

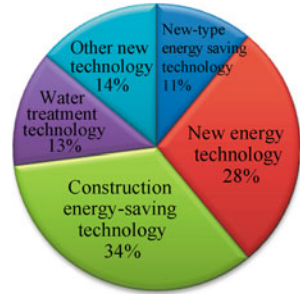
Chapter 2

Application and Analysis of Low-Carbon Technologies in Expo 2010 Shanghai

The use of new materials that are energy-efficient and eco-friendly has become one of the highlights of Expo 2010 Shanghai, China, as seen in the large solar panels on pavilion roofs, the LED lights illuminating the whole Expo Park, and the new energy vehicles shuttling between pavilions. This is an initiative to put into practice the low-carbon concept and to test and demonstrate how the new energy is to be used in the future. Undoubtedly, the successful integration of “green” and “low-carbon” elements has better embodied the theme of Expo 2010 Shanghai China, “Better City, Better Life.”

In the Expo Park, the solar power technology, wind turbine, new energy-driven vehicles and smart power grid (SPG), and other technologies were extensively used, most of which will be popularized after the Expo. Expo 2010 has been so far the largest demonstration area for new energy-driven vehicles to enter into operation. Over 1,000 new energy-driven vehicles running in the Expo site led to reduction of 13,000 tons of carbon dioxide emission, ensuring that public transport inside the Expo achieved “zero emission.” As for the solar power photovoltaic (PV) generation, the building-integrated solar PV system (BIPV) designed by the Expo organizer had the largest applications with the most technologies involved. A solar power generation system of 4.68 MW was installed on the roofs and glass curtain walls of the China Pavilion, the Theme Pavilions, the Expo Center, and the Art Performance Center, which can reduce 4,000 tons of carbon dioxide emission annually and has been the largest solar PV cells demonstration area in China. The “power generated floor” in Japan Pavilion can transform the energy treaded by humans into electric energy. The solar cells on the outer wall of the Japan Pavilion enabled the wall to generate energy by itself. All the construction materials used in the UK Pavilion could be recycled, with zero carbon dioxide emission in the whole building. The curtain outside the Switzerland Pavilion was made from degradable soybean fiber, which is capable of generating power that can be degraded naturally. The roof of the pavilion was covered with grass and dandelion. Once visitors take the cable car to the rooftop, they can smell the fragrance of the dandelion.

Fig. 2.1 Proportion of different low-carbon technologies applied in the Expo



In terms of the green lighting application, LED lights were used in China Pavilion, Expo Axis, Expo Performance Center, and Urban Best Practice Area (UBPA). This was the first time LED lighting was being used so extensively in city blocks in China.

The Shanghai Expo also served as a large platform for showcasing the new energy technology, energy conservation technologies, water treatment technologies, low-carbon transportation technologies, waste disposal technologies, etc. Figure 2.1 shows a proportion of the various low-carbon technologies applied at the Expo site.

2.1 Renewable Energy and New Energy

Renewable energy refers to energies that are renewable and replenished regularly or recycled, including solar energy, wind power, water power, biomass, tidal energy, etc. Most renewable energies are in fact storehouses of solar energy.

2.1.1 Solar Energy

2.1.1.1 Overview

Solar energy is a radiant energy that comes from a celestial body (the Sun) outside the Earth. A majority of energies that people use come directly or indirectly from the Sun. Various kinds of plants convert solar energy into chemical energy through photosynthesis so that it can be stored in the plants. Fossil fuels such as coal, oil, and natural gas are formed by plants and animals buried underground over long geological ages. They are in essence the solar energy fixed from ancient creatures. Besides, hydro energy, wind energy, wave energy, and ocean current energy are all converted indirectly from solar energy.

Fig. 2.2 Solar water heaters

(1) Major Uses of Solar Energy

(i) *Solar Energy Photo-thermal Utilization*

The principle of photo-thermal utilization is to first collect the solar radiation energy through its interaction with a substance and then convert it into heat energy for utilization. Currently, there are three types of solar thermal collectors that are mostly used: flat plate collectors, evacuated tube collectors, and concentrating collectors. Based on the different temperature and different usage, solar photo-thermal utilization is normally classified into low-temperature utilization ($<200\text{ }^{\circ}\text{C}$), medium-temperature utilization ($200\text{--}800\text{ }^{\circ}\text{C}$), and high-temperature utilization ($>800\text{ }^{\circ}\text{C}$).

Apart from solar water heaters (Fig. 2.2), solar photo-thermal applications include solar houses, solar cooker, solar greenhouses, solar drying system, solar earth ozone sterilization technologies, etc.

(ii) *Solar PV Power Generation*

Solar power generation is an effective way of making use of solar energy. There are a number of methods for solar power generation, of which the following two have already been put into practical use.

- a. Light-heat-electricity conversion. It utilizes thermal energy produced by solar radiation. First, it uses the solar thermal collector to convert the absorbed heat into steam, and then generates electricity driven by the steam turbine. The former process is the conversion from light to heat and the latter is from heat to electricity.
- b. Light-heat conversion. The basic principle is to transfer solar radiation energy directly to electrical energy by making use of PV effect. Its key device is the solar cell. Figure 2.3 shows the solar PV panel.

(iii) *Photochemical Utilization*

It is a light-chemical conversion using the sun's radiant energy to decompose water directly into hydrogen.

Fig. 2.3 Solar PV panel

(iv) *Photobiological Utilization*

It is a process of converting solar energy into biomass through the photosynthesis of plants. At present, these include fast-growing plants such as firewood forest, oil crops, giant seaweed, etc.

(2) Development and Utilization of Solar Energy

People have long been working at how to make use of solar energy. But only a small portion of the energy radiated by the Sun strikes the Earth, say one part in 2 billion. Yet this amount of energy is enormous, 30,000–40,000 times as much as the total amount of energy needed globally. So it is inexhaustible. Moreover, different from mineral fuels such as oil and coal, solar energy will not lead to greenhouse effect or global climate change, nor will it pollute the environment. For this reason, countries are paying more attention to the utilization of solar energy and competing to develop various new photoelectric technologies and materials so as to extend the application field of solar energy. Especially in the past decade, faced with the two major crises of increasingly dried up exploitable oil and deteriorating eco-environment, people are increasingly longing for the arrival of the “Solar Era.” Solar energy is now extensively used, from power generation, heating and water supply to a variety of solar power plants. In some fields, solar energy has entered into the application stage.

Recently, a Russian company incorporated its self-developed solar water-jet propeller and cold spraying propeller into solar pond engineering, and installed an ice groove to the solar pond, thus designing a new type of solar pond suitable for farming. With this design, building a solar pond of 70 m², a household of six to eight in 100 m² of housing will be supplied with abundant electricity consumption all the year round. Another research institute put forward an idea of a combined solar pond design that integrates solar energy, geothermy, and waste heat in the house by making use of the technology of heat pump and heat pipes, which greatly

reduce the cost of solar power generation. In the Ciscaucasian area, solar generation stations can even compete with thermal power stations. Solar energy is available all the year round for air conditioning in summer and heating in winter.

(3) Advantages and Disadvantages

(i) *Advantages:*

- ① Available to all: As the Sun clasps the Earth without regional restrictions, whether land or sea, mountains or islands, solar energy can be directly exploited and utilized and there is no need for mining or transportation;
- ② Pollution-free: Development and utilization of solar energy does not pollute the environment. It is one of the cleanest energies, which is extremely valuable today when environment pollution is becoming more and more serious;
- ③ Enormous: Every year the Sun's radiant energy arriving at the surface of the Earth amounts to about 130 trillion tons of coal, which is the largest among the world's exploitable energies;
- ④ Long-lasting: According to the present rate at which the Sun produces nuclear power, hydrogen reserves will be adequate to maintain for up to 10 billion years, while its lifetime is about several billion years. In this sense, we can say that the Sun's energy is inexhaustible.

(ii) *Disadvantages:*

Dispersity: Although the amount of solar radiation that arrives at the surface of the earth is huge, the energy flux density is very low. On average, on a fine summer day near the Tropic of Cancer, solar radiation has the largest irradiation at noon: the solar energy received at 1 m^2 area perpendicular to sunlight is about 1,000 W; allocated to every day and night of a year, it is only about 200 W. However, in winter it is roughly half the amount, on cloudy days only 1/5, when such energy flux density is very low. Therefore, if you wish to get certain converted power using solar energy, often quite a big set of collecting and conversion equipment is needed, the cost of which is rather high;

Instability: Restricted by natural conditions such as day and night, seasons, geographic latitude and altitudes, and subject to the random factors such as sun, cloud, or rain, solar irradiation in certain areas of the Earth is not continuous or stable, which adds much difficulty for application of solar energy at large scale. In order to make solar energy a continuous and stable energy as well as help it eventually become an alternative energy source that can compete with conventional energy, the problem of energy storage should be effectively solved, i.e., to store the solar radiant energy on sunny days as much as possible for use at nights or on cloudy and rainy days. Yet, currently energy storage is one of the hardest nuts in the use of solar energy;

Inefficiency and high cost: At present the development of solar energy utilization is theoretically feasible in some aspects and is mature in technology. However, due to its low efficiency and high cost, the economical efficiency cannot compete with that of conventional energy resources. For quite a period of time in the future, the further development of the solar energy utilization will be restricted.

(4) Economic Analysis

An increasing number of countries are aware that a society of sustainable development should be one that can meet its social needs without endangering its future generation. Therefore, utilizing clean energy as much as possible instead of high carbon mineral energies should become the basic principle for energy construction. With the change in energy forms, conventional energy reserves are declining; as a result, its prices will inevitably rise and environmental pollution control will require more investment consequently.

China is the world's largest producer and consumer of coal. Coal accounts for 76 % of commercial energy consumption, which has become the major source of air pollution in our country. Vigorously developing new energies and using renewable energy technologies will be an important measure to reduce environmental pollution. The energy problem is a global problem and a new energy period will come sooner or later. In the long run, wide applications of solar energy utilization technologies and devices will inevitably constrain the rise in prices of fossil energy.

(5) The Prospect of the Industry in China

The promulgation and implementation of China's Renewable Energy Law has provided policy support for the development of the solar energy industry. The signing of the Kyoto Protocol, the unveiling of the environmental protection policy, and the commitment to the international community has brought opportunities to the solar energy industry. The West Development Program has provided the industry with an enormous domestic market. At the same time, the rise in crude oil prices and adjustment of China's energy strategy urge the government to strengthen the support for renewable energy development. All of these will bring great opportunity for China's solar energy industry.

2.1.1.2 Solar Energy Application in the Expo

The solar energy technology used in the Expo accounted for over 50 % of the low-carbon and energy conservation technologies utilization, which was the best demonstration of "Better City, Better Life."

The solar PV energy technology was applied at large scale in Expo 2010 Shanghai, accounting for 87 % of the entire solar energy utilization in the Expo (Fig. 2.4). Table 2.1 gives the use of solar energy in the Expo.

