# Sustainable Design and Implementation of New Energy Highway Service Station: A Case Study of Zhaoshan Service Station Renovation Project

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**Abstract.** With the rapid development and popularization of new energy vehicles, the demand for charging facilities is increasing. As an important charging and maintenance base for new energy vehicles, the new energy expressway service station has important strategic significance. However, the current design of service stations is often unable to meet the needs of new energy vehicles, and there are problems such as insufficient charging facilities and unreasonable layout. Therefore, it has become an urgent need to design a highway service station that can meet the needs of new energy vehicles. This requires consideration of the layout of charging facilities, the design of buildings, the setting of maintenance facilities and the planning of other support facilities. Through reasonable design, the charging efficiency of service stations can be improved, the charging demand of new energy vehicles can be met, and the development and popularization of new energy vehicles can be promoted. Sustainable design aims to reduce the impact on the environment, improve the efficiency of resource utilization, and promote the sustainable development of economy and society. In the design of new energy highway service stations, sustainability considerations include energy efficiency, water resource management, waste disposal, building material selection, ecological protection, etc. Through reasonable design and planning, sustainable new energy highway service stations can provide more environmentally friendly and efficient charging and maintenance services for new energy vehicles.

**Keywords:** Sustainable design, new energy, highway service area, principles.

## 1. Introduction

With the change of global energy structure and the increasingly serious problem of environmental pollution, the development of new energy has become a common goal pursued by governments and enterprises. In this context, the new energy highway service station came into being, providing an important energy supply for new energy vehicles [1]. However, how to ensure the sustainable design of the service station has become an urgent problem to be solved while meeting the traffic needs. The purpose of this paper is to discuss the sustainable design and implementation of new energy highway service stations, in order to provide reference for related industries.

The purpose of this study is to analyze the advantages, feasibility and environmental impact of sustainable design of new energy expressway service stations and provide theoretical support for optimizing service station design and promoting the development of green transportation [2]. The significance of the research is to achieve the optimization of the energy structure and environmental protection, promote the development of the new energy vehicle industry, and improve the use experience and economic benefits of the service station.

In order to achieve the research purpose, this paper adopts the methods of literature review, case analysis and establishment of evaluation model [3-6]. First of all, the concept and practice cases of sustainable design of modern new energy highway service station are sorted out by consulting relevant literature. Secondly, combined with the actual case, the energy utilization, environmental impact and economy of the service station are deeply analyzed. Finally, an evaluation model is established to comprehensively evaluate different design schemes and provide reference for optimizing the sustainable design of the service station.

Through research, this paper finds that the advantages of sustainable design of new energy highway service stations are improving energy utilization efficiency, reducing environmental load, promoting green travel and enhancing economic benefits. In terms of feasibility, sustainable design can not only meet the energy needs of new energy vehicles, but also effectively reduce the carbon emissions of service stations, contributing to the development of green transportation.

To sum up, the advantages and feasibility of sustainable design of new energy highway service stations are discussed in this paper. In order to realize the green development and efficient utilization of the service station, it is suggested that the future design should pay attention to energy diversification, optimize energy management, improve energy utilization efficiency, and strengthen ecological environmental protection to achieve the coordinated development of economic, social and environmental benefits.

In short, the sustainable design and implementation of the new energy highway service station is a systematic project, which needs to be continuously promoted under the joint efforts of the government, enterprises and scientific research institutions. It is hoped that the research in this paper can provide useful reference for related industries and contribute to the realization of the goal of green and low-carbon transportation.

## 2. Preliminary Research

### 2.1. Development of New Energy Vehicles

At present, oil resources are decreasing and non-renewable, and China is rich in electric power resources. Environmental pollution is increasing day by day. And the state vigorously advocates, issued a series of policies to encourage and promote the development of new energy vehicles. The development of new energy vehicles is widely optimistic in our country [5].

New energy vehicles refer to the use of unconventional vehicle fuel as a power source (or the use of conventional vehicle fuel, the use of new on-board power devices), the integration of vehicle power control and drive advanced technology, the formation of advanced technical principles, with new technology, new structure of the car. New energy vehicles include pure electric vehicles, extended-range electric vehicles, hybrid electric vehicles, fuel cell electric vehicles, hydrogen engine vehicles, etc. [7-9].

