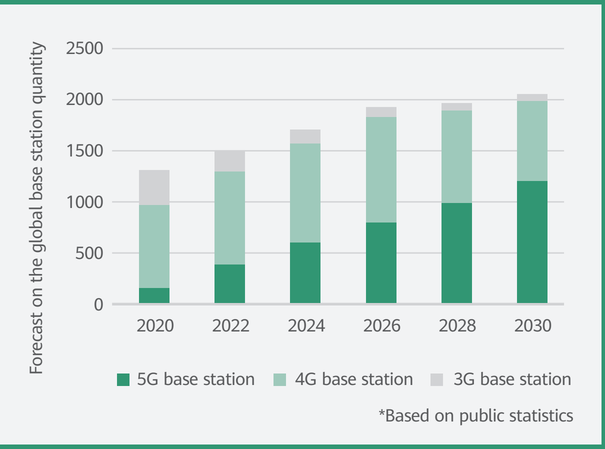


Figure 2-1 Trend of global base station quantities and the number of new base stations

2.1.2 Conventional site deployment is complex and with low energy efficiency

The 5G era is seeing a power consumption surge of sites.The average power consumption of a 5G site is two to six times that of a 4G site. Besides, the coverage of 5G sites is low, equipment will generate more heat, leading to a larger power consumption.

Conventional site deployment often resort to building shelters or adding cabinets, resulting in low energy efficiency and high carbon emissions.

• In terms of site energy efficiency (SEE):

The SEE of a shelter site is about 55% to 75%. The power density and efficiency of power supplies are low. In-room cooling is used, resulting in a waste of cooling resource. Moreover, building and reconstructing a shelter often involves change of utility power and cooling and crane renting. The whole process is costly and time-consuming.

The SEE of a cabinet site is about 80% to 85%. Besides low power density and efficiency of power supplies, cabinet sites usually expand capacity by adding devices, which occupies site space and makes O&M hard to perform.

• In terms of energy consumption proportion:

For conventional shelters, energy is mainly consumed by air conditioners, whose energy consumption account for 55% to 60% of the total. Some 40% to 45% of energy is used by power supplies and other devices. The conversion efficiency of power modules is about 90%. Large amount of energy is not consumed in working phase, causing a huge waste.

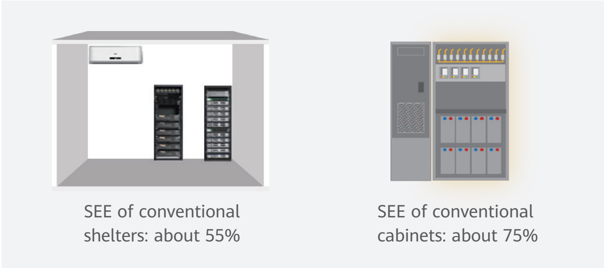


Figure 2-2 Energy efficiency of a conventional shelter and cabinet site

2.1.3 Low proportion of green power

Using green power to save energy and cut carbon emissions demonstrate enterprise responsibility. Compared with other clean energy sources like hydro power, tidal power, and wind power, photovoltaic (PV) power has the most mature application.

However, PV power utilization is still in early stages for telecom carriers. Take a top carrier in a developed economy as an example. In 2021, 50% of electricity used by its sites is generated by coal and natural gas, 35% by water and wind, and only 5% by sun light. The proportion of PV power is even lower in developing countries.

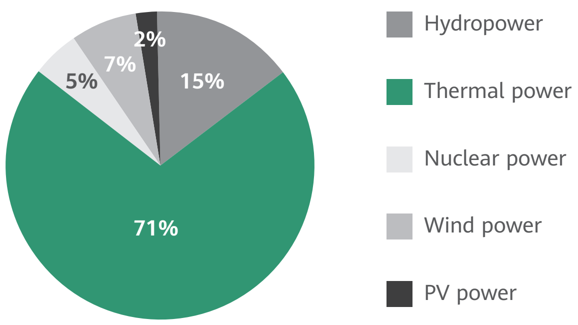


Figure 2-3 Low proportion of PV power (in China)

2.1.4 SEE optimization and carbon reduction are hard to perform in the conventional O&M system

In a conventional site management system, energy efficiency and carbon emissions are invisible and difficult to optimize. Site data cannot be perceived because site devices are not intelligent. Simple sensing can be realized in some monitoring systems, but the accuracy is low.

Low digitalization level and manual onsite troubleshooting result in high labor costs. According to the statistics of a carrier, 60% of the sites cannot be intelligently managed, 90% of the sites do not support energy-saving measures such as peak staggering, and the cost of manual site visits accounts for 60% of the O&M cost.

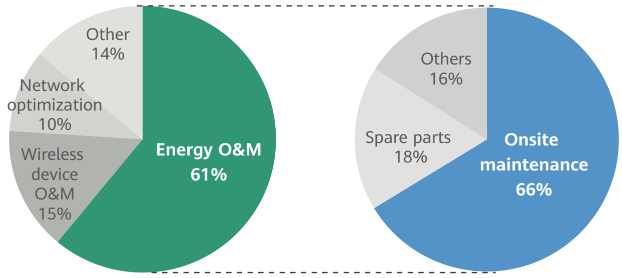


Figure 2-5 O&M cost composition of a carrier

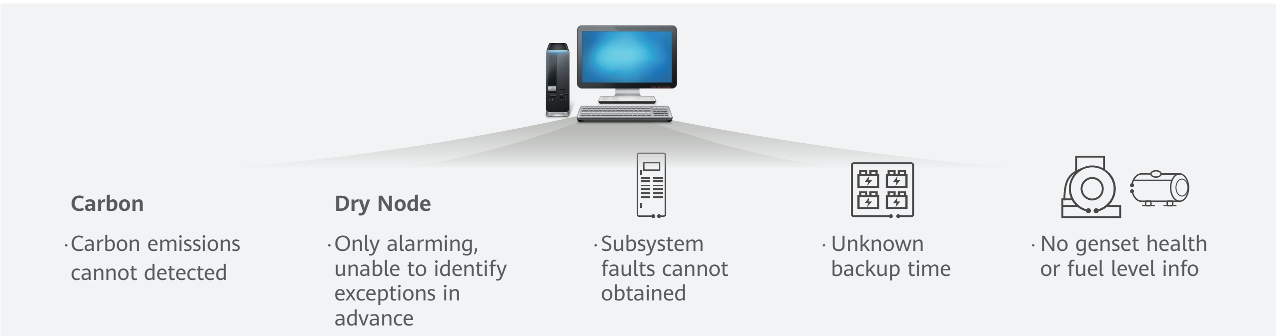


Figure 2-4 Unknown site status

2.2 Carbon Reduction Evaluation System

Currently, the site energy efficiency (SEE) is used to measure site energy saving effects. SEE is the ratio of site equipment energy consumption to total site energy consumption, which reflects system energy conversion efficiency.

However, SEE focuses only on energy efficiency and does not apply to carbon reduction assessment.

ITU–T L.1331

$$\text{SEE} = \frac{\text{(Telecom Energy Consumption(kWh))}}{\text{(Total Site Energy Consumption (kWh))}}$$

Figure 2-6 SEE Indicator

2.3 Trend of Energy Saving and Carbon Reduction

New services such as V2X and XR are emerging. Clean energy will continue to be connected. Grid connection of sites as part of power grid scheduling will emerge. Socialization process of sites continues to evolve. As a result, sites quantity will increase rapidly, the power consumption will continue to increase, and complex problems in power grid coordination, power grid stability, and O&M will increase. In this trend, energy saving and carbon reduction will face greater challenges. Therefore, in order to solve current challenges and to be ready for the future, we need to build new energy networks.

03 Design Concept of Low Carbon Target Network

3.1 Definition

Legacy site power facilities are troubled with complex construction process, low energy efficiency, extensive management, and lame energy scheduling. To address these problems and build a simplified, efficient, green, and intelligent energy network, Huawei proposes the "Site Power Low Carbon Target Network."

It uses advanced power electronics, information and communications, and artificial intelligence (AI) technologies to manage watt using bit. Solutions in it are able to simplify site construction, improve site operation efficiency, reduce power consumption, and implement intelligent site management. By adopting these solutions, energy can flow on demand, generating more bits with less watt.

3.2 Key Values of the Target Network

3.2.1 Simpler Architecture

Thanks to varied technical breakthroughs, site power facilities are embracing a simpler architecture with high energy density and efficiency, broad application of intelligent features, and refined device and system management.

To satisfy power needs spawned by network evolution, service convergence, and complicated operation in the 5G era, Huawei's Green Energy Target Network reshapes and simplifies the sites. It advocates that we should replace equipment rooms and shelters with cabinets and substitute cabinets with poles, adopt modular design and intelligent O&M to lower deployment and O&M requirements, reducing site power consumption and carbon emissions. As 5G development deepens, Huawei's Site Power Low Carbon Target Network will continue to shepherd site power facility towards a simplified architecture.

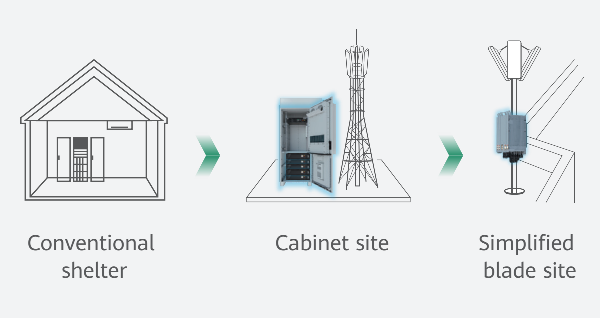


Figure 3-1 Simplified architecture evolving towards a blade power site

3.2.2 Better User Experience

User experience is an important part of site power facility's values. Nowadays, site power facilities are becoming smarter and more connected with each other, fueling the change from inefficient manual O&M to remote intelligent O&M and from single functions of devices to integrated asset scheduling.