2.1.1.3 Application of Solar PV Technology in Expo 2010 Shanghai

(1) Power Generation by Solar PV

In the major pavilions such as China Pavilion, Theme Pavilion, Expo Center, South City power plants as well as the self-built Pavilions of Japan, Australia and some other countries, solar cells were installed on the rooftops and glass curtain

Fig. 2.4 Application of solar energy in the Expo

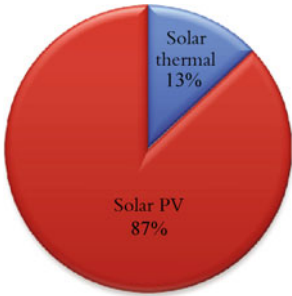


Table 2.1 List of the solar energy application items in the Expo

Pavilions	Solar energy technology	Applications
Japan Pavilion	Solar photovol-taic cells	Power-generating floor
		Solar panel with membrane technology
Israel National Pavilion	Solar photovol-taic cells	Solar power system
		Pest control device with solar black light technology
India Pavilion	Solar photovoltaic	Solar photovoltaic panels
Expo Axis	Solar energy technology	PECVD filming technology
China Pavilion	Solar photovol-taic cells	Solar photovoltaic power generation system
Macau Pavilion	Solar photovol-taic cells	Solar photovoltaic power generation
Expo Center	Solar photovoltaic	Solar photovoltaic power generation system
World Meteorology Pavilion	Solar photovol-taic cells	Photovoltaic power generation and vehicle recharging column
DEVNET Pavilion	Solar photovol-taic cells	Solar street lights
Theme Pavilion	Solar water heating	New solar water heater
	Solar photovol-taic cells	Megawatt level solar power station
Germany Pavilion	Solar photovol-taic cells	Building integrated solar photovoltaic components
Belgium-European Union Pavilion	Solar photovol-taic cells	Sun-dance flowers
		Solar vehicles
Norway Pavilion	Solar energy	Water purification device with solar energy
Portugal Pavilion	Solar energy	Multifunction solar system

(continued)

Table 2.1 (continued)

Pavilions	Solar energy technology	Applications
Switzerland Pavilion	Solar photovoltaic cells	Solar energy cells
Italy Pavilion	Solar energy	Photovoltaic solar integrated modules that can absorb solar energy, improve the indoor temperature, and power for the pavilions
Finland Pavilion	Solar photovoltaic power generation	Providing electricity for refrigeration equipment of the pavilion
Netherlands Pavilion	Solar photovoltaic power generation	Umbrella affixed with solar panels
		Solar car
USA Pavilion	Solar photovoltaic power generation	Solar photovoltaic power generation
State Grid Pavilion	Solar photovoltaic power generation	Solar photovoltaic panels
Shanghai Enterprise Joint Pavilion	Solar water heating	Generating power with the hot water of 90°
China Private Enterprises Pavilion	Solar photovoltaic power generation	Solar photovoltaic power generation and solar water heater
Information and Communication Pavilion	Solar energy	Solar energy power generation
City Future Pavilion	Solar photovoltaic power generation	Solar energy power generation
Shanghai's UBPA Case	Solar photovoltaic cells	Solar film photovoltaic power generation
	Solar water heating	Photovoltaic solar
Osaka Case Pavilion	Solar photovoltaic cells	Thermoelectric conversion
Madrid Case Pavilion	Solar cooling	50 translucent film solar modules were installed on the rooftop, which can keep any room cool by use of the cooling device, without affecting the building lighting
Hamburg House Case Pavilion	Solar photovoltaic cells	Solar photovoltaic power generation
London Case Pavilion	Solar optothermoel	Solar energy heater
	Solar photovoltaic cells	Wind-solar hybrid public lighting systems
	Solar cooling	Air conditioning refrigeration

(continued)

Table 2.1 (continued)

Pavilions	Solar energy technology	Applications
Alsace Case Pavilion	Solar photovoltaic power generation	Exterior wall solar panel technology
Mobile Communications Base	Solar photovoltaic power generation	“Wind-solar hybrid system” can provide nearly 30 % of the energy consumption of the base station.
Expo Park	Solar photovoltaic lighting	Decorative lights with solar energy
Mexico Pavilion	Solar photovoltaic power generation	Lighting for indoor pavilions
United Nations Pavilion	Solar thermoelectricity	Building integrated with solar and thermoelectricity

walls with a total installed capacity of more than 4.68 MW, which combined with the main grid of Shanghai to generate electricity. Among them, the total installed capacity of the Theme Pavilion was about 2.825 MW, with the solar panels covering 30,000 m², and the annual generating capacity reaching about 2.5 million kWh. It has been the largest single solar PV generating project as well as the BIPV project in China. Figure 2.5 shows the solar PV panels on the roof of the Expo Center.

(2) Solar refrigeration

The most typical use of solar refrigeration in the Expo was in London’s UBPA Case and Madrid’s UBPA Case Pavilion.

Solar thermal-power transducers on the roof of London’s UBPA Case Pavilion collected enough power for daily use in the building (Fig. 2.6); the collected heat was changed into power for the building refrigeration. According to the survey, by use of various energy-saving measures, the solar power generated output in the London Case Pavilion actually exceeded the needs of the entire pavilion.

On the rooftop of Madrid Pavilion were installed 50 translucent film solar modules (Fig. 2.7), which could cool any room through the refrigeration device, without affecting the lighting in the building.

(3) Solar PV lighting

Outside the Swiss National Pavilion, a 17-m-high translucent curtain was trimmed with 10,000 red “Little Suns,” as shown in Fig. 2.8. Each “Little Sun” was a disk-sized red photosensitive device making use of the most advanced solar power technology. With the interaction of solar cells, light sensors, and LED, it absorbed

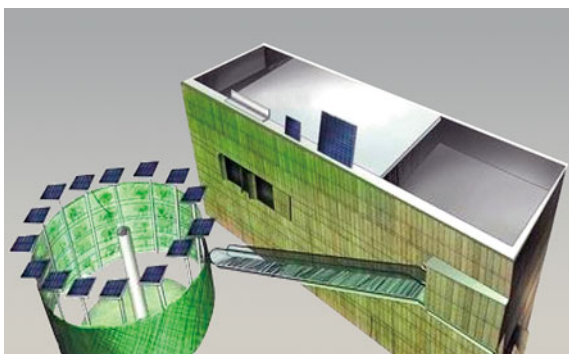
Fig. 2.5 Solar PV panels on the roof of the Expo center



Fig. 2.6 Solar energy systems on the roof of the London's UBPA case



Fig. 2.7 Solar energy system in Madrid Pavilion



and stored light energy and converted it into electricity based on the angle and intensity of light. The “little Suns” shone independently while interacting with the curtains.

Fig. 2.8 “Little suns” of the Swiss National Pavilion



Fig. 2.9 Solar photo-thermal devices on the roof of Shanghai's UBPA case



(4) Solar Photothermal

Shanghai is recognized as a model city for building energy-saving in China by the World Wildlife Fund (WWF); “Shanghai’s Eco-Home” at the UBPA is just the integral demonstration of the building energy efficiency technologies. On this building, the BIPV film solar PV generating system installed on the southern exterior walls can generate clean power of 11 kWh (Fig. 2.9), and meanwhile acts as the sunshading frame over the roof garden to reduce direct radiant heat. The flat plate solar water heating system on the southern sloping roof integrated with the PV generating system on the roof can produce an average of 900 L of hot water per day, accounting for about 50 % of the total hot water consumption of the pavilion.

(5) Solar water heating

On the roof of Shanghai Enterprise Joint Pavilion, there was a solar collector panel of 2,200 m², which collected 95 L hot water generated by solar energy. Through the ultra-low temperature power generation technology, the output power

Fig. 2.10 Integrated solar thermoelectric system on the top of the waiting area of the UN Pavilion



can be over 200 kW. This technology opens up new ways of solar power generation; the generated power can satisfy the needs for construction exhibitions and daily power supply in the pavilion.

(6) Solar PV/photo-thermal building integration

Solar thermoelectric integration used in the waiting area of the United Nations Pavilion (Fig. 2.10) was developed and designed by Nanjing Nanzhou New Energy Development Co, Ltd. This area, 40 m long, 5 m wide, and 3.8 m high covered an area of 232 m². On the roof of this area were laid 150 new type tiles (Hanwa) that generated power and heat at a total installed capacity of 15.12 kW. It could generate electricity of 60–80 kWh after being exposed to sunshine 5 h on a sunny day.

The solar thermoelectric integration in the waiting area of the UN Pavilion designed by Nanjing Nanzhou New Energy Research and Develop Co., Ltd. was the only demonstration in the Expo site, as well as the only one with such a large area.

It was therefore recommended that “solar PV roof” and “photo-thermal wall project” be widely promoted in urban constructions, which can save materials and generate multi-energy, resulting in reduced comprehensive costs. This technology can meet the need of power supply, thermal heating, cooling, as well as hot water for daily use.

For extensive promotion of this technology there are still some difficulties faced:

- (1) Lack of interworking between the solar industry and the construction industry;
- (2) Lack of normalization and standardization of the heat-collector components;
- (3) New building materials for the solar energy house need to be further developed.

(7) Solar vehicles

The venues in the Shanghai Expo that displayed solar vehicles were Belgium-EU Pavilion (Fig. 2.11) and Netherlands Pavilion (Fig. 2.12). Belgium-EU Pavilion displayed a new type of solar vehicle. Its body was made of pre-impregnated carbon

Fig. 2.11 Solar vehicle shown in Belgium-EU Pavilion



Fig. 2.12 Solar vehicle shown in the Netherlands Pavilion



composite material, its chassis, torsion box, and scroll bar of integrated carbon fiber hard shell, and its tires were low rolling resistance tires specialized for solar vehicles developed by Michelin. The length, width, and height of the car were, respectively, 4.3, 1.8, and 1.04 m, with a mere weight of 170 kg, driving speed of 100 km/h, and maximum speed of 140 km/h.

(8) Solar energy technology application in the Expo Site

The communal facilities at the Expo site such as street lights, lawn lights, park lighting, and mosquito killing devices made good use of solar technology, shown in Figs. 2.13, 2.14, and 2.15.

Fig. 2.13 Solar energy black-light mosquito-killing device



Fig. 2.14 Solar decorative lights



Fig. 2.15 Solar intelligent recycling bins outside the London's UBPA case



Fig. 2.16 Applications of solar energy in the Expo (Statistics by continents)

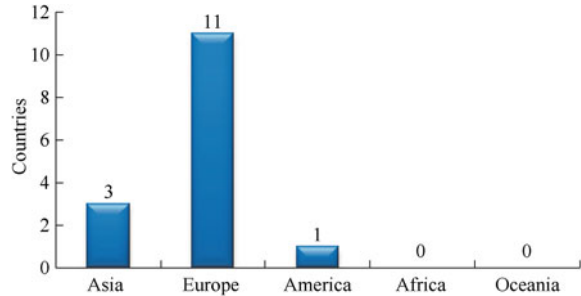
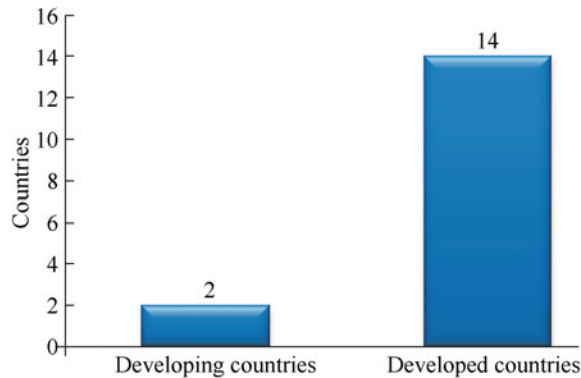


Fig. 2.17 Applications of solar energy in the Expo (Statistics by developed and developing countries)



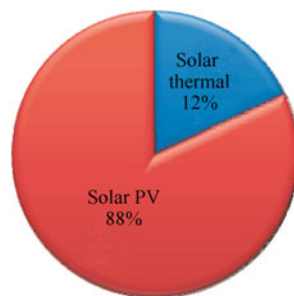
2.1.1.4 Statistics of Solar Energy Applications in the Expo

The applications of solar energy in the Expo are shown in Figs. 2.16 and 2.17. The application of solar energy technology in the G8 and G20 countries (as shown in Figs. 2.18 and 2.19), accounts for 60 and 85 % of the global GDP respectively. Being global economic leaders, G8 and G20 also lead the world in development of new energies.