Since the epidemic, new energy vehicles have taken the lead in resuming growth, not only hitting a new high in sales, but also breaking new ground in the proportion of sales in passenger cars, making important contributions to the recovery of the entire passenger car market. In the past 2022, the new energy vehicle market has shone. Driven by the twin engines of policy and market, the market growth has far exceeded expectations, and the penetration rate has repeatedly reached a new high, with the annual penetration rate approaching 26%, an increase of 12 percentage points over last year. The development of new energy vehicles in China is imperative.

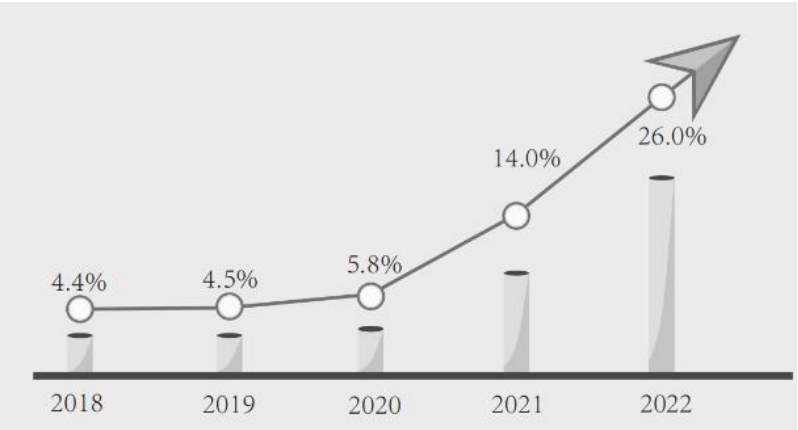


**Figure 1.** The development of policy and market. (Picture credit: original)

### 2.2. Case Study of Domestic and Foreign Service Station Design

The charging station designed by the Danish design company COBE will be displayed in the form of a "big tree" to provide shelter for the space below and create a calm atmosphere. The modular construction means it will be a quantifiable form of design, with a 'tree' that can be endlessly replicated and eventually transformed into a 'forest' to meet the growing demand for charging stations. The tree is made of environmentally friendly materials and is fitted with solar cells. In addition, the charging station is surrounded by low shrubs, lawns and real trees [3, 10].

The project site is adjacent to Zipingpu Town in the east, Zipingpu Reservoir in the southeast, Yingxiu Town in Wenchuan County, Aba Prefecture in the west, and Hongkou Township in the north. It is 18 kilometers away from Dujiangyan City. The base is close to the highway test site, with beautiful natural conditions surrounded by mountains and streams.

In order to highlight the streamlined exterior outline of the building, the architect took design inspiration from the continuous traffic flow and the city's crisscrossing road traffic lines. By abstracting and refining the road traffic flow, the architect simplified the dynamic design lines, and then refined the architectural form from the flow lines, presenting a more extreme sense of "speed and passion" in the expression of the facade effect. Representing the new era of human automatic driving in the future.

### 2.3. Necessity of Investigation and Transformation of Zhaoshan Service Station

The Beijing-Hong Kong-Macao Expressway is a state-level expressway radiating the capital. China's National expressway network, No. G4, is China's North-South traffic artery, with a total length of 2,285 kilometers [4]. The Zhaoshan Service Area is located at 1,524 kilometers of the Changsha to Xiangtan section of G4, covering an area of 175 mu. Built in 1996, it is an important post station on the G4 expressway [4].

The traffic flow of Changsha section of G4 Expressway is one of the largest in China. The daily flow is large, and the flow doubles during holidays. Changsha section of the expressway was built in the 1990s, compared with the present stage of the expressway, the carrying capacity of facilities and cannot adapt to the present stage of various complicated work. Changsha section is located in the middle of the section, which is an important node. Nowadays, self-drive travel has become the mainstream and many people want to travel by themselves. Service station reconstruction is inevitable!

Zhaoshan is located on the east bank of the Xiangjiang River, 20 kilometers northeast of Xiangtan City. It is the junction of Changsha, Xiangtan and Zhuzhou. 185 meters above sea level, it is the original site of "Mountain stone green LAN" in the old "Eight scenes of Xiaoxiang".