By exploiting advanced sensing and AI technologies, Huawei solutions facilitate autonomous driving of sites. Proactive site management can be implemented through sensing devices. AI algorithms empower automatic site fault prevention, raise site energy efficiency, and curb carbon emissions.

In an era of digitalization, Huawei's Site Power Low Carbon Target Network guarantees a user experience optimization.

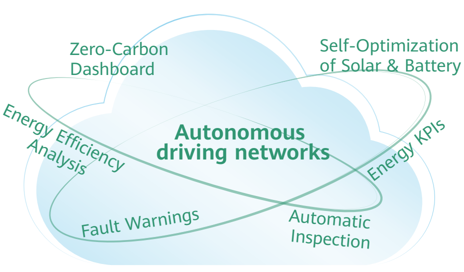


Figure 3-2 Autonomous driving network

3.2.3 Lower OPEX

The operational expenditure (OPEX) used to be exorbitant due to site rent, fuel and maintenance costs of gensets, labor costs of frequent site visits, and electricity fees. It is now expected to drop with the advancement of technologies and the change of business models.

A simplified site architecture proposed by Huawei's Site Power Low Carbon Target Network can reduce site footprint and cut site rents. Through PV deployment and generator-free sites, energy consumption and carbon emissions can be slashed. Intelligent O&M can be adopted to increase O&M efficiency and conduct energy collaboration. In a nutshell, site power facilities are evolving from energy-intensive and manually-maintained to green, efficient, and intelligent. The OPEX will decline accordingly.

Huawei's Site Power Low Carbon Target Network will enable users to build site energy networks with extremely low OPEX.

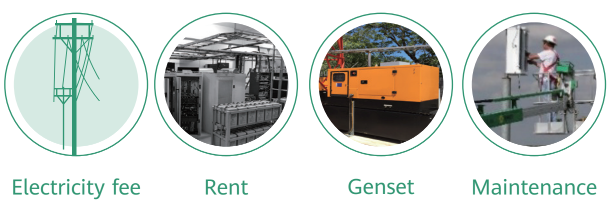


Figure 3-3 Site OPEX composition

3.3 Evaluation Factors

3.3.1 NCIe

In the pursuit of carbon neutrality, carbon reduction has become a theme for site power facility. Selection of carbon reduction evaluation factors is also of great importance. The existing power management system in a lot of sites cannot evaluate carbon emission effect because related parameters cannot be obtained.

NCIe (Network Carbon Intensity) was proposed by the ITU in October 2022. It defines the carbon emission intensity of a network and consists of carbon emission factor and network energy efficiency, which can clearly indicate the carbon emission status of a network.

ITU–T L.1333

$$NCIe=\frac{E\ total}{Total\ Data\ traffic}*EF=\frac{(\sum Ej*EFj)}{(\sum Data\ trafficj)}$$

E total: Total Carbon Emission of network operation ($kgCO_2e$)

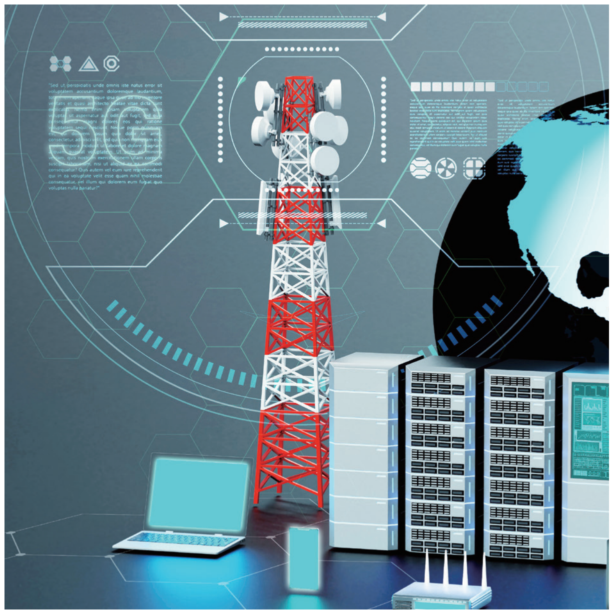
EF: Emission Factor ($kgCO_2e/kWh$)

Total Data traffic: TB

Figure 3-4 NCIe Indicator

Huawei Site Power Low Carbon Target Network uses NCIe as a measurement factor. EF in NCIe is an indicator closely related to site power. An advanced perception model and big data analysis are used to visualize carbon emissions of sites and optimize carbon reduction measures.

Huawei's Site Power Low Carbon Target Network adopts the well-recognized evaluation factor to help carriers achieve carbon neutrality.



3.3.2 SEE

SEE is an important parameter for measuring site energy efficiency.

Huawei Site Power Low Carbon Target Network upgrades components with advanced underlying technologies and cutting-edge material technologies to raise power conversion efficiency, and innovates heat dissipation structure and cooling methods to maximize cooling efficiency.

Huawei's Site Power Low Carbon Target Network keeps improving the SEE, making carbon reduction a reality.

3.3.3 OPEX

OPEX is an important cost indicator in the life cycle of a site. It is composed of the site rent, electricity fee, fuel fee, and manual maintenance cost.

Huawei's Site Power Low Carbon Target Network is committed to reducing the OPEX of telecom sites.

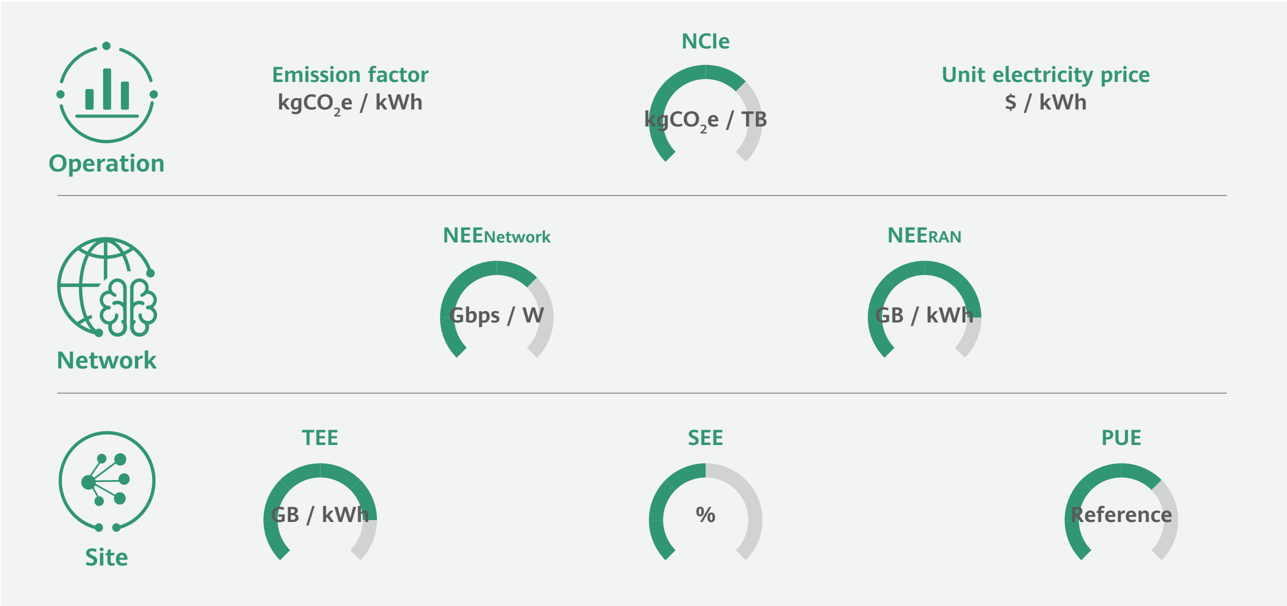


Figure 3-5 Network energy efficiency measurement at different layers

3.4 Key Technologies of Low Carbon Network

The construction and development of the Site Power Low Carbon Target Network cannot be achieved without the support of advanced technologies. It has constructed a platform displays the energy flow and information flow by integrating power electronics and digital technologies and by applying sophisticated materials, components, batteries, cooling device, sensors as well as mature connectivity, cloud, and AI technologies in an attempt to build a green network infrastructure.

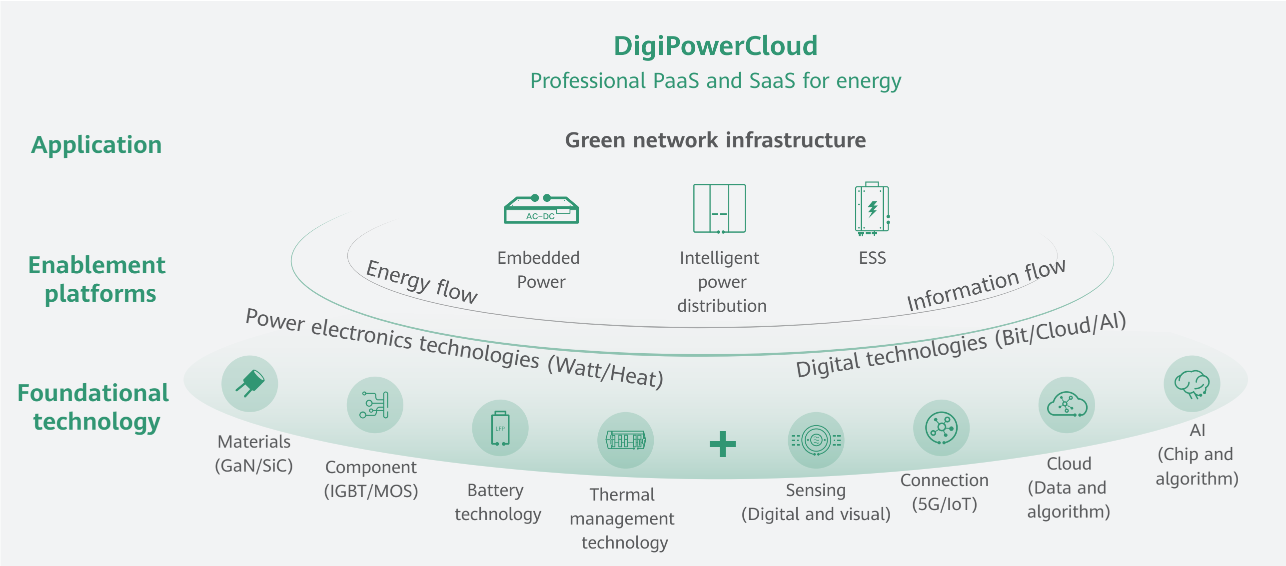


Figure 3-6 Key technologies used by the Low Carbon Target Network

3.4.1 Power Electronics Technologies

• Material and component technologies

Application of new materials such as graphene, silicon carbide, and gallium nitride and next-generation wide bandgap semiconductor modules allow power supplies to support high energy density and efficiency, natural cooling, and bidirectional energy flow.