2.1.1.5 Status of Solar Energy at Home and Abroad

At present, 136 countries around the world are promoting solar power generation technology, of which 95 countries are researching and developing large-scale solar power generating equipment and solar applications. In 2005, the total output of the world’s solar cells production reached 2,000 MW. Japan takes the lead in terms of solar energy development, whose solar cells output account for about 50 % of the world’s total production. Global solar PV capacity in 2009 increased by 44 % and new installed capacity reached 6.4 billion MW, making the global installed capacity to more than 20 billion MW.

Fig. 2.18 Applications of solar energy in G8 national pavilions



Eighty-five percent of the world's total installed capacity of PV power generation is the grid-connected PV power generation system, 90 % of which is the roof system. Grid-connected PV systems in the European countries, Japan, the United States are mainly building integrated PV (BIPV).

In 2007, production of PV cell in China exceeded (that of) Germany and Japan for the first time, ranking first in the world. The production continued to increase in 2008, reaching 2 GW. Over the past 5 years the annual growth rate of output of PV cells in our country is 1–3 times. The proportion of solar PV cells output in global production has increased from 1.07 % in 2002 to nearly 15 % in 2008. The efficiency of commercial crystalline silicon solar cells has increased from 13 to 14 % 3 years ago to the current 16–17 %.

Solar BIPV applications in the Expo involved a number of key technologies, many of them China's own innovative technologies, such as the combination of solar energy with building technology, BIPV component technology, brick-type PV module, large area Transmission-type PV module, PV waterproof module, shaped PV modules, high-power inverters and efficient combination technology, large-scale PV building control technology, and systems engineering technology. Currently, China has introduced a number of supportive policies on the promotion of BIPV projects and applications. BIPV of large public buildings is the international trend and will be the biggest growth point of the future domestic market as well.

2.1.2 Wind Energy

2.1.2.1 Overview

Wind energy is the kinetic energy generated by a large amount of air movement on the Earth's surface. It is a converted form of solar energy. Wind energy resource is determined by the density of wind energy and the annual accumulative hours of available wind energy. It is estimated that the total amount of wind energy worldwide is approximately 130 GW, 10 times more than the total amount of global exploitable water energy. Wind has long been utilized by man, mainly for pumping water and milling grains through windmills. But at present, people are interested in

Fig. 2.19 Applications of solar energy in G20 national pavilions

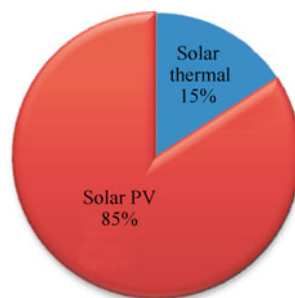


Fig. 2.20 Wind power generation



how to make use of wind power to generate electricity. Figure 2.20 shows wind power generation in Inner Mongolia Huitengliang.

(1) The Principle of Wind Power Generation

The principle of wind power generation is to drive the windmill blades to rotate by wind and then to increase the speed of rotation through the speedup gearbox, to prompt the generation of electricity. According to the existing windmill technology, when wind speed reaches approximately 3 m/s (breeze speed), it begins to generate power. The advantages of wind energy explain why it is the fastest-growing energy source in the world. By using clean fuel source, wind power generation does not pollute the air nor generates radiation. Currently, wind power generation is becoming popular throughout the world.

Wind turbines include large fans and small fans. Wind turbine is composed of a handpiece, rotor, empennage, and blades. Each part functions as follows: blades receive the wind power and convert it into electric energy; empennage keeps the blades facing the direction of wind all the time so as to obtain the maximum wind

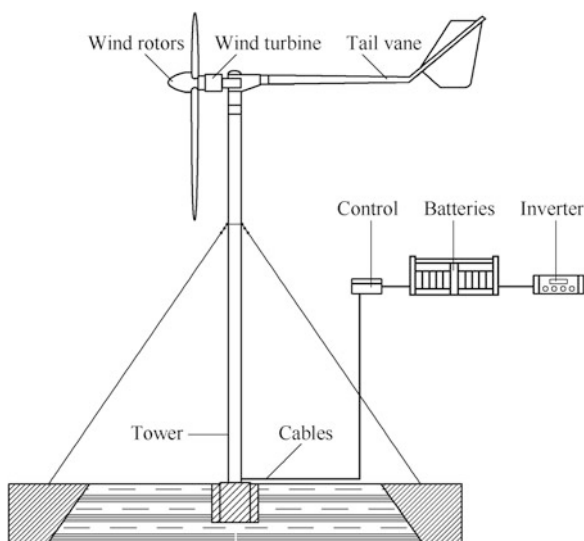


Fig. 2.21 The working principle of wind power generation

energy; rotor makes the handpiece rotate slickly to achieve the direction adjustment by the empennage; the rotor of the handpiece is a permanent magnet and stator winding curves up the line of magnetic force to generate electric energy. The principle of wind power generation is illustrated in Fig. 2.21.

(2) Classification of Wind Turbines

Although there are a variety of wind turbines, there are generally two kinds: (1) horizontal axis wind turbine (HAWT) (as shown in Fig. 2.22), in which the rotor shaft of the turbine blades are parallel to the wind direction; (2) vertical axis wind turbine (VAWT) (Fig. 2.23) in which the rotor shaft of the turbine blades are perpendicular to the ground or to the direction of airflow.

Horizontal axis wind turbine (HAWT)

HAWT can be again classified into the type of lifting force and dragging force. Lifting force wind turbine rotates more quickly than dragging force wind turbine. In wind power generation, HAWT with lifting force is widely used. Most HAWTs are equipped with wind-facing devices that will rotate to the change in wind direction. For small wind turbines, tail vane is used in this device, while for large-scale wind turbine, transmission device consisting of wind direction sensors and actuating motor are used.

HAWT is divided into upwind turbine with the wind rotor in front of the tower and downwind turbine with the wind rotor behind the tower. There are many types of HAWT. Some are installed with wind rotor of blades reversal and some with several wind rotors installed on one tower so as to reduce the cost of the tower at certain output power; still for some type of turbines, swirls are produced around the wind wheel to centralize air flow and therefore increase air velocity.

Fig. 2.22 Horizontal axis wind turbine (HAWT)



Fig. 2.23 Vertical axis wind turbine (VAWT)



Vertical axis wind turbine (VAWT)

Compared with the HAWT, VAWT does not have to face the wind when the direction of wind changes which is an advantage. It not only simplifies the structure, but also reduces the resistance of wind rotor when facing the wind.

There are several types of VAWT rotating utilizing the resistant power for rotation, including the one with the wind rotor made of plate and rotor which is a pure resistance device; the S-shaped windmill has a part of the lifting force but is still a kind of resistance device. These devices have bigger starting torque, but the tip speed ratio is low. However, at a constant wheel rotor size, weight, and cost, such devices have lower output power.

Fig. 2.24 Distribution of global installed wind power capacity (2008)

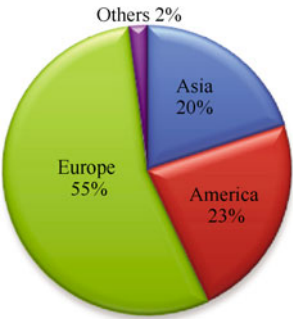
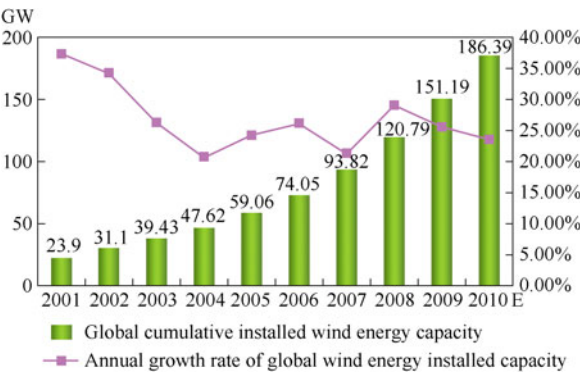


Fig. 2.25 Growth of global cumulative installed capacity (2001–2010)

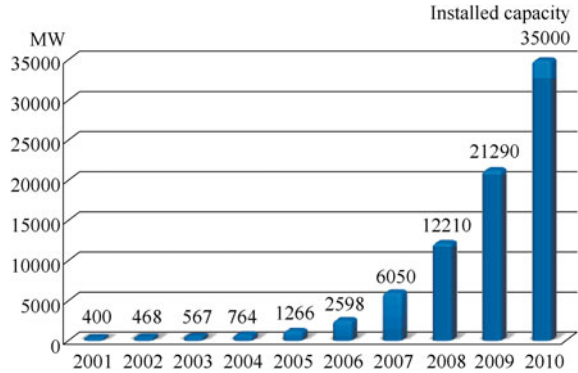


(3) The Status of Wind Power at Home and Abroad

Over the past decade, wind power generation stations have grown rapidly. Since 2001, the capacity of the installed wind power worldwide has increased at the rate of 20–30 % per year. In 2008, the newly increased installed wind power capacity worldwide was 27,050 MW, making the total global installed capacity to 120,000 MW, up by 28.8 % compared to 2007. Distribution of global installed wind power capacity in 2008 is shown in Fig. 2.24. Global growth of wind power installed capacity from 2001 to 2010 is shown in Fig. 2.25.

Wind power in China started in 2003, and has grown rapidly especially after the launch of the Wind Power Concession Project. In 2006, a total of 1,454 wind turbines were produced in China, with the newly added installed capacity reaching 1,337 MW, not including Taiwan, exceeding the total cumulative capacity of the past 20 years, ranking only after the US, Germany, Spain, and India. In 2008, China doubled its installed wind power capacity by adding 6,300 MW of wind turbines, ranking second globally in terms of the newly increased capacity, second only to the United States. By the end of 2009, the total installed capacity in China was 21,290 MW, with a year-on-year growth of 74.36 %, surpassing Spain, ranking third in the world and among the top wind power countries with the installed wind power capacity over 10,000 MW. Figure 2.26 reflects the installed wind power growth in China since 2001.