## 3. Significance and Design Principles of Sustainable Development of New Energy Highway Service Area

### 3.1. Significance of Sustainable Design of New Energy Vehicle Charging Stations

The sustainable design of new energy vehicle charging stations is very important because it can minimize the waste of energy and resources, protect the environment and reduce the dependence on fossil fuels. Sustainable design can be achieved in a variety of ways. (i) Use renewable energy: New energy vehicle charging stations can use solar, wind and other renewable energy sources to generate electricity, which can reduce carbon emissions, extend the service life of the charging station, and save energy costs. (ii) Reduce waste of resources: The design of charging stations should make full use of existing infrastructure and reduce inherent costs, such as the design of cables and switchboards. (iii) Reusable materials: The construction of charging stations should consider the use of reusable materials, such as recycled steel and recycled plastics, to reduce the need for new materials.

Through sustainable design, NEV charging stations can lower carbon emissions and reduce the impact on the environment and resources, thereby leaving a more sustainable and environmentally friendly world for our future.

### 3.2. Principles of Sustainable Design for Highway Service Areas

For environmental protection design, highway service stations should consider environmental protection factors in the design, such as reducing environmental pollution, waste generation and treatment, energy utilization optimization, etc., through the application of renewable energy and energy-saving technology, reduce the energy consumption of service stations, in order to achieve the purpose of reducing carbon emissions.

For social acceptability design, the expressway service station is a traffic facility serving the majority of drivers, and the design needs to consider social acceptability, such as reasonable planning of idle space, noise control, landscape increase, and coordination of the surrounding environment of the park, so as to improve the comfort of drivers and passengers, improve the service level, and reduce the inconvenience and interference to the surrounding residents.

For economic benefit design, the design of expressway service station should consider economic benefit, improve the equipment efficiency of service area facilities, avoid equipment aging, try to reduce space cost and save operating cost, so as to improve its long-term income capacity and maintenance cost efficiency.

For safety design, in order to ensure the safety of drivers and passengers, the design of highway service station should consider the safety principle, such as fire extinguishing system, electrical insulation and other facilities, to ensure that the safety and health conditions meet the requirements, in order to ensure the basic principle of safety first.

For humanized design, the design of the highway service station should meet the humanized needs, such as providing facilities such as catering and entertainment, tourism and shopping, toilets, charging piles, etc., to improve the service comfort of the passengers, and strengthen the connection between the service station and the driver and other subjects to improve service quality and satisfaction

## 4. Sustainable Design and Effective Strategy of Design

### 4.1. Design Space According to People's Residence Time

People's residence time is short, medium and long. In order to adapt to the people who want to quickly supply through the service station, the short time is mainly to rest, shopping and taking meals. It is suitable for most people (people who need to charge for a certain period of time), mainly for rest, dining and temporary office. It is suitable for people who need to rest for a long time, mainly for accommodation, dining and private office [9].

### 4.2. Optimize the Layout of Charging Facilities

Charging facilities are mainly based on charging piles, some of which are set as changing stations, and a small part of which are charging stations for special fuel vehicles (methanol fuel cells, hydrogen fuel cell vehicles, etc.) [9].

### 4.3. Sustainable Design Scheme

#### 4.3.1. Design of Electric Energy Generation Device Using Plants

The essence of plant power generation is to use microorganisms in the soil to generate electricity. Because the main energy substances in the power generation process come from the organic matter produced by plant photosynthesis. Only a small part of these organic matter is provided for the growth of the plant itself, and most of the rest will be secreted into the soil environment through the root system of the plant. Some specific "electrogenic" microorganisms present in the soil can effectively use this part of organic matter, oxidize it through metabolism inside the cell, and transfer the electrons generated in the process to the outside of the cell through the respiratory chain of the cell. If you put the cathode and anode of the circuit in the soil, then these electrons will eventually be received by the anode, and then transferred to the cathode through the external circuit. At the cathode, the electrons combine with oxygen in the air, plus hydrogen protons from the anode, to form water. Throughout

the process, plant photosynthesis provides the basic fuel for the "electricity-producing" microbes to generate electricity, which is collected by artificial external circuits [1].