Such power supplies feature multiplied power density in a smaller size. Low resistance and switching loss guarantee an elevated system efficiency and less heat. In addition, air-cooled heat dissipation can be seamlessly switched to natural cooling, greatly cutting the power consumed during heat dissipation.

Advanced materials and components transform site power and reconstruct product forms while providing better performance.

• Battery technologies

Lead-acid batteries in legacy sites are difficult to manage. They often occupy large space and have relatively short service life. Lithium-ion batteries and sodium-ion batteries are the new trend in the industry, especially lithium-ion batteries, which are widely used as a substitute of lead-acid batteries.

Another salient technology trend is digitalization of batteries. By virtue of the development in sensing technologies, high-saturation magnetic materials, and high-speed sampling technologies, battery status can be accurately detected. Advanced connection technologies help transmit battery data in a timely and precise manner. Isolated and scattered batteries can cluster into a network. What's more, cloud, big data, and AI technologies pave way to automatic analysis and unified scheduling. All these enable a fully networked and automated site power facility system.

• Thermal Management Technologies

Heat dissipation has always been a major energy consumer for site power facilities. We're glad to see more and more heat dissipation technologies emerge. For example, next-generation components with low heat consumption, gravity thermo siphon tubes, and root-shaped heat dissipation system are adopted. With the help of these technologies, heat dissipation of site power gradually develops from air conditioner, air cooling, to natural cooling.

3.4.2 Digital Technologies

• Sensing and Connection Technologies

Great progress has been made in site perception thanks to the advancement of sensing and connection technologies.

Site status, such as the temperature and humidity, genset, and mains, can be clearly obtained using advanced sensing devices. In addition, status perception is shifting from absence detection to intelligent monitoring.

Different interfaces of site devices, such as Ethernet interface, dry contact, and wireless interface, brings compatibility issue. With the latest connection technologies, information can be transmitted to the management system with ease. Site data is reported automatically and wirelessly, making site management in remote areas more convenient.

• Cloud and AI Technologies

Conventional site deployment is costly and manual O&M is hard to perform. As cloud computing, big data, and AI technologies keep innovating, site power deployment and management are becoming cloud-based and intelligent. In terms of device deployment, more and more carriers deploy servers on the cloud, greatly reducing the number of local servers and improving system maintainability. As for site management, big data and AI are used to predict site risks in advance and implement remote and automatic maintenance. Intelligent management capability is a must for site power in a new era.

04 Huawei Site Power Low Carbon Target Network

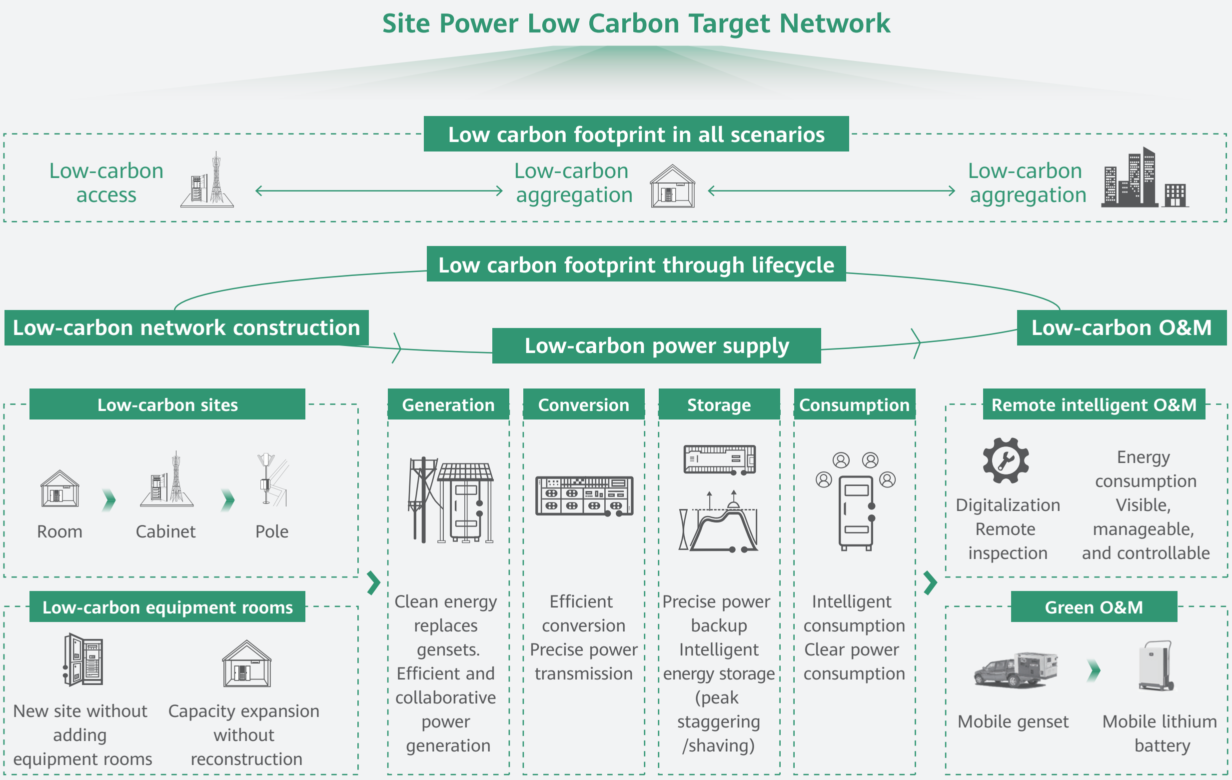


Figure 4-1 Architecture of the Low Carbon Target Network

4.1 Architecture

Huawei's Site Power Low Carbon Target Network helps build low-carbon sites along the energy flow. Advanced components are used to implement site digitalization, thereby achieving low-carbon construction. Introducing green power, efficient conversion modules, lithium battery, and intelligent power distribution to realize low-carbon power supply along the link of power generation, conversion, storage, distribution, and consumption. A unified digital management system is used to implement smart management and low-carbon operation.

Huawei's Site Power Low Carbon Target Network advocates low carbon in all scenarios and through lifecycle, helping carriers evolving to 5G without adding OPEX. During network construction, change the site form and use simplified sites, simplified equipment rooms, low-carbon construction, low-carbon power supply, and low-carbon O&M to comprehensively upgrade the existing site construction mode.

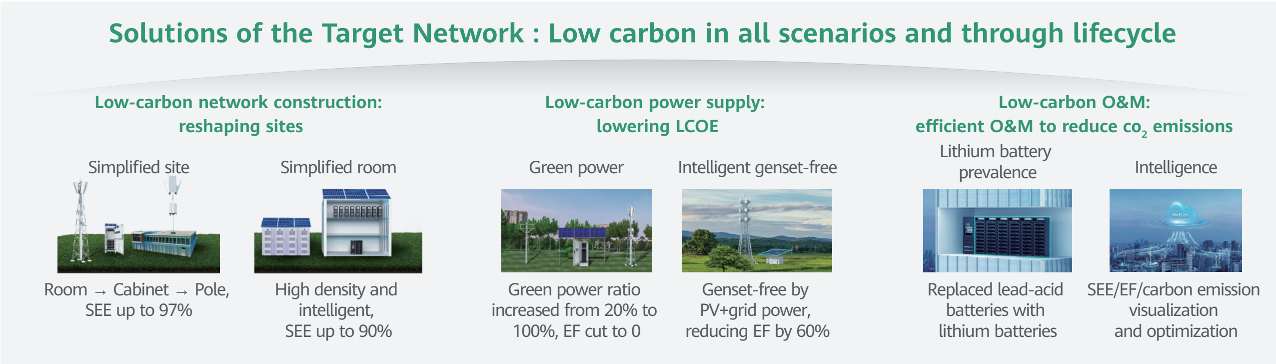


Figure 4-2 Solutions of the Target Network

4.2 Low Carbon Network Construction

Low-carbon network construction refers to simplifying the network architecture and devices while raising device efficiency in an attempt to save energy and reduce carbon emissions. First is to simplify architecture. Redundant links on the network architecture and basic power supply architecture, such as the C-RAN of 5G networks and integrated power supply system, should be cut. Second is to simplify site deployment. Move indoor sites to outdoor cabinet sites, and even to pole-mounted blade power site to minimize site footprint, material consumption, and cooling energy consumption. Low-carbon network construction reduces carbon emissions as well as OPEX.

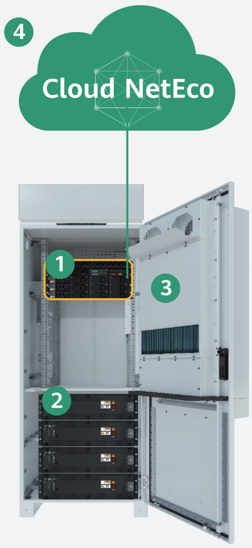
4.2.1 Simplified Site: Adopting Cabinet and Blade Power

After 5G gains popularity, site power consumption is bound to skyrocket and a large number of sites may face the shortage in grid power, power supply and battery capacity, cooling capacity, and AAU voltage. Meanwhile, the increase of devices and sites will bring more energy-related OPEX, such as electricity fees, rent, and O&M fees.