Fig. 2.26 Installed capacity in China (2001–2010) (MW).
Source www.wwindea.org



The above data were collected before Dec. 31, 2009, when China’s wind turbine grid connection rate reached 76 %. According to the types of China’s wind power installed turbines in 2008, the capacity of double-fed turbine accounted for a huge proportion. Owing to a shortage of components, direct drive wind turbine accounts for only a small proportion. With the impact of supply of the above components, in the next few years, direct drive and double-fed wind turbines will coexist.

2.1.2.2 Wind Power Application in the Expo

Wind power applications in Expo 2010 Shanghai can be divided into three categories: First, the practical application of wind turbines, second, wind turbine components, and third, display of wind power enterprises and wind power projects. Detailed information is given in Table 2.2. New energy utilization by classification is shown in Fig. 2.27.

- (1) **Wind Power Application in the Expo** The Turbines applied in Expo 2010 Shanghai include VAWT and HAWT. According to the statistics, in terms of the types of turbines applied in the Expo, VAWTs accounted for 67 %, while horizontal types accounted for 33 %.

Demonstration of wind power enterprises: domestic enterprises focus on technology-based demonstration, while foreign enterprises focus on the complete turbines demonstration, which are from large wind turbine manufacturers.

The survey showed that the pavilions with wind power applications included the India pavilion, Japan pavilion, Shanghai UBPA case pavilion, London UBPA case pavilion, Madrid UBPA case pavilion, Pavilion of Future, the Expo Ferry, Mobile base stations, and the State grid Pavilion. Many wind turbines used in the above pavilions were small VAWTs, which is due to the fact that chaotic wind often exists in the city. VAWTs need not face against the wind when the wind direction changes, which not only features the simplified design structure, but also, the relatively small gyroscopic force when the wind wheel faces the wind results in

Table 2.2 Wind turbines display and applications in Expo 2010

Pavilions	Category	Wind turbine type	Displayed items and features
India Pavilion	Practical use	Vertical axis wind turbine	Lift-type wind turbine, H type, 3 kW
Japan Pavilion			Resisting type wind turbine wind-solar hybrid
Shanghai's UBPA Case			Lift-type wind turbine, H
London's UBPA Case			Lift-type wind turbine, H-type, wind-solar hybrid
Madrid's UBPA Case		Horizontal axis wind turbine	5 turbo generators
Pavilion of Future		Vertical axis wind turbine	Lift-type wind turbine, H type
Expo Ferry		Horizontal axis wind turbine	Inland riverboat wind turbine
Expo Mobile Base		Vertical axis wind turbine	Lift-type wind turbine, H type, Peak power output 3,000 W/h
State Grid Pavilion		Horizontal axis wind turbine	Breeze started vertical axis wind turbine
Sweden Pavilion	Wind turbine components		Super bearing
China Pavilion			Pitch and Yaw bearings
Joint Pavilion of International organization			Bamboo composite wind blades
Pavilion of Urban Planet			Gearbox
Pavilion of future	Wind power companies display		Wind power control device
Theme Pavilion			Large wind turbine equipment
Portugal Pavilion			Wind farm management
Denmark Pavilion			The world's first wind power company
Netherlands Pavilion			Business display, the National Wind Resource Development
Meteoworld Pavilion			Business display
Shanghai Donghai Bridge 100 MW offshore wind farm	Provide green energy for world Expo		The total installed capacity of 102,000 kW

Fig. 2.27 New energy utilization by classification

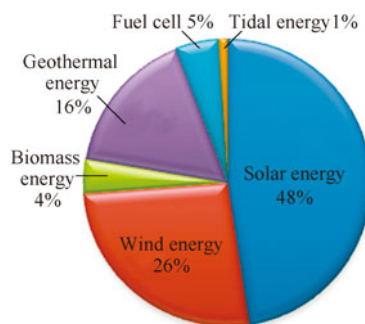


Fig. 2.28 Wind-solar hybrid power supply system in London's UBPA case



high safety in running. The above features allow the vertical wind turbine to have superiority in application in urban buildings than the horizontal axis. New VAWTs with low wind speed, or even with breeze starting, were eye-catching in the Expo.

Wind-solar hybrid power supply system in London's UBPA case is shown in Fig. 2.28.

The wind-solar hybrid power supply garden lamps from Panasonic displayed outside the Japan pavilion (Fig. 2.29) was a typical resistance wind wheel (Savonius), which have the following advantages: (1) Adapt to the frequent change in wind direction; (2) easy starting, with low wind speed; (3) safety in design; (4) marvelous appearance, with the effect of landscaping, different in design from the ordinary type; (5) convenient height, easy for erection and maintenance; (6) zero noise; (7) match with wind status at the roof of ordinary building height. The disadvantage is its relatively low material utilization; for the given structural material, the front surface of the wheel is small.

Fig. 2.29 Scenery wind and solar lamp outside Japan Pavilion



Fig. 2.30 Vertical axis wind turbines on the top of the India Pavilion



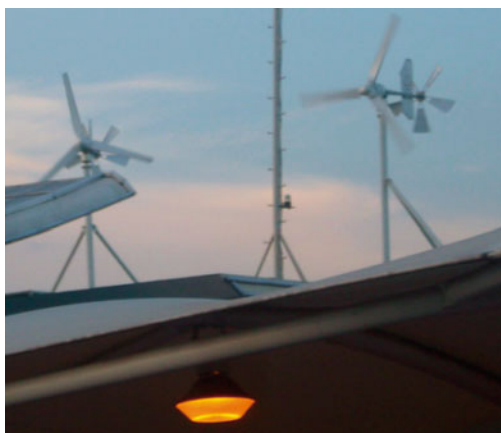
The typical application of building integrated wind power was at the India Pavilion. It used a VAWT (Fig. 2.30), with rated power of 3 kW, generating AC of 3 kW at 12 m/s of wind speed. The wind power generation system complemented the solar power systems on the rooftop of its pavilion. Wind and solar hybrid power supply system was also used in the Expo mobile base station (Fig. 2.31). The fans used in the station had peak power output of 3,000 W/h; the usual generating capacity and amount of installed solar power exceeded the total electricity consumption in the base station by over 1/3, which ensured the self-sufficiency in daily light supply within the base station.

Small HAWTs were used in the State Grid Pavilion, Expo Ferry, and Madrid's UBPA case pavilion (Fig. 2.32). Five wind turbine generators were installed in the Air tree system in Madrid's UBPA case pavilion (Figs. 2.33 and 2.34). With the Air

Fig. 2.31 Wind-solar hybrid power supply system in the mobile base of the Expo



Fig. 2.32 300 W Horizontal axis wind turbine on the Expo Ferry



tree system, the total generating capacity reached 1.7 kWh. Wind turbines can generate electricity even in at wind speed of less than 2 m/s. All the power generated is fed into the Shanghai power grid.

(2) Wind Turbines Components

Wind turbine is composed of rotor, gearbox, generator, yaw device, control system, and tower. However, the most critical component of wind turbines is the blades. Blade design is especially important because proper design of the blades will ensure the generating unit to obtain the desired power. Besides, fatigue characteristics of blades are also critical, which is related to the materials of the blades. The Joint Pavilion of international organization demonstrated bamboo composite wind blades (Fig. 2.35), which showed better performance at 30 % higher than that of the widely used glass fiber reinforced plastic; it also reduces energy consumption in production and can be recycled. Aside from meeting the strength requirements,

Fig. 2.33 “Air trees” in Madrid Pavilion



Fig. 2.34 Wind turbine topped the “Air tree”



the blade is lighter in weight, longer than the old type, and has higher output power with lower comprehensive cost. This kind of blade has been put to use in Zhangbei Power Plant in northern China and has begun to be connected to the grid.

The bearings of the turbine were displayed in the Sweden and China Pavilions. Pitch bearings and yaw bearings were shown in China Pavilion (Fig. 2.36). Pitch bearings can adjust blade angle, keep the speed constant, and the generated power stable; yaw bearings track wind direction, align the windward side, and improve power generation efficiency. The 1.5 MW wind yaw bearings and pitch bearings manufactured by Ma'anshan Fangyuan Slewing Ring Limited liability Company have superior performance. SKF super bearings displayed in the Sweden Pavilion (Fig. 2.37) can be used for large-scale wind turbines and are characterized by:

Fig. 2.35 Wind blades made of bamboo composite



Fig. 2.36 Pitch and yaw bearings showed in China Pavilion



- (1) Lightweight, small friction allowing wind turbines to run by breeze;
- (2) The bearings optimize the performance of the units and maximize their life span;
- (3) The novel bearings receive a special treatment of corrosion-resistant surface, and special oils and fats used to limit the indentation and damage of the surface;
- (4) The bearings are equipped with innovative automatic lubrication system, which can allocate the appropriate amount of oil to all the lubrication points during a 6-month period, thereby reducing maintenance cost and oil consumption;
- (5). Patent sealing solutions are used so as to avoid oil leaks and water intrusion, and can cope with the deformation bearing ring result from overload and effect of internal fat overpressure of the bearing.

Fig. 2.37 The Super bearing displayed in Sweden Pavilion



Fig. 2.38 Wind turbine pitch—and yaw-control system



In addition, by adoption of an innovative double-layer surface coating design, the bearings can also provide lasting corrosion protection even in bad weather.

Gearbox as part of wind turbine is also displayed in City Earth Pavilion, where Bosch showcased the gear box it manufactured (Fig. 2.38). Quiet and reliable REDULUSGPV-type generator gear box (Fig. 2.39) and compact REDULUSGPV-D-type differential gearbox became the company's flagship product used in wind turbines. The gearbox has high strength anti-wear bearings, lubrication performance, compact gear combination, big gear ratio range, low noise, accurate and timely monitoring, etc.

(3) Wind power companies in the Expo

In London Case Pavilion, ZK Energy Technology Co., Ltd displayed not only vertical wind turbine products, but also a full permanent magnetic suspension wind and solar power generation technology (see Fig. 2.40). Full-permanent magnetic

Fig. 2.39 REDULUSGP
type gear box generator

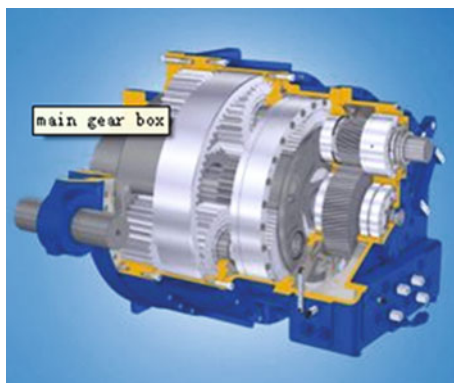


Fig. 2.40 Permanent
magnetic suspension wind
power turbine in London Case
Pavilion



Fig. 2.41 Wind-solar hybrid
power supply system in
communication base station

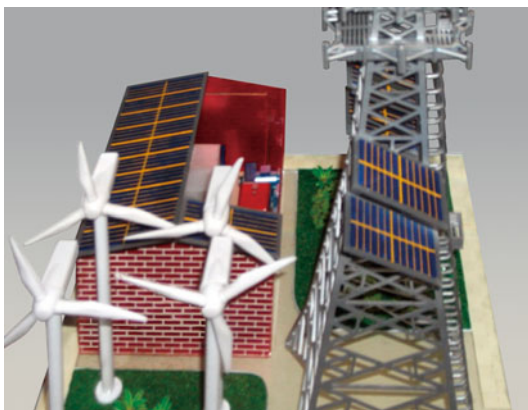


Fig. 2.42 Direct drive wind turbine of EWT Company



levitation wind turbine was the highlight of the display, while a communications base station wind and solar power supply system (see Fig. 2.41) in The Low-carbon Demonstration Town was also on display. The Theme Pavilion showcased a large-scale wind turbine Integral Blade with Siemens technology, which can achieve full, seamless blades manufacture in a close process. The blades were made of glass fiber reinforced epoxy resin.