### 4.3.2. Design of Device Using Wind Energy to Generate Electric Energy

Wind turbine is a device used to generate electric energy by using wind energy. It consists of four parts: wind wheel, transmission, generator and controller. The wind wheel is the part that converts the energy of the wind into mechanical energy. It is usually designed with three blades, which can maximize the use of wind energy. The transmission is to convert the speed of the wind wheel into the speed required for the generator. The generator consists of magnets and coils, and when the wind turns the blades, the blades interact with the magnets inside the generator to create an electric current, which produces electrical energy. The controller, in turn, is used to monitor and control the power output of the wind generator to ensure a stable grid connection.

Vertical axis fans are not designed to face the tuyere, so they can be installed in more complex environments. It is usually composed of shaft, beam, frame, generator, control system and other parts. The shaft is usually vertical, while the blades are fixed to the shaft, and when the wind blows over the blades, mechanical energy is generated, which generates electrical energy through the generator. The control system is used to monitor and control the amount of wind energy produced to ensure the high efficiency of the generator [6].

### 4.3.3. Design of Electric Energy Generating Device Using Light Energy

Set up a huge array of solar panels in a city or public place to generate electricity from the sun's energy. These solar panels can be placed on top of buildings, on the walls, or on the ground. These panels can be made of transparent materials, such as glass or clear plastic, in order to be able to see the landscape below them.

In addition to the solar panel arrays, designers can also add some landscaping fixtures around them. For example, plant walls, pools, or sculptures can be added around the solar panels to create a harmonious environment. Alternatively, designers can use some special lighting effects to emphasize the presence of solar panels, such as lighting up the panels at night or using mirrors to reflect sunlight onto the panels during the day.

Finally, designers can set up some seating or lounge areas below the solar panels for people to rest or view the solar panels (Fig. 2). These seats or lounge areas can be made of environmentally friendly materials, such as biodegradable plastic or bamboo, to reinforce the good environmental concept. These seats or lounge areas can also be fitted with USB ports or power outlets, making them ideal places for people to charge or connect their electronic devices [7].

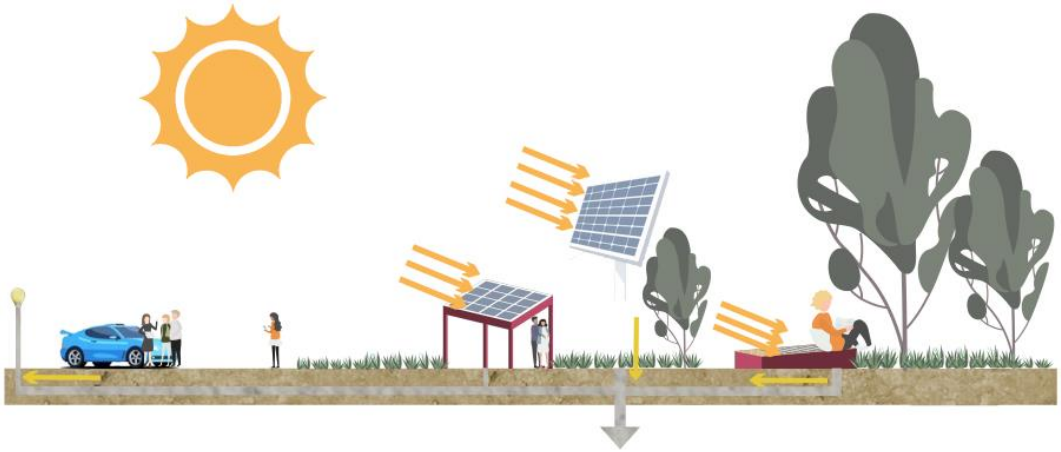

**Figure 2.** The design of solar panels for people. (Picture credit: Original)

### 4.3.4. Design of Electric Energy Device Using Waste and Heat Generated in the Station

The invention relates to a design idea of combining two power generation methods using waste heat to achieve the purpose of using domestic waste heat to generate electricity. The specific

realization method includes waste electricity generation and thermoelectric power generation, and the two parts are connected by a combined circuit. The device can be used not only as an emergency power supply in resource-limited areas, but also as a daily environmental protection energy for families, factories and enterprises. High quality circuit board, battery and generator materials are used to ensure the safety and stability of the system [8].