The prevailing capacity expansion methods include building new equipment rooms and shelters and adding more cabinets. However, these simple and crude methods often involve complex engineering workload and produce high end-to-end costs. For example, grid reconstruction will cost US$5000 and the period is as long as 3 months in an Asian country. Renting a crane in Europe requires US$1500/time. Let alone the costs for laying foundation (US$500, TTM > 2 weeks @ a country in Asia), site rent (US$7000/year @ a country in Asia), cable replacement fee (US$806@global), and so on. Besides, the conventional power system has multiple cabinets and each with a separate cooling device (80% SEE). Load power consumption management is rough and cannot identify loads with high power consumption and provide optimization measures, resulting in high carbon emissions. (The carbon emissions of a site with one 4G frequency band and one 5G frequency band are 28 tons per year.) In addition, the conventional site power supply supports only –48 V and cannot meet varied power supply needs of different services.

Huawei's cabinet power solution is able to accommodate 2G/3G/4G/5G equipment and support shared site needs in just one cabinet. One Huawei cabinet outperforms multiple conventional cabinets. One cabinet for one site helps realize simplified deployment and drastically cut end-to-end costs.

One cabinet for one site



1 High-density and efficient power supply:

Software-defined and intelligent power management

eMIMO and modular devices

Ultra-large capacity and high density

2 CloudLi

Cloud-based management

High density

Intelligent feature

3 Cabinet

Cabinets to rooms, fast deployment

ICT convergence

Modular capacity expansion for temperature control

4 Management system: NetEco

Network status visible, manageable, and controllable

Digital site

Intelligent O&M

Figure 4-3 Huawei one cabinet for one site solution

• The solution has the following features:

High density:

The eMIMO power supply features a power density up to 24 kW@3 U or 36 kW@5 U, which is twice that of other vendors (24 kW@7 U). The capacity of intelligent lithium batteries (CloudLi) is 150 Ah@3 U, which is twice that of lead-acid batteries (150 Ah@8 U), doubling battery capacity at the original position.

High efficiency:

Efficient components, lithium batteries, and temperature control help achieve a maximum SEE of 90%, cutting 10% energy consumption and reducing 3124 kg carbon emissions per site per year.

eMIMO:

Multiple input and output modes are supported. One power system equals to multiple conventional power systems and applies to various scenarios.

Full modular design:

The temperature control unit, rectifier, battery, AC input unit, and DC output unit are all modular to facilitate smooth service evolution.

All-link intelligence:

All-link intelligence is implemented from power generation, conversion, storage, distribution, to consumption. Intelligent features such as peak shaving and voltage boosting simplify deployment and reduce CAPEX. Intelligent features such as peak staggering and energy slicing can be used to reduce OPEX.

Intelligent power consumption management: Intelligent circuit breakers integrate functions of a shunt and contactor, and circuit breaker capacity can be customized by software, realizing on-demand power distribution. Energy consumption of each load branch is accurately measured. Energy slicing enables on-demand backup power, reducing battery configurations.

To stay in lockstep with the simplification trend, Huawei then launched the one blade for one site solution. The green and simplified blade power boasts large power and full natural heat dissipation design. The product has zero footprint and therefore zero rent. What's more, it is maintenance-free with extremely low energy consumption. Due to a compact size, the power system can be installed within 1 hour. It can be used in macro and micro base stations and shared sites. Compared with a cabinet site, the TCO of this solution is 30% lower.

This solution is two generations ahead of the industry. The present industry level is one blade for one frequency band. Huawei has launched similar product in 2020. In 2021, Huawei kept making breakthroughs and released 12 kW blade power. The capabilities of a 12 kW blade power are in par with those of a cabinet, achieving the industry's first 2G/3G/4G/5G full-band solution.

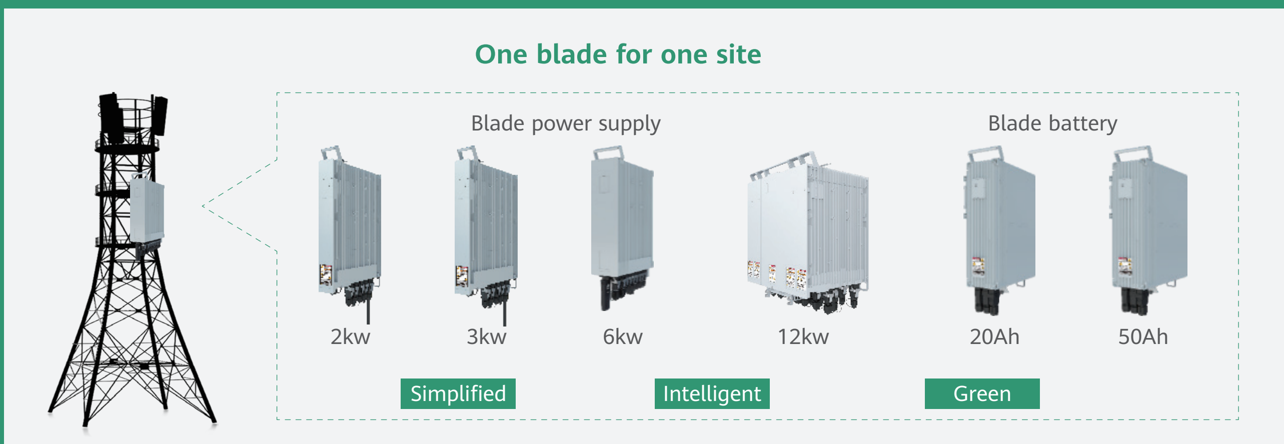


Figure 4-4 Huawei one blade for one site solution

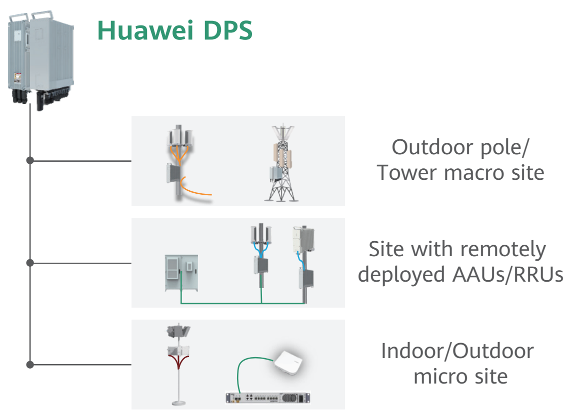


Figure 4-5 DPS application scenarios

Huawei blade power (or distributed power system, DPS) features multiple innovations, such as butterfly-shaped structure and bionic root-like heat dissipation, improving heat dissipation capability by 25% and reducing the size and weight by 40%. It also supports efficient and intelligent power consumption, pole-mounted PV, intelligent measurement, peak shaving and peak staggering, and energy slicing. In terms of reliability, the solution is IP65-rated and supports N+1 redundancy, which enables maintenance without power-off.

4.2.2 Simplified Equipment Room: CO Equipment Room Modernization

Emerging new 5G services like Internet of Everything (IoE) and HD video require faster network access rate and larger traffic. In addition, cloudification of core networks, edge computing, and CDN sinking drive the CT networks towards ICT convergence. In this context, existing power facilities in equipment rooms are facing huge challenges. To meet service needs, new IT equipment is added. As a result, the power consumption of the equipment room surges. Different equipment has diversified power requirements, so AC and DC power supplies need to be integrated.

• The existing capacity expansion methods for equipment rooms have the following problems:

- The temperature control capability is insufficient, and hot spots exist. Local hot spot occurs and heat dissipation requirements of new devices cannot be met. New air conditioners need to be added for capacity expansion, resulting in high investment and long payback period. In addition, existing in-room air conditioners have low cooling efficiency and high power consumption.
- The SEE of legacy equipment rooms is less than 50%. The in-room cooling mode and batteries of old power systems are inefficient and energy-consuming. The power consumption is invisible and cannot be optimized.
- The equipment room space is limited, making reconstruction difficult and prolonging project duration. The power supply, battery, air conditioner, and cabinet all need capacity expansion, causing more footprint, long project duration, and high cost.
- Multiple AC and DC power supplies and backup power need to be added for service expansion.

Huawei's green equipment room power solution integrates temperature control, power supply, and backup power into one cabinet, which is unique in the industry. It combines the eMIMO power system, CloudLi, and modular temperature control system into one, offering a one-stop power solution for equipment rooms. With it, 5G and new fixed network services can be deployed in a green and simplified way.

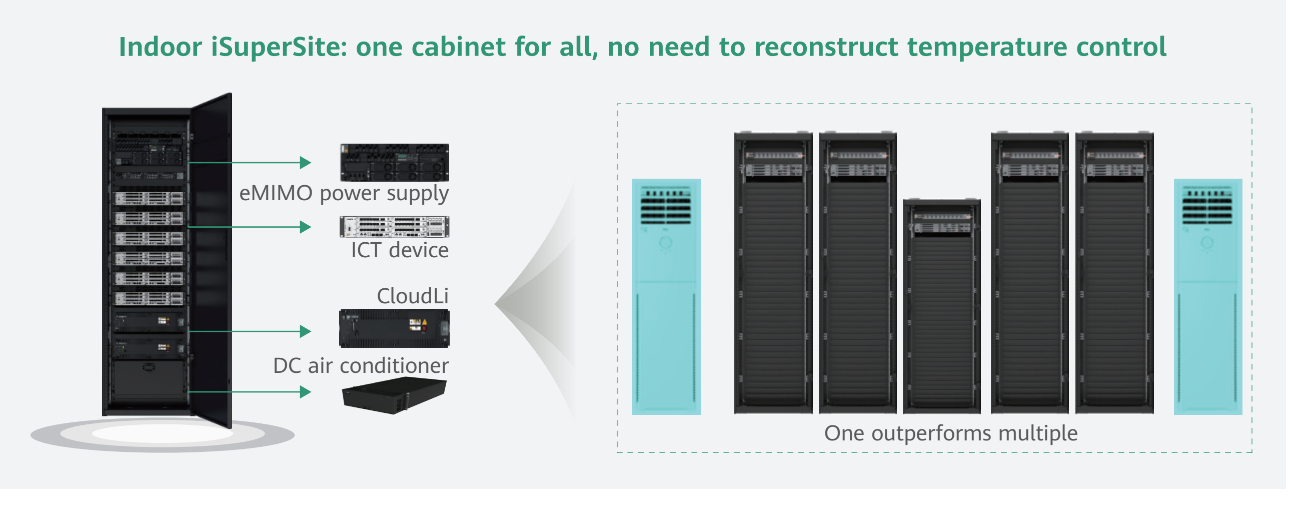


Figure 4-6 Huawei indoor iSuperSite solution

• The solution has the following features:

No need to add temperature control:

Temperature control, power supply, and backup power are integrated in a high-density manner. The air conditioner in the cabinet implements precise cooling, effectively addressing the issue of local hot spot. Since the cooling system is inside the cabinet, air conditioners are near the equipment, which is more efficient compared with in-room cooling. A maximum of two 5 kW DC air conditioners can be deployed, raising the cooling capability of a single cabinet to up to 10 kW.n be customized by software, realizing on-demand power distribution. Energy consumption of each load branch is accurately measured. Energy slicing enables on-demand backup power, reducing battery configurations.