A large wind power company in China displayed in the Meteoworld Pavilion was United Electric Power Technology Co., Ltd. The company developed wind turbines especially suitable for abnormal weather conditions such as marine, intertidal, high altitude, low velocity, cold, sand; it also developed wind power prediction and remote control technology and conducted R&D on green manufacturing technologies such as wind turbine weight reduction, the key components repair and life extension, and wind turbine blade material recycling. Its R&D equipment include: 50 HZ/60 HZ 1.5 MW constant frequency variables pitch wind turbine; high-altitude low-wind speed model leaves 1.5 MW; 3 MW offshore wind turbines; Electro-hydraulic/solenoid coupled synchronization wind turbines.

Netherland Pavilion showed the utilization of wind energy resources at home (Fig. 2.42). EWT's direct drive technology, DW90-2.0 MW, DW54-750/900 kW large wind turbines were the most attractive highlight.

Portugal Pavilion introduced EDP Company (Fig. 2.43), the world's second largest wind power company located in its country. The company is very professional in wind farm operation and management with operations throughout Europe, the United States, and Brazil. Its installed capacity is 5.8 GW. In 2010 the company achieved its annual target of 10.8 GW. EDP Company worked with the Principle Power Company and A. Silva Matos Company in developing an offshore wind farm project—The Sea Floating. The wind power generating platform with innovative design can be installed on water surface with depth of more than 50 m, allowing exploration of renewable energy that could not be reached previously.

葡萄牙EDP-Renováveis公司负责管理遍及全球的业务网络,在欧洲、美国和巴西均有风电场,其装机容量为5.8吉瓦,预计2010年实现10.8吉瓦的目标。这些风电场由位于葡萄牙波尔图市的调度中心统一控制,该中心管理风力涡轮机全球第二大业务网络。

A empresa portuguesa EDP – Renováveis é responsável pela gestão de uma rede mundial de parques eólicos na Europa, Estados Unidos da América e Brasil, com uma capacidade instalada de 5,8 GW, prevendo-se para 2012 uma meta de 10,8 GW.

Fig. 2.43 EDP Company in Portugal Pavilion



Fig. 2.44 Donghai bridge offshore wind farm

(4) Expo offshore wind farm

China's first large offshore wind farm—Shanghai Donghai Bridge Offshore Wind Farm (Fig. 2.44)—is one of the offshore wind power demonstration projects determined by National Development and Reform Commission. Shanghai Donghai Bridge Offshore Wind Farm is made of 34 sets of 3,000 kW turbines from Sinovel Wind Power Technology Co., Ltd., with a total installed capacity of 102,000 kWh. Its annual generation capacity achieved 267,000 MW, providing green power from the sea to the World Expo.

2.1.2.3 Analysis on Wind Power Application in the Expo

The study on Expo 2010 Shanghai showed that cases of wind power application are less than that of solar power application and the use of small urban-type wind turbine is relatively fewer. Hence the development of urban-type wind turbines still

Fig. 2.45 Wind power applications in the Expo (Statistics by continent)

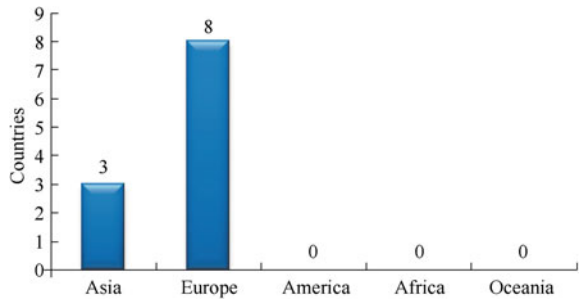
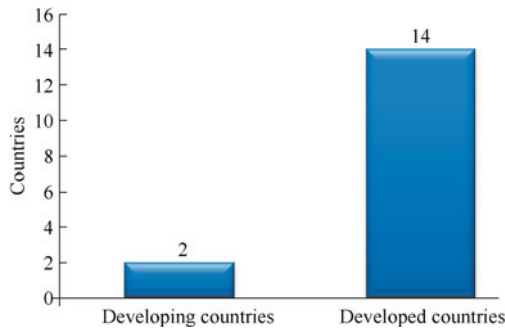


Fig. 2.46 Wind power applications in the Expo (by developed and developing countries)



has space for improvement. The urban-type has good prospect in application, and is beneficial to alleviating the tension of urban energy.

The demonstration of wind turbine products and technologies were mainly seen in the pavilions of the Asian and European countries. Other pavilions did not display wind turbines due to various reasons. Figures 2.45 and 2.46 show wind power applications in the Expo.

Donghai Bridge Offshore wind farm, with installed capacity of 100 MW, is expected to generate electricity of 267 million kWh and meet the demand for electricity of more than 20 million residents of Shanghai a year. After completion, Shanghai can save 100,000 tons of coal annually, and reduce 200,000 tons of carbon dioxide emission, 1,200 tons of sulfur dioxide, and about 670 tons of nitrogen dioxide.

2.1.2.4 Recommendations on Wind Power Promotion

In the pavilions of the Expo site, cases of large wind turbines utilization were shown through models and texts. Large wind turbines have developed rapidly both at home and abroad, expanding from land to ocean, from large type to huge type. Most of the small wind turbines used in the Expo site were the vertical axis type wind turbines which require high startup speed, of which China is accelerating its

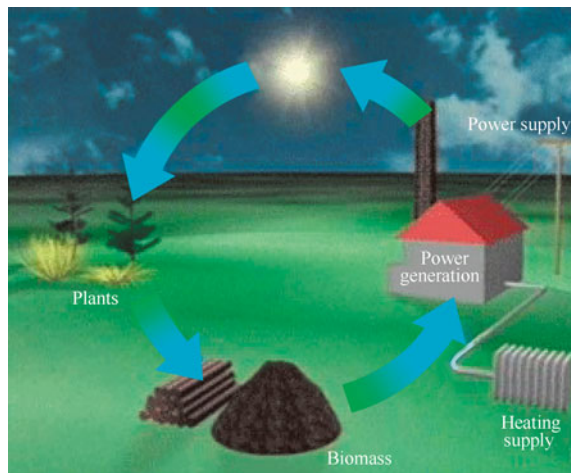
R&D and gradually keeping in line with US and European countries, while the demand from abroad is converted into that of landscape and environment-friendly type. Our recommendation is to speed up the R&D in light breeze-start products and its industrialization pace to match with the building greening, urban landscaping and lightening.

2.1.3 Biomass Energy

(1) Introduction to Biomass Energy

Biomass refers to all kinds of organisms formed through the process of photosynthesis, including all animals, plants, and microbes. The so-called biomass energy is the captured solar energy stored in the biomass in the form of chemical energy. In other words, it is a kind of energy with biomass as the carrier. It comes directly or indirectly from the photosynthesis of green plants and converted into solid, liquid, and gas conventional fuels that can never be used up. It is one of the renewable energies and the only renewable carbon source as well. The primary energy source in biomass energy is derived from the Sun. In a broad sense, biomass energy is a manifestation of solar energy. Biomass converted from the solar energy is stored in the living organisms such as plants, animals, and microbes. All the energy sources except mineral fuels of organisms, including wood, forest wastes, agricultural wastes, water plants, oil plants, urban, and industrial garbage and animal wastes, etc., belong to the biomass energy. Figure 2.47 shows biomass energy utilization. At present, many countries are actively developing the biomass energy to put it into use.

Fig. 2.47 Biomass energy utilization



Biomass resources are abundant in China, but it is not evenly distributed in different provinces. More than half of the biomass resources are concentrated in the nine provinces: Sichuan, Henan, Shandong, Anhui, Hebei, Jiangsu, Hunan, Hubei, and Zhejiang, while a relatively small amount is in the vast northwest regions and other provinces. Annual straw production capacity is 800 million tons, most of which is burned or buried except for a small amount used as household firewood and feed. Fuel wood output is 250 million tons. Besides, there are plenty of wastes from man, and livestock organic waste residues from industrial emission.

- (1) **Classification of biomass** Based on different sources, the biomass that is suitable for energy utilization can be divided into: forest resources, agricultural resources, domestic sewage and industrial organic wastewater, urban solid wastes, and livestock manure.
- (i) *Forest resources*: Forest biomass resources refer to the biomass energy resources provided during the processes of forest growth and forestry production. They include firewood forest, scattered wood and residual branches, leaves and bits of wood during tending of woods and intermediate cutting, twigs, sawdust, top wood, slab produced during the timber harvesting, and process as well as garbage of the forestry byproducts such as shuck and kernel, etc.
- (ii) *Agricultural resources*: Agricultural biomass resources refer to the agricultural crops (including energy crops), wastes produced during the process of agricultural production like straws residual after crops harvesting (corn straw, sorghum stalks, wheat straw, rice straw, soybean, cotton stalk, etc.), agricultural processing wastes like remainder of rice husk produced in the process of agricultural production. Energy plants generally refer to various kinds of plants that are used to provide energy, usually including herbal energy crops, oil-bearing crops, plants for making hydrocarbons and aquatic plants.
- (iii) *Domestic sewage and industrial organic wastewater*: Domestic sewage is drained water from urban residents' wastewater, commerce and service's wastewater, such as cooling water, bath drainage, washing drainage, clothes washing drainage, kitchen drainage, fecal sewage, etc. Industrial organic wastewater mainly contains sewages drained from the production process of alcohol, wine-brewing, food, medicine, papermaking, and slaughtering industries, which are rich in organic matters.
- (iv) *Urban solid wastes*: Urban solid wastes are mainly composed of solid wastes such as urban living garbage, commercial, service industry garbage and some construction garbage, etc. Its composition is complicated, which is influenced by the factors like average living standard of local residents, energy consumption structure, urban construction, natural conditions, and traditional customs and seasonal variation.
- (v) *Livestock manure*: Livestock manure is the generic term for livestock feces, which is the converted forms of other biomass (mainly grain, crops straw, pasture, etc.), including animal feces and urine and its mixture with bedding.