## 5. Sustainable Design Development Direction of New Energy Highway Service Station

The sustainable design and development of new energy expressway service stations should pay attention to energy self-sufficiency, ecological friendliness, diversified services, intelligent management and networking. The design should incorporate renewable energy sources, such as solar and wind power, and utilize energy storage technology to store excess energy for future use. Gas stations should give priority to ecological energy saving, adopt green building materials, promote energy-saving lighting and implement intelligent energy-saving equipment. Service stations, which include a variety of services such as charging, refueling and even sharing economy models, should meet the various needs of consumers. Through an intelligent management system that uses Internet of Things technology and big data analysis, the station can effectively monitor energy usage and improve service quality while minimizing management costs. In addition, through interconnection and information sharing among gas stations, the network can improve energy utilization efficiency and improve service standards.

## 6. Conclusion

At present, oil resources are decreasing and non-renewable, so new energy vehicles are popular all over the world. China is rich in power resources, and environmental pollution is becoming increasingly serious. Since the epidemic, new energy vehicles have also taken the lead in recovering growth. We take the investigation of charging stations in the form of "big trees" by the Danish design company COBE as an example to propose the necessity of upgrading Zhaoshan service station. The significance of sustainable design for the service area of the new energy highway is discussed and proposed, including "use of renewable energy", "reduce waste of resources" and "reusable materials", and the design principles include "environmental design", "social acceptability design", "economic benefit design", "safety design" and "humanization design". In the sustainable design and the effective strategy of design, we design different service areas for short, medium and long periods according to people's stay time. In terms of charging facilities, charging piles are mainly used, some of them are set as changing stations, and a small part is set as charging stations for special fuel vehicles. In terms of sustainability design, we have five directions, namely, "Design of plant generating electric energy", "design of wind generating electric energy", "design of light generating electric energy", "design of waste generated in the station and heat generating electric energy" and "special fuel vehicle refueling device". Finally, we put forward the sustainable design of new energy highway service station development direction suggestions.

## Authors Contribution

All the authors contributed equally and their names were listed in alphabetical order.

## References

[1] Chen R., biological photovoltaic: Your pot of flowers can also generate electricity, 2015, guangfu.bjx.com.cn/news/20150521/621312.shtm.

[2] Liu S., Car manufacturers winter, new energy vehicles skyrocketing, China News Weekly, 2022, http://www.inewsweek.cn/auto/2022-04-13/15463.shtml.

[3] Li Y., Jiang X., Yang J., Roof greening radiation heating structure, 2020, CN111322664A, xueshu.baidu.com/usercenter/paper/show?paperid=1e1k06t0uk200gw0n04608t0rr327665&site=xueshu_se&hitarticle=1.

[4] Baidu Encyclopedia, Beijing-Hong Kong-Macao Expressway, 2022.

[5] Chu L., Research on the Strategy of coping with World Oil Peak, Journal of Beijing Petroleum Management Institute, 2010, xueshu.baidu.com/usercenter/paper/show?paperid=02e8208e14eefd2572083a81315d5c6e&site=xueshu_se.

[6] Li J., Zhang A., Research on New Energy and Renewable Energy Development Forecasting Methods in China-Wind Power Generation Forecasting Case, Renewable Energy Journal, 2021, xueshu.baidu.com/usercenter/paper/show?paperid=cb925a50b929031cef7d81f65a0ee392&site=xueshu_se.

[7] Xin P., Comprehensive Evaluation and Application Prospect of solar power generation Technology, 2015, xueshu.baidu.com/usercenter/paper/show?paperid=9690e6ae7836d08be415dd6519d9064d&site=xueshu_se.

[8] Lan J., Japan Develops High Efficiency waste power generation Technology, 2005, xueshu.baidu.com/usercenter/paper/show?paperid=0d2416a0e11f29e397936cc6e8690fb9&site=xueshu_se.

[9] Song Y., Research on Layout Planning of Urban Electric Vehicle Charging Facilities, 2011, xueshu.baidu.com/usercenter/paper/show?paperid=c76d3087e0eb44ce78c9af357d835df8&site=xueshu_se.

[10] Li Z., Unique ultra-High Speed Charging station in Frederiksia, Denmark, 2021, xueshu.baidu.com/usercenter/paper/show?paperid=1u0800u032160670at1g0rd0k9068858&site=xueshu_se.