No need to build equipment rooms:

Integration of the eMIMO power supply, CloudLi, and modular temperature control provides high energy density. One cabinet outperforms three, eliminating the need to build new equipment rooms.

No need to change cables:

The unified power supply platform provides AC and DC power at the same time. The 57 V voltage boosting increases the cable through-current capacity by 30%, eliminating the need for cable replacement.

High efficiency and energy conservation:

Heat dissipation design such as precise cooling, intelligent linkage, and adjustable temperature control component help build a smart low-carbon equipment room and save energy efficiently.

Since its launch, Huawei's green equipment room power solution has won wide recognition. It was awarded the Grand Prize at Interop Tokyo 2020.

4.3 Low Carbon Power Supply

4.3.1 Site PV Deployment

Energy yields of distributed off-grid DC PV systems are subject to shading around the sites, deployment area, PV module orientation, and tolerance. In addition, the PV systems cannot collaborate with energy storage devices and gensets, which restricts PV power consumption. Besides, it is difficult to locate faults among a large quantity of dumb devices. Large output voltage of the PV systems may cause lead-acid battery damages and disconnection of long PV strings, inviting fire risks.

To address the preceding problems and further reduce the site OPEX, Huawei launches the iSolar2.0 by fusing innovations such as the module-level power electronics (MPLE), power carrier communication, power electronics control chip, and adaptive optimization algorithm. The smart PV modules in the iSolar2.0 solution can upload the energy yield information and alarm status of the PV modules to the NetEco in real time. In this way, the energy yield is visible and faults can be detected. The integrated four-in-one PV controller inherits the simplified blade style and features high power, small size, high efficiency, and easy deployment in all scenarios. Equipped with Huawei CloudLi batteries, the iSolar + ESS system can further improve the PV power consumption ratio. In areas with time-of-use rates, PV power can be preferentially used to leverage electricity price differences between peak and off-peak periods, cutting network OPEX and facilitating energy transition.

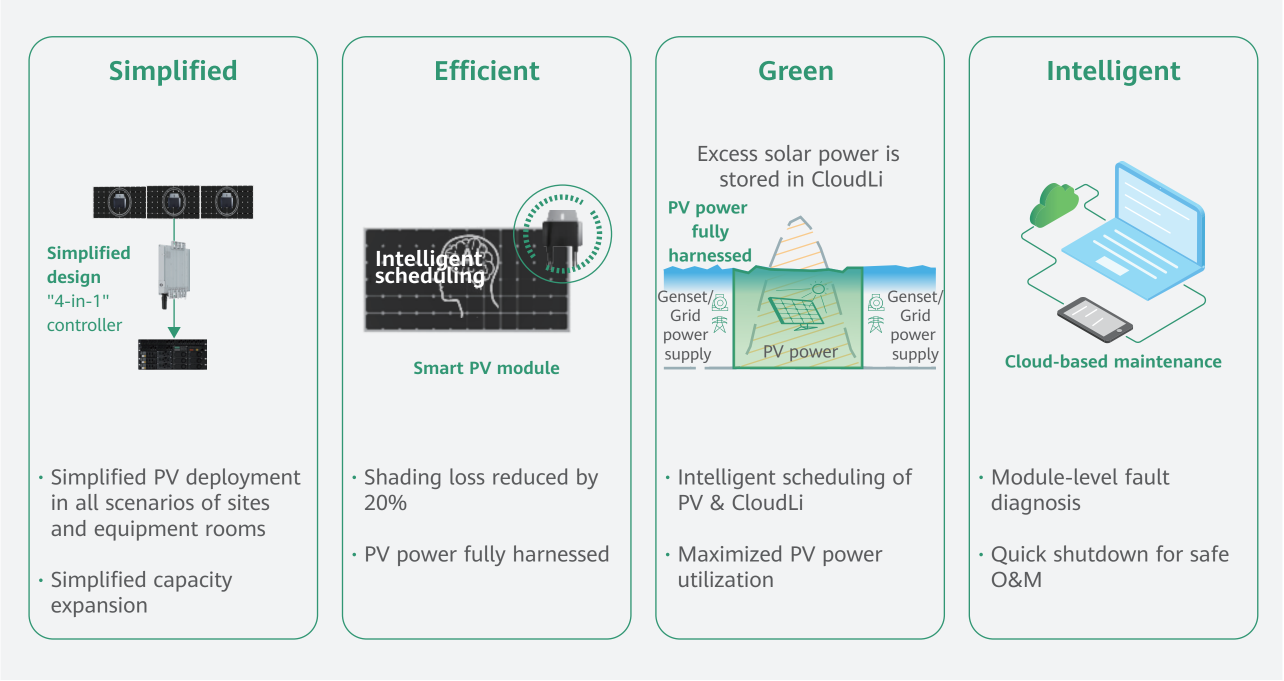


Figure 4-7 Huawei iSolar solution

• From invisible string-level optimization to PV module-level optimization and high safety

The existing PV deployment solution supports only the string-level optimization and cannot mitigate issues like PV module shading and installation azimuth difference. Faulty PV modules need to be located by specialized devices. The high-voltage PV string disconnection function is not supported, which does not meet the industry safety standards. These problems will lead to low power generation efficiency and high O&M cost, jeopardizing the benefits of the project.

Powered by the MPLE technology, Huawei's next-generation iPV2.0 smart PV modules support module-level optimization and flexible deployment. The orientation of PV modules can change, minimizing the shading loss. Equipped with the industry-leading PLC communication technology, the energy yield information of each PV module can be displayed on the NetEco. In this way, the status and faults can be obtained. Working with the optimizer, the iPV modules in a long string can be quickly and safely shut down when cables are disconnected or a PV module is faulty. The voltage can be reduced to less than 30 V DC within 10 seconds, meeting related safety standards.

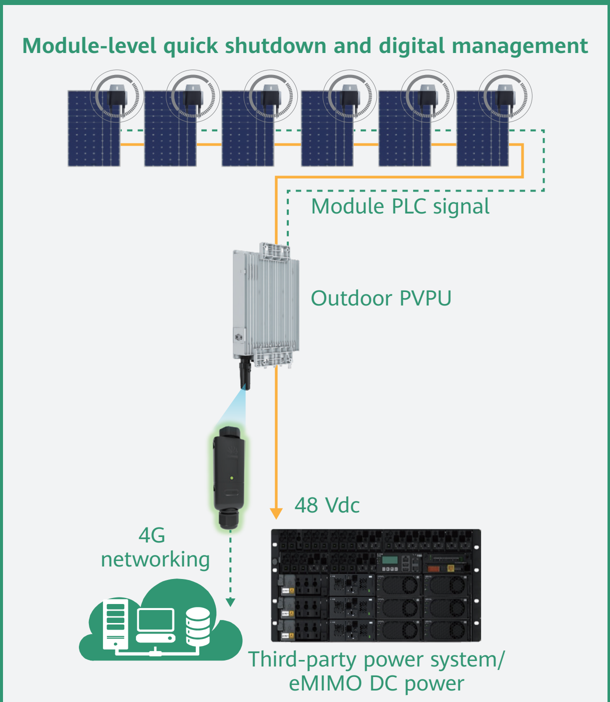


Figure 4-8 Module-level quick shutdown and digital management

• From multi-point string access to four-in-one simplified architecture:

The networking architecture of the existing solution is complex and often involves four nodes to form a system. The PV output needs to be connected to the junction box, rectifier, DC power distribution module, and finally networked with a specific control unit. Such an architecture means excessive maintenance workload and period. Besides, the application scenarios are also limited.

Huawei's four-in-one PV controller integrates the PV junction box, PV module, PV power distribution module, and control unit, simplifying access nodes. In addition, the new PV controller supports multiple networking modes (IP, 4G, and in-band networking) to meet requirements in different scenarios. IP65 rating and 20-year service life guarantee stable clean power supply for sites for a longer time.

• From scattered components to collaborative PV + ESS system:

In a legacy PV power system, it is difficult to adjust the charge and discharge settings of the ESS based on season changes when PV modules are over-configured. As a result, excess energy yields are wasted, and the PV power consumption ratio is limited. PV systems and batteries are separate from each other. In areas with time-of-use rates, the electricity price differences cannot be utilized and the revenue is not maximized.