(2) Characteristics of Biomass Energy

- (i) *Reproducibility*: Biomass energy, like wind energy and solar energy, is a renewable resource, which can be reused through the photosynthesis of plants and is abundant enough to ensure the everlasting use of the energy.
 - (ii) *Less Pollution*: Biomass contains low sulfur and nitrogen, so it generates little SO_x and NO_x (nitrogen oxides) during combustion process. When Biomass is used as a fuel, the amount of carbon dioxide it requires during its growth is equivalent to the amount of carbon dioxide it lets out, thus the net carbon dioxide emission to the atmosphere is kin to zero, which can effectively reduce the greenhouse effect.
 - (iii) *Wide Distribution*: In regions with a shortage of coal, biomass energy can be widely used.
 - (iv) *Huge Storage*: According to biologists estimate, there are about 100–125 billion tons of terrestrial biomass and 50 billion tons of ocean biomass per annum. The annual production of biomass is far more than the world's demand for all energies, equivalent to 10 times of the current total global energy consumption. In 2010 the biomass resources that could be developed in China amounted to 300 million tons.
- (3) Biomass energy utilization**: There are three ways in using biomass energy: direct combustion, thermo-chemical conversion and biochemical conversion. Direct combustion of biomass will be the dominant way of biomass energy utilization for a long time in the future in China. The program of making transformation of the traditional firewood stove with the thermal efficiency of only about 10 % into the energy-saving stove with the promoting efficiency up to 20–30 %, is listed as one of the key tasks in the new energy construction in rural areas. Thermochemical conversion of biomass is the technology to make biomass gasification, carbonization, pyrolysis, and catalytic liquefaction at a certain temperature and condition, so as to produce gaseous fuels, liquid fuels, and chemical substance. Biochemical conversion of biomass includes biomass-methane conversion and biomass-ethanol conversion. Methane conversion is the technology to put organic matter in the anaerobic environment, to produce methane through microbial fermentation as the main component of a combustible mixture of gases; Ethanol conversion is to produce ethanol through fermentation by using carbohydrate, starch, and cellulose as raw materials.

Biomass energy has always been an important energy source for human's life, which is only second to coal, oil, and gas and ranks fourth with regard to total energy consumption. It plays an important role in the whole energy system. Experts estimate that biomass is likely to become an integral part of sustainable energy system in the future. By the middle of the next century, a variety of biomass alternative fuels produced with new technology will account for more than 40 % of global energy consumption.

Fig. 2.48 Microalgae oil plant of ENN group the in China Pavilion



Fig. 2.49 Microalgae railings shown in the Shanghai Case Pavilion



2.1.3.1 Biomass Energy Utilization in the Expo

In the north corner of the London ZED Pavilion, there is a biomass boiler which has been placed in a separate room. When the tourists finished eating, biomass boilers can immediately degrade the leftovers into electricity and heat. It can dispose the restaurant's one-off plates, forks, and a variety of food wastes by biological anaerobic degradation. When the degradation is completed, the final "products" can be used as fertilizers for the green vegetation on the northern slope of the roof.

While most companies are still investing a lot of fund and human resources on how to reduce carbon dioxide emissions or sequester carbon dioxide, a private enterprise named China ENN Group displays a new technology—"microalgae oil"—to the visitors in China Pavilion, and also exhibits "microalgae railing" in the Shanghai Case Pavilion (Figs. 2.48 and 2.49). It can absorb carbon dioxide with the cultivated microalgae, and ultimately produce bio-diesel, carotenoid, and other derivatives through photosynthesis. It can change carbon dioxide into what can be utilized.

The principle of the microalgae-oil is through photosynthesis of the microalgae, to change the carbon dioxide produced in the chemical production process into biomass of microalgae so as to fix the carbon elements, and then through the self-induced reactions to change the substance of carbon into oil. After that the oil inside the algae cells will be transferred outside the cells by physical or chemical methods, and lastly, with further refining process, bio-diesel is produced.

According to reports, compared with corn, soybeans, and rapeseed, algae cultivation requires a relatively small area with short growth cycle. It takes just 2 weeks from birth to oil production, while oil crops generally take several months for the same process. Besides, oil production of microalgae per unit area is several hundred times that of corn; which is 15,000–80,000 L of bio-diesel per ha.

2.1.3.2 Economic Returns of Biomass Energy

About 70 % of the population in China lives in rural areas, where straw and firewood and other biomass fuels are the major fuels for daily life. Although coals and other commercial fuels used in rural areas are increasing rapidly, biomass energy still plays an important role. In 1998, the total energy consumed in rural areas amounted to 365 million tons of coal equivalence, of which straw and firewood represented 207 million tons of coal equivalence, accounting for 56.7 % of the total. Therefore, promoting biomass energy technologies to provide energy for the daily use and production in rural areas is the best way to eliminate poverty in these areas and help to achieve the target of building a well-to-do society.

China boasts its abundant mountainous resources and therefore there is great potential in the development of forestry biomass energy: about 44.04 million ha of barren hills, wasteland can be used for cultivation of energy forests; nearly 100 million ha of desert land, mines, oil fields, and other lands can be used as energy forests; about 6 million ha of woodlands and 53.12 million ha of low-yield forests can significantly increase the amount of forest resources. According to *National Forest Biomass Energy Development Plan* being compiled, by 2020 up to 20 million ha of biomass forests will be achieved, the annual transformed forestry biomass energy can replace the petrochemical energies of 20.25 million tons of coal equivalence, accounting for 3 % of all the renewable energies.

2.1.4 Fuel Cells

2.1.4.1 An Overview of Fuel Cells

Fuel cell is a kind of chemical cell that needs to be replenished constantly. Viewed from its structure and working principle, fuel cells are no different from the conventional chemical cells; Substantially, fuel cells are not conventional chemical

cells which are energy storage device, they are, however, kind of power generation device. The fuel cell converts the chemical energy from the fuels and oxidizers directly into electricity. It is a newly developed fuel-cell power generation technology after the hydroelectric power, thermal power, and nuclear power generation technologies, which is characterized by its high efficiency and environmental friendly advantage. Compared with the piston engine, the fuel cell has a longer history but developed slowly in the past years.

In 1800, Volta invented the first battery.

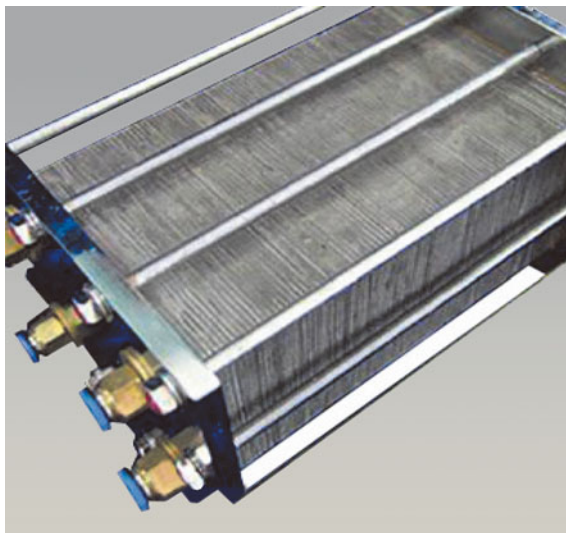
In 1802, Davy trial-made the carbon-oxygen cells with carbon and oxygen as fuels and nitric acid as electrolytes. He pointed out that it is possible to make fuel cells.

In 1839, Groveth electrolyzed water to have reverse reaction. He used dilute sulphuric acid to make hydrogen react with oxygen, which produced the current, and by doing the experiment he discovered the working principle of hydrogen-oxygen fuel cell.

In 1894, Ostwald made an analysis and pointed out that the generating efficiency of fuel cells could reach 50–80 %, while the generating efficiency of the heat energy was less than 50 % due to the limitation of Carnot Cycle. But for a long period of time after that, limited by the applied materials and design, the fuel cell demonstrated such low dynamic performance that the experimental research developed rather slowly with little achievements.

From the 1950s, came a turning point in the development of fuel cells. Bacon of the Cambridge University conducted a long-term study on oxyhydrogen alkaline fuel cells (AFC) which was very productive. He successfully made a 5 kW AFC that can last 1,000 h. This was the first practical fuel cell. The achievements that Bacon made successfully established the technical idea for the modern fuel cells. In the 1960s, the race in space technology between United States and the Soviet Union needed cells with high-performance badly to provide power in the space. By analysis and assessment of different batteries, NATO chose fuel cells, by adopting Bacon's technology they developed the fuel cell used for the Apollo space craft. The great success of the fuel cell used in space flight spurred the development boom of the fuel cells. In the 1970s, the energy crisis was arisen after the Middle East war and people paid much attention to fuel-cell power generation technology. The United States, Japan and some other countries all made long-term plans in developing fuel cells. Some developed countries led by the US embraced the development of fuel cell power stations for civil use and established a number of tentative medium and small power stations. At the same time, the United States and Japan started to transfer the surface station research to high temperature fuel cells with better properties. After the 1990s, fuel cells were further developed. The focus of the research turned to the solid fuel cells, namely proton exchange membrane fuel cell or PEMFC. Because it gives off low emission or zero emission, the fuel cell is becoming an increasingly hot spot in vehicle industry.

Fuel cells can either be used as auxiliary power unit (APU) for vehicles or as the engine to supply power to the motor-driven vehicles. When it provides APU for a car, the car still uses internal-combustion engine where some fuel is directly

Fig. 2.50 Fuel cells

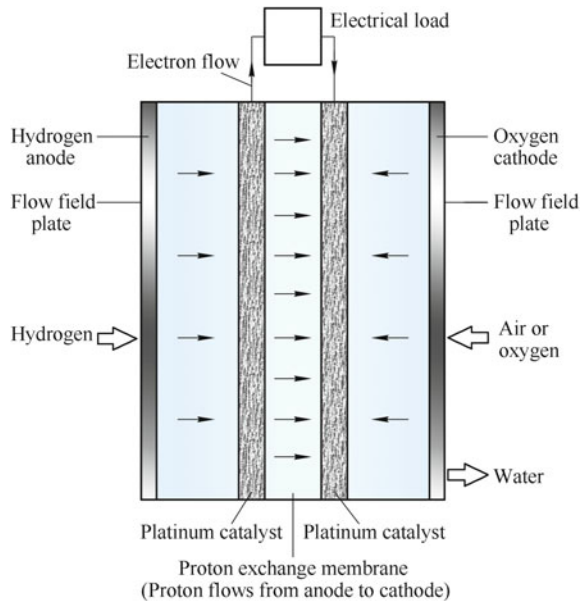
transferred to electricity through fuel cells to provide for the vehicles. This is more efficient than the pattern of traditional engine plus battery pack. The fuel cells-driven cars mentioned above usually refer to the cars that use fuel cells as its main motivation. In that case, fuel cells can be coupled with storage battery which is used only at the automobile starting stage requiring peak power. In addition, storage battery can also be used to absorb the braking power of the cars as well. Figure 2.50 shows fuel cells.

Based on different electrolytes, fuel cells can be divided into AFC, phosphoric acid, the fuel cell (PAFC), molten carbonate salt fuel cells (MCFC), solid oxide fuel cells (SOFC) and PEMFC, etc. Not confined by Carnot cycle, fuel cells have such advantages as high energy conversion efficiency, cleanness, pollution-free, and low noise that they can be made into the modules structures, with power density higher than that of conventional batteries, which is suitable for both centralized and distributed power supply. The main application in cars is the PEMFCs using hydrogen as its fuel.

Figure 2.51 shows the diagram of the PEMFC structure. At present, the prominent feature of fuel cells in structure is they can only choose pure hydrogen as fuel and platinum (noble metal) as catalyzer for electrode reaction. The working temperature should be between 20 and 80 °C.