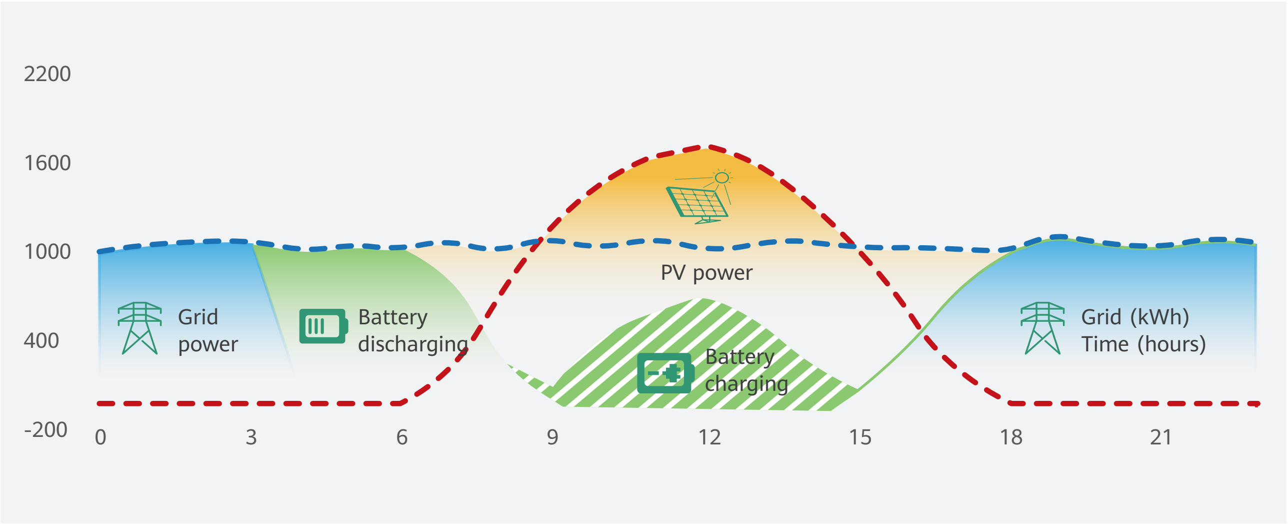


Figure 4-9 Huawei PV + ESS solution

Huawei's PV + ESS solution consists of cyclic CloudLi batteries and iSolar. Its peak staggering feature ensures that PV power is used preferentially during peak periods, fully harnessing PV power and generating more benefits. After the PV + ESS collaboration algorithm is enabled on the intelligent management system NetEco, the PV controller automatically collects statistics on historical power generation data and predicts the extra PV power on the next day. Then, the algorithm adjusts the CloudLi charge and discharge depth and duration based on the daily prediction data to achieve 100% PV consumption.

In areas with time-of-use electricity rates, the PV + ESS collaboration algorithm adjusts the lithium battery charge and discharge time based on the electricity price differences and CloudLi capacity while ensuring that PV power is preferentially consumed, further cutting the OPEX and carbon footprint of the site. Meanwhile, the PV controller adaptively adjusts the output based on the busbar voltage to ensure that the cycle life of the battery will not be shortened due to high PV output voltage in the float charging phase, improving the reliability of the site.

4.3.2 Genset-Free Site

In areas where grid power is unstable or inaccessible, such as Asia, Africa, and Middle East, gensets are still the main power source. It is estimated that more than 500,000 telecom sites in these areas are equipped with gensets. However, gensets bring high energy OPEX. In some areas of Africa, diesel is US$1 per liter. The 24-hour operation of gensets brings high fuel costs. In addition, gensets need to be maintained frequently, so maintenance is also costly. In addition, batteries and fuel are prone to theft. The global average theft rate is 10%. Site breakdown caused by battery theft or lack of genset maintenance accounts for more than 80% of the total. Besides, gensets causes vibration, noise, and large amount of carbon emissions during operating. As the power consumption keeps surging during network evolution, a power solution without gensets is in urgent need.

This is what Huawei has been striving for. From 2008 to 2018, Huawei has launched five generations of hybrid power solutions to help carriers get rid of gensets. Huawei's genset-free solution applies to the following scenarios:

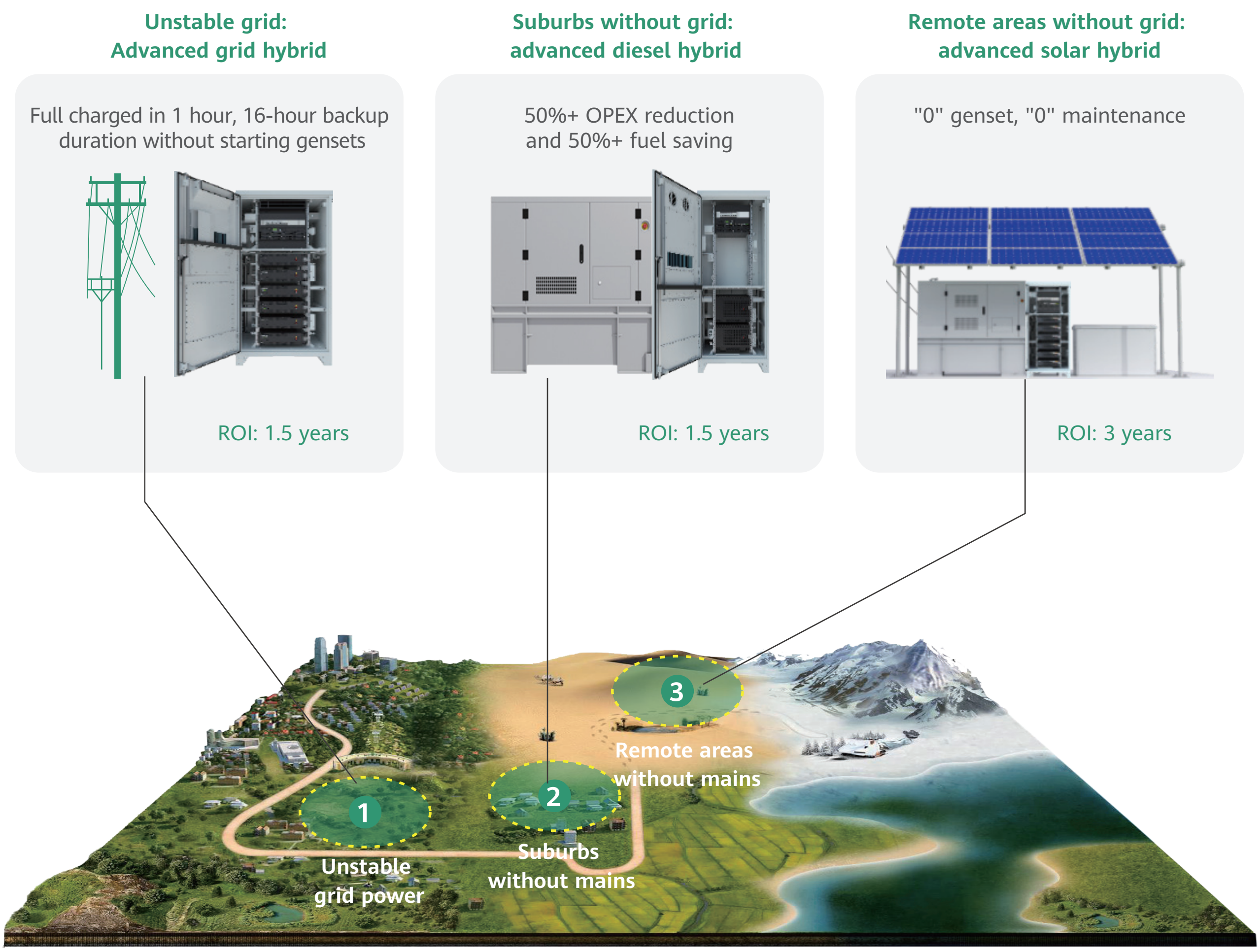


Figure 4-10 Huawei genset-free solution

■ **Advanced grid hybrid:**

In scenarios with unstable grid power supply, the CloudLi uses the fast charging function and become fully charged in just one hour. In addition, the AI technology is used to predict the outage model, prolonging the battery lifespan. The Grid-MPPT technology is used to track the maximum output power of the power grid, maximize grid power usage in scenarios with frequent outage. Mobile lithium batteries are discharged in the case of occasional ultra-long outages. These features ensure that the SLA can be met (payback period < 2 years) while minimize the genset runtime.

■ **Advanced diesel hybrid:**

In areas without grid power, gensets used to work all day long. The advanced diesel hybrid solution reduces the genset runtime by 75% through the cyclic running of genset + CloudLi. CloudLi can also increase the load rate of gensets. AI technology is used to maintain a constant load rate of 80% for gensets, cutting fuel consumption by 50% and reducing the payback period to less than 1.5 years.

■ **Advanced solar hybrid:**

In areas without grid supply but with sufficient sun light resources, solar energy is harnessed to reduce genset operation. The genset is used only as a backup. PV + battery energy storage + genset backup mode saves fuel and achieves zero genset runtime and maintenance. The payback period of the solution is 4 years.

The legacy power supplies and batteries can be reused in the intelligent genset-free solution, eliminating service interruption caused by power cutover, avoiding 50% of engineering workload, and reducing the reconstruction ROI.

The solution has gained popularity in the Middle East, Asia, and Africa. After a customer in the Middle East completed power reconstruction using this solution, more than 2000 sites became genset-free, slashing the OPEX by 69%, increasing PAV by 2%, and increasing site revenue. The consolidated revenue reaches US$9,000 per year, the payback period is less than 1.5 years. All new sites use Huawei CloudLi batteries to replace lead-acid batteries. The NetEco is introduced to establish a digital energy efficiency management platform. Network KPIs can be remotely checked, risks are predicted in advance, and site visits are reduced by 30%. In Africa, the solution helped a customer achieve zero genset operation in 12 hours of power outage, and the payback period was just 1.2 years. The solution also helped a carrier change from two gensets per site to one genset, halving fuel consumption and cutting monthly OPEX by US$661. The site availability was improved by 7%, the revenue was raised by US$1079/month, and the payback period was 1.2 years.

Besides reducing OPEX, the solution can also help tower companies earn money. In areas where the grid supply is unstable or unavailable, telecom sites can lease power to nearby residential buildings, offices, small shopping malls, and enterprises. New business models, such as electricity offsets rent, electricity access with network, and site sharing, can further maximize site revenues.

4.4 Low Carbon O&M

4.4.1 Lithium Battery Prevalence

During site evolution, the backup power capacity also needs to increase to meet the service requirements. Lead-acid batteries or common lithium batteries are dumb devices and cannot communicate with the power system or upper-layer management system. Therefore, their status is invisible and manual O&M is needed. In addition, batteries serve only as backup power and the values are not fully exploited. For example, during capacity expansion on the live network, old and new batteries cannot be used together, causing resource waste. Extensive configuration brings investment waste and low reliability.

To address the problems, Huawei launches the fifth-generation CloudLi that integrates power electronics, IoT, and cloud technologies into one intelligent lithium battery. CloudLi batteries can communicate with Huawei power systems or the NetEco management system through an IoT gateway to implement cloud-based energy storage management in all scenarios and visualize energy storage parameters and status. This feature unleashes the values of energy storage devices, improves O&M efficiency, and visualizes battery status in any power supply scenario.

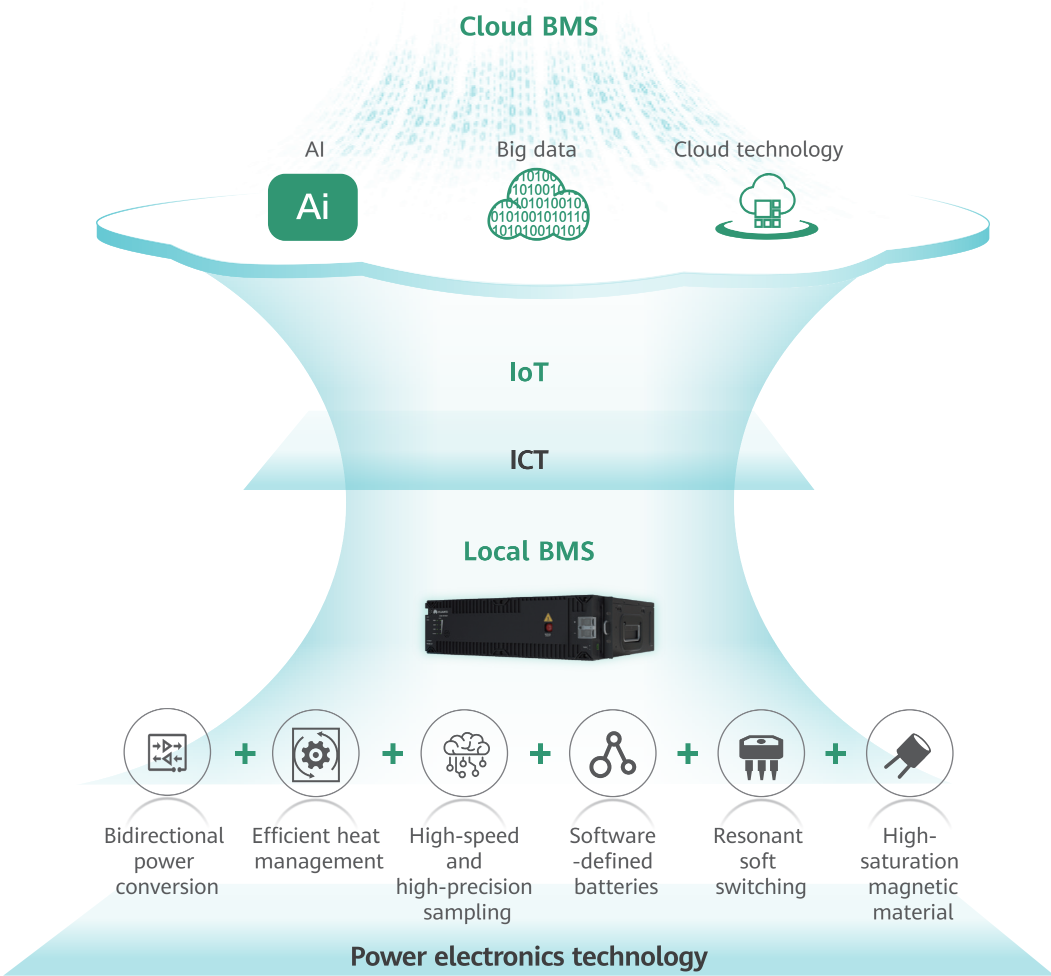


Figure 4-11 Architecture of Huawei CloudLi

• From manual O&M to simplified cloud-based O&M

Lead-acid batteries are not intelligent. The voltage, current, SOC, usage status, aging degree, and remaining backup time cannot be detected. To obtain the information, manual site visits are required. However, manual operation is time-consuming, costly, and inefficient. For example, to perform a battery test, O&M engineers need to visit the site, record data, draw curves, and analyze the test. Although common lithium batteries are equipped with simple battery management system (BMS) to detect SOC, voltage, and current, they cannot communicate with the management system, which means the information cannot be displayed on the management system and manual onsite detection is still required. In the 5G era, the number of sites increases and site management becomes even more complex. Manually managing this many of sites will lead to high OPEX and delayed O&M, threatening site reliability.

The CloudLi can upload lithium battery data, such as voltage, current, SOC, SOH, location, and theft statistics, to the NetEco through the IoT gateway in all scenarios without any power networking transmission. The NetEco analyzes various data uploaded by lithium batteries and provides optimization suggestions and timely warnings. Users can remotely set battery parameters, functions, and perform one-click battery tests on the NetEco, eliminating the need for site visits. This greatly reduces O&M costs, improves O&M efficiency, and reinforces backup power reliability.

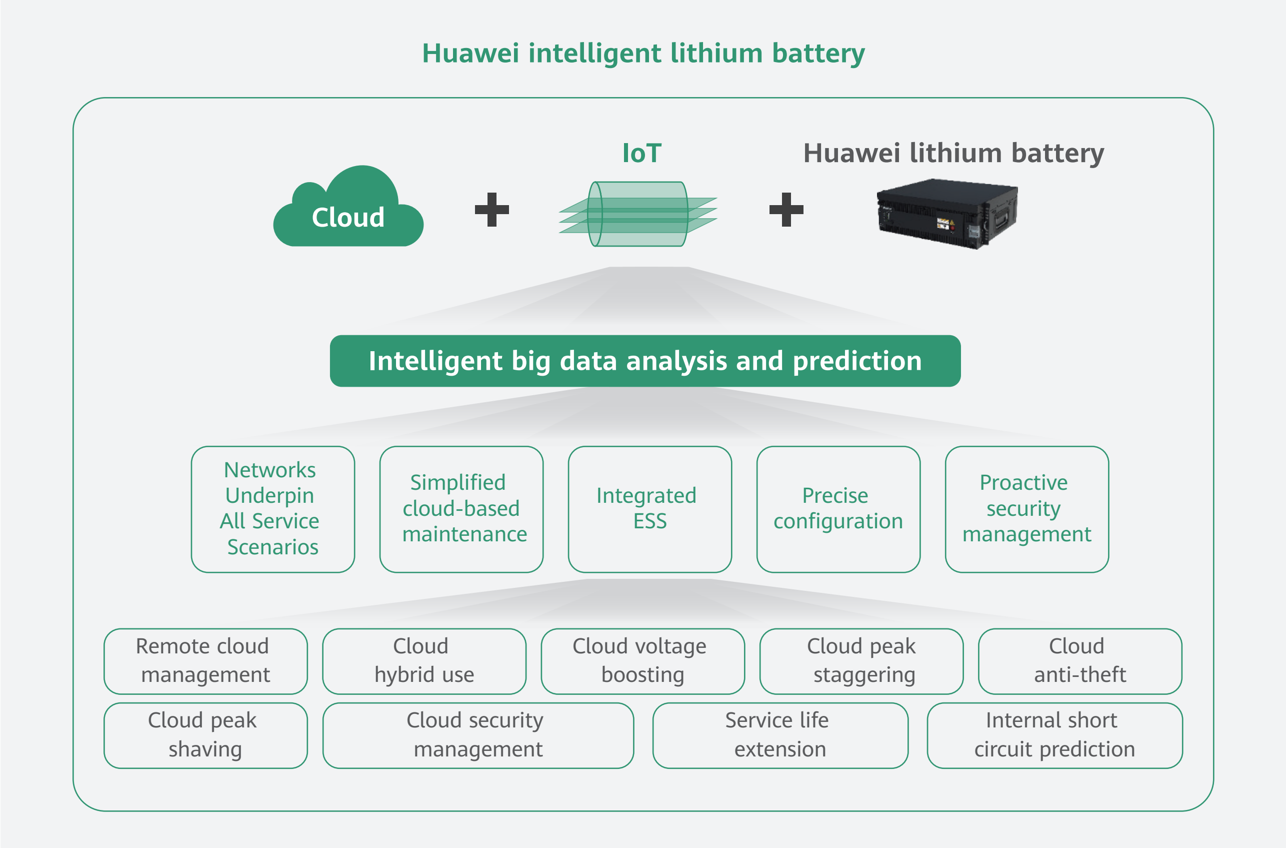


Figure 4-12 Huawei intelligent lithium battery solution

• From backup power to intelligent ESS

Lead-acid batteries or common lithium batteries are used only as backup power. When grid power supply is available, they are float charged for a long time and turn into idle assets. In the 5G era, telecom sites pose higher requirements on batteries. They are expected to become digital and offer more functions.

Intelligent lithium batteries collaborate with the NetEco to implement intelligent features in all scenarios, simplify evolution, and activate idle assets.

Cloud-based voltage boosting:

Intelligent lithium batteries collaborate with the cloud to boost voltage. With this feature, cables do not need to be replaced in long power supply distance scenarios and battery capacity can be fully discharged.

Cloud hybrid use:

With this feature, old and new batteries can be used together without battery combiners. Batteries on the live network can be reused during site capacity expansion, avoiding investment waste.