The reaction on the Anode side of the cell is formulated as: $\text{H}_2 \rightarrow 2\text{H}^+ + 2\text{e}^-$, on the cathode side of the cell is $\text{O}_2 + 4\text{H}^+ + 4\text{e}^- \rightarrow 2\text{H}_2\text{O}$. The hydrogen fuel cells vehicles have the advantage of zero-emission or low emission. In addition, compared with the traditional piston engine, as fuel cells have no moving parts, they will not produce any vibration or noise, besides, the fuel is more efficient. Compared with battery pack in the traditional electric car, fuel cells get longer driving mileage, lighter weight, longer service life, and quicker refuel time.

Fig. 2.51 Working principle of the proton exchange membrane fuel cell



Since the beginning of the twenty-first century, energy crisis and environmental pollution have become a challenge facing all countries. Fuel cell is a power generation device which converts chemical energy directly into electrical and heat energy through the chemical reaction of fuel (mainly hydrogen) with oxidant (oxygen in the air) under certain conditions. They have the advantages of high efficiency, little pollution, low noise, high power density, and modular structure. Because of these outstanding advantages, fuel cells generating technology is widely used in vehicles power generation systems, fixed power generating systems and portable power, other systems, etc.

Fuel cells have been in demonstrated applications for years in many countries, which provide adequate evidence for the commercialization of fuel cells. But at present the fuel cells have not been fully industrialized partly because the fuel cells are very expensive, and partly because the technology of fuel cells is immature at the moment.

In today's world, when the energy crisis and environmental pollution are getting increasing attention, fuel cell technology is considered as the preferred clean and efficient power generation technology in the twenty-first century. Governments of different countries and large companies have invested heavily on the fuel cell technology research and development. The U.S. government takes the fuel cell technology as one of the key technologies to maintain the U.S. economic prosperity and national security. The Japanese Government gave strong support to the fuel cell technology research in the "Project Moonlight" and "Project Sunshine." The Canadian government determines the fuel cell the first choice in terms of the

Fig. 2.52 The household fuel cell displayed in Japan Pavilion



clean energy system in the twenty-first century. In Germany and Korea, fuel cell technology has been considered as one of the key power generation technologies in the future. China government has also paid much attention to research of fuel cells. The study of hydrogen energy and fuel cell technology has been listed as one of the major cutting-edge technologies in “Outline on National Planning for Medium and Long-term Scientific and Technological Development (2006–2010).” As the problems in fuel cell technology are gradually solved and the cost reduced, fuel cell will go to commercialization soon. In short, fuel cell is going from the stage of “research–development—demonstration” to the stage of commercialization.

2.1.4.2 Review of the Fuel Cell Applications in the Expo

Fuel cells are widely used at present, mainly reflected in the application of vehicles. In Expo 2010, there were 196 vehicles which used the fuel cell to provide energy, including 6 fuel cell buses, 90 fuel cell cars, 100 fuel cell sightseeing buses. To support the running of new energy vehicles, one hydrogen refueling station was built inside the Expo site and one recharging line was added on the Expo avenue to charge the buses of electric capacity; one hydrogen replenishing station and two moving hydrogen refueling vehicles were built around the Expo site near Jiyang Road, refueling the 50 fuel cell cars, 6 fuel cell buses, and 100 fuel cell tour buses.

At the Expo, a green household fuel cell named ENE-FARM from Panasonic (shown as Fig. 2.52) was displayed in Japan Pavilion. Launched in 2009, the product has the output power of 1 kW, providing 60 % household electricity for the average family, reducing 37 % of the carbon dioxide emission (compared with thermal power generation), ensuring a minimum 40,000-h running, and durable enough to last about 10 years. Home fuel cells have a promising market, it is

Fig. 2.53 Fuel cell model in Airbus A320 aircraft



estimated that in 2010, about 60,000 sets were sold, with the value of 650 million US dollars. On January 28, 2009, six Japanese companies namely, Tokyo Gas, Osaka Gas, Toho Gas, Western Gas, Nippon Oil, and Astomos Energy jointly established a union called ENE-FARM (energy farms) with the common purpose as “to build a nation on environment,” proposed a slogan of “working towards the popularization of home fuel cell system for carbon dioxide emission reduction,” announced that in 2009 the home fuel cell cogeneration system production program would be launched, with the first batch as 5,000 units, and expected to achieve a goal of selling 2.5 million units by 2030, equivalent to reducing 30 million tons of carbon dioxide emissions, about 1 year’s carbon dioxide absorption by 5,600 km² forests. The ENE-FARM program received a strong support from the Japanese government—each ENE-FARM home fuel cell system enjoyed 45 % of the government subsidy (1.4 million Japanese Yen).

In the Hamburg Home Pavilion, people can see a fuel cell model used in Airbus A320 aircraft in the proportion of 1:20 (shown as Fig. 2.53). This is an important part of the general plan that Airbus is committed to the environmental aviation industry construction.

2.1.4.3 Proposal for Fuel Cell Promotion

Being an efficient, clean power generation technology, fuel cell technology is the hot and frontier technology in international energy research and development, which can solve the contradiction between the power generation efficiency of fossil fuel and environmental pollution, thus it has great potential of development and wild prospects of application. The promotion and application of fuel cells will provide huge economic and social benefits.

Fig. 2.54 Working principle diagram of ground source heat pump

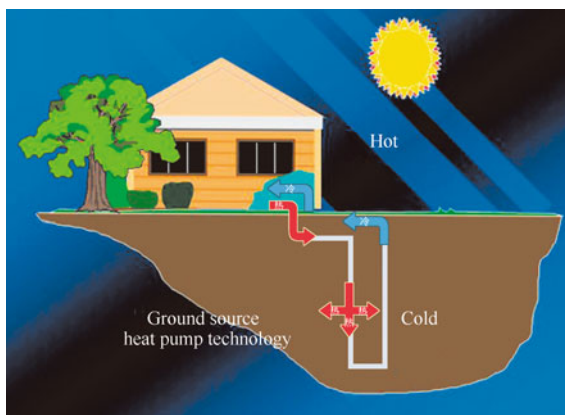
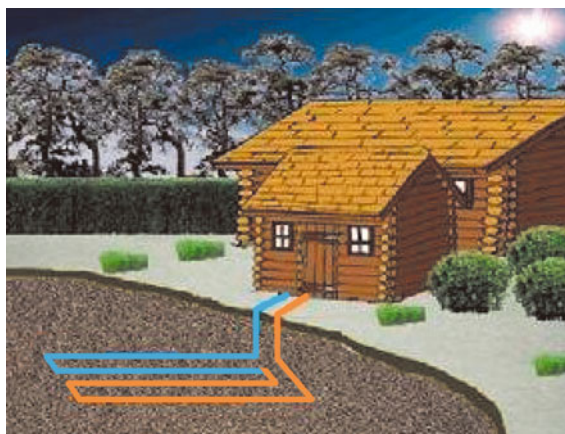


Fig. 2.55 Horizontal ground source heat pump



2.1.5 Geothermal Energy

2.1.5.1 Ground Source Heat Pump

Ground source heat pump (GSHP) is a central heating and/or cooling system that uses the water source on the earth's surface (groundwater, river, and lakes) and the solar energy and geothermal energy absorbed in the soil. It is an efficient and energy-saving air-conditioning system.

GSHP conveys a small amount of high quality energy (electrical energy) and uses a heat pump to force the transfer of thermal energy from low temperature to high temperature. Geothermal energy can be used as both the heat source in winter and cooling source in summer. That is, in winter, the stored energy in the ground is "extracted" to heat the room; in summer, the indoor heat is transferred back into the

Fig. 2.56 Vertical ground source heat pump



Fig. 2.57 Pond/lake ground source heat pump



ground. Normally, when geothermal pump consumes 1 kW energy, over 4 kW energy heat or cool energy will be obtained. Figure 2.54 shows the working principle diagram of the GSHP.

There are four basic types of GSHPs: horizontal, vertical, pond/lake (closed-loop systems) and underground water type (open-loop option) (See Figs. 2.55, 2.56, 2.57, and 2.58).

- (1) **Horizontal ground source heat pump:** A horizontal closed loop system composed of pipes is buried horizontally 2 m underground (Figure 2.55), making heat exchange with soil. This type of system is the most common layout used in the buildings with small heating and cooling areas, such as villas and compact monomer buildings. It requires less initial investment and easy construction.

Fig. 2.58 Underground water GSHP



- (2) **Vertical ground source heat pump:** A vertical closed loop field is composed of pipes that run vertically in the ground, typically 50–400 m deep in the rock-soil to have heat transfer with the soil (Fig. 2.56). This type of system is commonly used in the buildings with large heating or cooling areas and with certain space around, such as villas and office buildings. This system requires great initial investment and complicate techniques in construction.
- (3) **Pond/lake ground source heat pump:** the system achieves heat exchange with the river, lake, and seawater through closed system lying at the bottom of the water (Fig. 2.57). This system is suitable for the building with mid- and small cooling and heating area and located close to the water.
- (4) **Underground water source heat pump:** with the closed system of the unit, heat exchange is made between a heat exchanger and deep groundwater drawn by pumps (Fig. 2.58).

GSHP can save more than two-thirds of the electricity than electric boiler and more than half of the energy than fuel boilers. The heating temperature of GSHP is stable throughout the year, which is usually 10–25 °C. The coefficient of cooling and heat is up to 3.5–4.4 which saves plenty of energy and power. One set of the equipment only can meet the requirement of heating, cooling, domestic water supply, which reduces the initial investment of equipment. When GSHP is running, it does not consume water nor pollute water. Nor does it need any boilers, cooling towers or site for the waste fuel, which has significant environmental benefits. The power consumption of GSHP can be over 40 % less than air source heat pump and 70 % less than electric heating. Its efficiency of heating system is nearly 50 % higher on average than that of gas fired-boiler.

GSHP can be used in hotels, residential quarters, apartments, factories shopping malls, office buildings, schools, and other buildings. The small GSHP is more suitable for heating and air conditioning of villatic residences. The running costs are

Fig. 2.59 The water source heat pump unit



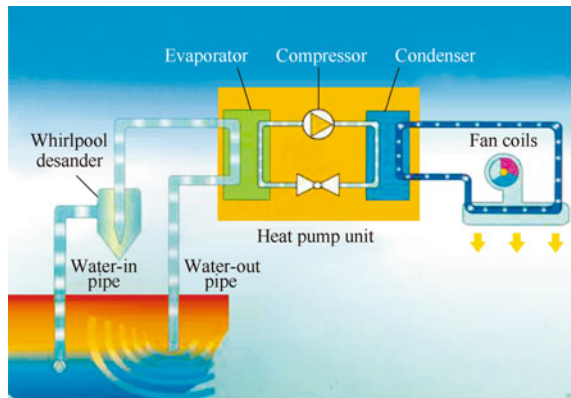
50–60 % higher than that of central air-conditioning. Over the past decades, especially in recent years GSHP system has made rapid development in North America such as USA, Canada, and some countries in northern Europe such as Switzerland, Sweden. China's GSHP market is gradually flourishing. It is estimated that this technology will become the most effective air conditioning technology for heating and cooling in the twenty-first century.