Cloud peak shaving:

This feature eliminates grid reconstruction when the peak power consumption increases but the grid power is insufficient. In addition, the solution can be quickly deployed, shortening the TTM from six months to one day.

Cloud peak staggering:

In scenarios with time-of-use rates, intelligent lithium batteries can be charged when the electricity price is low and discharged when the electricity price is high, helping customers reduce electricity fees and OPEX.

Cloud anti-theft:

Intelligent lithium batteries collaborate with the cloud to implement software lock anti-theft, gyroscope anti-theft, and GPS, reducing the theft rate and improving site energy storage security.

• From extensive configuration to precise backup power:

On the live network, batteries at different sites are configured in a unified mode based on typical site models, resulting in inaccurate investment. Redundant batteries are wasted, and under-configuration affects site reliability. In addition, it is difficult to know whether the configured battery capacity meets the needs.

The CloudLi communicates with the NetEco through an IoT gateway and reports battery data. The NetEco intelligently analyzes the matching between the energy storage capacity and site power consumption on the cloud, and provides accurate information to help users optimize battery configuration and achieve efficient resource allocation. With this feature, backup power can be configured on demand, reducing waste.

• From passive safety to proactive safety:

The status of lead-acid batteries and common lithium batteries is hard to obtain. When the backup power is insufficient or a fault occurs, warnings cannot be generated in a timely manner. As a result, O&M cannot be performed in time, and backup power reliability cannot be ensured.

CloudLi features end-to-end safety design from electro-chemical cells, pack, to intelligent BMS management, and has passed extreme verification in different scenarios. Through the synergy of the cloud and BMS, CloudLi implements intelligent management functions such as network-wide energy storage safety management and intelligent internal short-circuit prediction, safeguarding the safety of energy storage, services, and assets.

4.4.2 Comprehensive Intelligence: Digital O&M

The existing sites are troubled by invisible energy consumption and carbon emission, high manual site visit costs, and passive perception. Huawei Site Power Low Carbon Target Network uses digital methods to connect tens of thousands of isolated sites and equipment rooms to form a network, achieving visualized management on the entire network. Unique digital and AI technologies are used to achieve energy intelligence. Efficient collaboration and energy efficiency management are carried out to lower carbon emissions of power facilities, achieving autonomous driving of energy networks.

Figure 4-13 Huawei digital site O&M

Huawei Site Power Low Carbon Target Network brings three benefits to customers: green and low carbon, intelligent O&M, and intelligent power supply. Green and low-carbon management displays carbon emissions and provides mitigation measures. Intelligent O&M management supports remote control, remote test, and fault warning, achieving automatic O&M without site visits. Intelligent power supply management transforms the management system from passive fault response to automatic risk prevention, predicting risks in advance and reducing site breakdown.

• Green and low-carbon

In a conventional management system, energy efficiency and carbon emissions cannot be detected and no energy efficiency analysis is available. As a result, energy is wasted, devices do not collaborate with each other, and the system efficiency is low. Huawei Site Power Low Carbon Target Network identifies low-efficiency sites and devices through based on data such as carbon emissions, energy saving KPIs, and intelligent diagnosis, making carbon emission traceable.

The energy consumption of 2G/4G/5G load branches is visualized, and refined decarbonization methods can be offered.

Intelligent air conditioner management prevents air conditioners from running at low temperatures and saves electricity fees.

The intelligent peak staggering function controls battery charge and discharge based on electricity prices. This function has helped a Chinese carrier cut electricity fees by 17.1%.

In areas with good sun light resource, excess PV energy yields are often wasted. The PV + ESS optimization function can be used to store the extra PV energy to batteries, implementing intelligent scheduling of PV, grid power, and energy storage.

• Intelligent O&M

Traditional O&M mode relies too much on manual site visits. Take a carrier as an example, 46% of the site visits are made to perform battery tests, locate faults, and start a genset.

Huawei SmartSite management system reduces manual site visits through remote automatic O&M. Battery tests can be performed in offices by setting parameters on the management system, eliminating the need for site visits. According to the statistics of a carrier, the commissioning period is shortened from 6 months to one day without site visits.

In addition, fault locating and genset startup can be performed remotely to improve O&M efficiency.

• Intelligent power supply

Conventional management systems respond passively after a site breaks down. Risks cannot be warned beforehand, no emergency measures are taken during an event, and post-event fault recovery is slow.

To handle these pain points and improve reliability, Huawei intelligent O&M identifies risks in advance to prevent site breakdown.

NetEco functional architecture

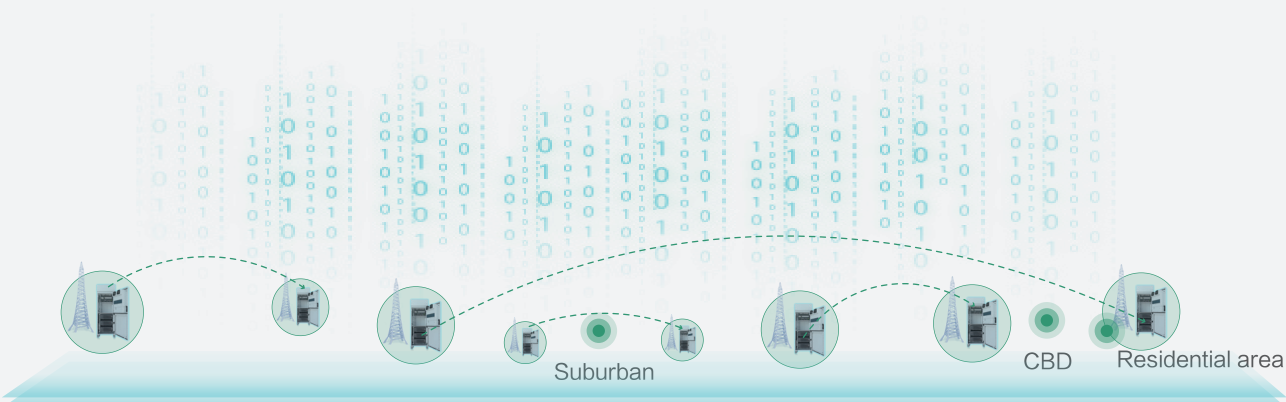
Advanced capabilities

Green and energy-saving	Intelligent O&M	Reliable power supply	Asset safety
Network-wide energy efficiency	Battery management	Emergency analysis and risk identification	Lithium battery safety
Staggering electricity usage	Software-defined	Intelligent peak shaving	Access control
...	...	...	...
Self-Optimization of Solar & Battery	Backup Slicing	Battery SOH	
Branch measurement	MPPT	Precise battery configuration	

Basic capabilities

Alarm mgmt.	Real-time mgmt.	Performance and report mgmt.	Configuration mgmt.	Software mgmt.
System and user mgmt.	Platform mgmt.	Log mgmt.	Asset mgmt.	Precise O&M

Figure 4-14 NetEco functional architecture



For example, the risky site prediction function can display risky sites and informs O&M personnel of the fault in a timely manner. Measures can be taken to rectify the fault and avoid site breakdown. During an event, backup power slicing supports differentiated backup power, prolonging the backup time of important loads and reducing site breakdown. For example, for a site where 5G services are fewer than 2G/3G/4G services, the majority of the backup power can be offered to 2G/3G/4G loads, ensuring reliable operation of important loads. After a fault is rectified, remote root cause analysis can be implemented to quickly locate the root cause and recover site services. Huawei intelligent O&M can analyze the cause of site breakdown in one-click mode to help quickly turn the site to normal.

Huawei's intelligent O&M system has won the trust of more than 300 customers. In Asia, Huawei helped a customer reduce the site breakdown time by 30%, saved 35% investment in specific reconstruction, and shortened the fault recovery time from 1.8 hours to 0.9 hours through remote root cause analysis.

4.5 Cases

Huawei's Site Power Low Carbon Target Network solutions have been deployed in more than 100 countries and regions around the world, helping customers build green and low-carbon networks.

By September 2022:

One cabinet for one site solution has been used in more than **600,000** sites.

Over **2** million blade power solutions have been deployed globally.

More than **100,000** sets of PV deployment and genset-free solutions have been delivered and the installed capacity reaches **600** MW.

The total shipment of intelligent lithium batteries is **10** GWh.

Intelligent O&M helps more than **300** customers worldwide implement digital O&M.

Huawei's Site Power Low Carbon Target Network has saved **9,260,214,897** kWh of electricity and reduced carbon emissions by **4,398,613** tons, equivalent to planting **6,009,034** trees.

These are just a beginning.

05 Visions and Objectives

Looking into the next decade, 5G will still be in the rapid construction period, and 6G will enter the deployment period. New service such as XR, Internet of Vehicles (IoV), and metaverse will grasp more attention, which will further increase the energy consumption and carbon emission of sites.

With the help of the Site Power Low Carbon Target Network, we hope that in the next decade, the SEE can be improved to over 95%, the network carbon emissions can be cut by 80%, the green power usage can be improved to 80% in sites, and the genset can be phased out from telecom sites. The number of site air conditioners can be slashed. The network management technologies like self-learning, self-scheduling, and self-repair can be promoted to realize unattended O&M and autonomous driving.

To this end, Huawei will introduce more green design concepts and advanced technologies to reduce site energy consumption, unlock more site values, and contribute to sustainable development while ensuring service and experience.

06 Acronyms

No.	Acronym	Full Name
1	CAPEX	Capital Expenditure
2	OPEX	Operating Expense
3	TCO	Total Cost of Ownership
4	TTM	Time to Market
5	ROI	Return On Investment
6	SEE	Site Energy Efficiency
7	NCIe	Network Carbon Intensity energy
8	PUE	Power Usage Effectiveness
9	VPP	Virtual Power Plant
10	EF	Emission Factor
11	SOH	State of Health
12	SOC	State of Charge
13	IGBT	Insulated Gate Bipolar Transistor
14	PLC	Power Line Communication
15	MIMO	Multiple Input Multiple Output

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