2.1.5.2 Water Source Heat Pump

Water source heat pump (WSHP), which is one or a group of systems, extracts the energy through water and provides heating and cooling. The WSHP unit is a device that extracts the low-grade heat from the surface water that cannot be used directly and then converts it into high-grade energy which can be used directly by consuming a small amount of high-grade energy. WSHP use solar energy and geothermal energy for cooling and heating, which is also regarded as one of the "GSHPs." After rigorous testing and calculations of the application examples of the heat pump in different areas, the heating COP of WSHP is estimated between 3.3 and 4.4 and the refrigerating COP is between 4.1 and 5.8. Figure 2.59 shows the WSHP unit.

The water source on the shallow surface of the earth (generally within 1,000 m depth), such as groundwater, surface rivers, lakes, and oceans absorbs considerable energy from the solar radiation and usually has a stable temperature. The working principle of the WSHP technology is that it achieves a transfer of low level heat energy to high level energy by imputing a small amount of high-grade energy (e.g. electric energy). It uses the water as a heat source in the winter or a heat sink heat in the summer. That is to say, heat is "taken out" from the building in summer and then released into the water. Since the water temperature is low, the heat can be removed efficiently to achieve cooling inside the building in summer. In winter, it is the WSHP unit that "extracts" heat from the water to the building. The working principle of WSHP is shown in Fig. 2.60.

Fig. 2.60 The working principle diagram of water source heat pump



WSHP has significant economic and environmental benefits, as in the following aspects:

- (1) **Environmental friendly:** WSHP is an energy conversion air conditioning system by using surface water as the heat source (in the winter) and heat sink (in the summer). When heating, no need for installing the boiler room system, including coal, gas, and oil, with no combustion process, which avoids smoke, sewage, and other pollution. When cooling, the pump does not need cooling tower so there is no risk of noise, mold pollution or water loss caused by the cooling tower. Therefore, WSHP is a technology using clean renewable energy.
- (2) **High Efficient:** In winter, water temperature used by WSHP unit is 12–21 °C, higher than the ambient air temperature, so the evaporation temperature of heat pump cycle will rise and energy efficiency is also improved. In summer, The temperature of water is 18–35 °C, lower than the ambient air temperature, so the refrigeration condensing temperature decreases and the cooling effect is better than air-cooled and cooling tower type and the efficiency is improved as well. According to U.S. Environmental Protection Agency (EPA), WSHP with proper design and installation can save an average of 30–40 % of the heating and cooling air conditioning running costs for users.
- (3) **Energy Saving:** The energy itself used by WSHPs is a clean energy, but in power generation, it consumes primary energy and leads to emissions of pollutants and greenhouse gas. Well-designed WSHP unit can reduce over 30 % electricity consumption compared to air source heat pumps and over 70 % electricity consumption compared to electric heating. Therefore, the WSHP can save energy as well as reduce pollution emission and greenhouse effect in the process of primary energy consumption.

WSHP technology is not only being widely used in all the central air-conditioning system of civil buildings, public buildings, military construction that need heating, cooling, and hot water, but also applied in the frozen, refrigeration, and

cooling technology system in the industrial fields, which is one of the most important technologies of energy saving and emission reduction.

2.1.5.3 Review of Applications of Ground/Water Source Heat Pump in the Shanghai Expo

The research on ground and WSHPs has made rapid development in recent years and more attention has been paid on its applications in China, especially in the process of urbanization. The ground and WSHP technologies have been fully demonstrated in the Shanghai Expo.

The Expo Pavilions site can be classified into three kinds based on the supply of heating and cooling, namely, permanent pavilions with both heating and cooling sources, temporary pavilions with only cooling sources and commercial service facilities that distribute heating and cooling.

(1) Applications of ground source/ water source heat pump in the Expo

River water and GSHP cooling/heating system are mainly used in the 3.22 km² covering five functional areas within the Expo fence, to ease the “heat island” effect in parts of the city. The landmark buildings in Shanghai Expo—the World Expo Axis, the Expo Center, Performing Arts Center and the Pavilion of City Future—have adopted such technology.

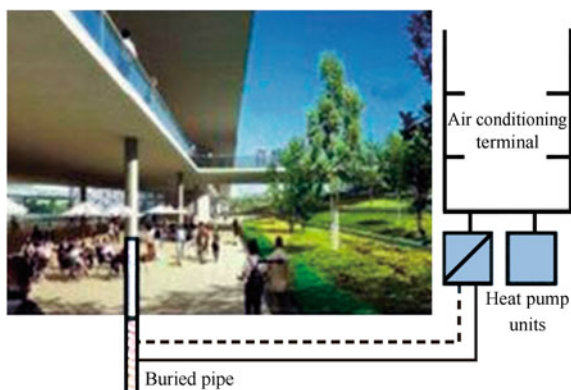
Taking geographic conditions and surrounding environment into account, closed-loop GSHP, the river WSHP (from Huangpu River) and ice storage system are the main cooling and heating methods used in the permanent pavilions. The main applied Pavilions are as follows:

- (1) Expo Axis: Base area of 130,000 m², total construction area of 248,000 m², 7 closed-loop GSHPs + 8 river WSHP units.
- (2) Expo Center: Total construction area of 141990 m², 3 river water source heat pumps + 2 duplex status screw ice storage units + 2 gas hot water boilers.
- (3) Expo Cultural Center: Total construction area of 140,277 m², 2 river water source heat pumps + 3 duplex state centrifugal ice storage units + 2 gas-fired boiler units.
- (4) China Pavilion: Total construction area of 153,000 m², 3 three-grade centrifugal cooling water units + 3 duplex state centrifugal ice storage units + 3 gas-fired boiler units.
- (5) Theme Pavilion (Pavilion of Future, Pavilion of Urban Planet and Pavilion of Footprint): Total construction area of 152,316.5 m², 3 sets of water cooled centrifugal chiller variable frequency + 8 sets of air source Screw heat pumps.
- (6) Other temporary pavilions applying ground/water source heat pump are: Hamburg House, London ZedPavilion, Shanghai Home and Iceland Pavilion.

Fig. 2.61 Hamburg house in the Expo

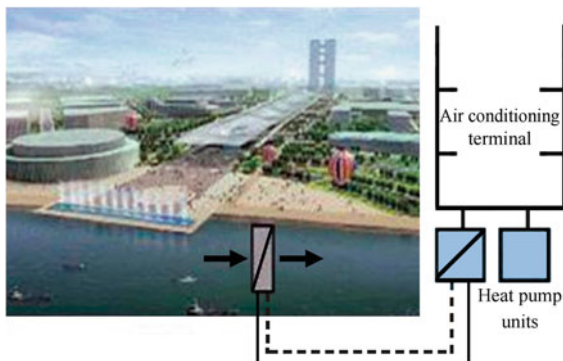


Fig. 2.62 Schematic diagram of the GSHP along the Expo Axis



The Hamburg House in Shanghai Expo (Fig. 2.61) uses under GSHP air conditioning system through the buried pipes, making the U-tube in close contact with the pile and the pile with the ground to reduce thermal contact resistance and strengthen heat transfer between the cycle fluid and the soil of the earth. This project uses a special type of 3U pipe laying, of which 2U for inlet water and 1U for backwater to ensure balance and efficiency of .heat transfer. This method is also known as “energy piles.” Due to the special requirements of its construction process, it is rarely seen at home. The application of this technology in Hamburg House indicates a new direction for the domestic GSHP development. Capillary radiant cooling/heating is used indoors, which is the most comfortable way, with multi-control combination modes available: refrigeration + fresh air, cooling + heating, heating, cooling, and dehumidifying mode (heat recovery at the same time), ventilation mode, among which the natural cooling mode is a new energy-saving way derived from the conventional GSHP system technology. Meanwhile, the host machine of the GSHP has complete control functions: loading and unloading (host with high efficiency at full load, low load adaptability), waste heat recovery control,

Fig. 2.63 Schematic diagram of the river WSHP along the Expo Axis



(the end, load, the source water) pump control, hot water pump, indoor temperature/humidity adjustment, water temperature control of the capillary side, anti-condensation, building automation and telecommunications connections, etc.

Take the Expo Axis as an example, near the end of the Huangpu River and the Dongjiadu Bend, a water intake was set up and then a heat pump was installed near the Expo Axis with about 1,200 tons of Huangpu River water running through the heat pump per hour which takes away the heat in the Expo Axis area and “exchange” the water of relatively lower temperature. The river water is discharged back to the river while the cool air is released through the different large and small channels. The river WSHP together with a small proportion of the GSHP will meet the cooling and heating demands of the Expo Axis. Figure 2.62 shows schematic diagram of the GSHP along the Expo Axis. Figure 2.63 shows schematic diagram of the river WSHP along the Expo Axis. Figure 2.64 shows joint design of Expo Axis River water and GSHPs.

In summer, river source heat pump system is used primarily, supplemented by the ground-source heat pump system, at the same time, the river water centrifugal chiller has the priority to be opened and used; in winter, it is the reverse, GSHP system is primarily used, supplemented by river WSHP system; when the river temperature is low, the suction flow of the river pump will be increased to ensure the thermal balance the of underground soil in winter and summer.

The engine room of the river WSHP system is located in the north of Expo Axis, concentrated in a room, which has five river WSHP units with cooling capacity of 1200 kW, heat capacity of 1100 kW, and three sets of river water centrifugal chillers with cooling capacity of 3800 kW. The utilization of the river water is of “direct style,” which means that the river directly enters into the heat pump condenser or the evaporator and the condenser centrifugal chillers after being filtered. Its characteristics are: no heat exchangers, no heat change energy level loss, high operating efficiency; circulating water pumps with one level reduced leading to great increase of energy-saving efficiency. Before the river enters into the heat exchanger unit they have to go through two-stage filtration, first, two wide-meshed grid screens are used before water intake; then water goes through secondary filtration with automatic

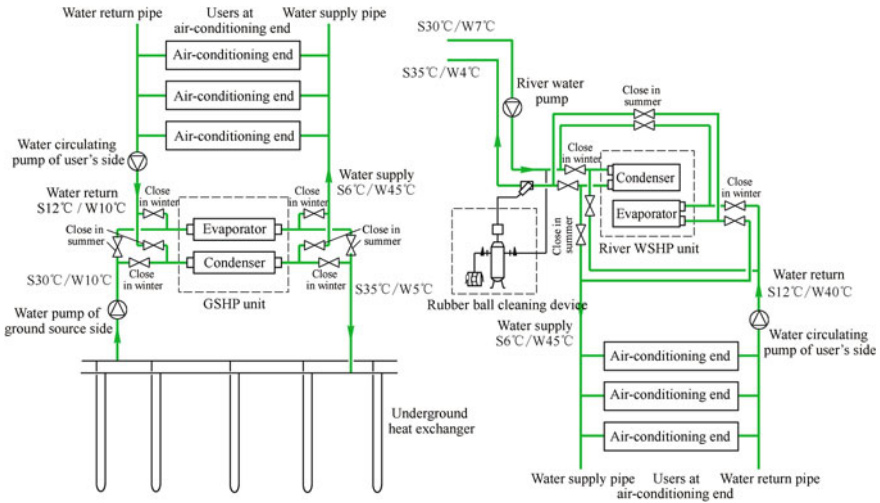


Fig. 2.64 Joint design of Expo Axis river water and ground source heat pump (source China Construction News)

backwash filter after it enters the room. The maximum designed amount of river is $6,000 \text{ m}^3/\text{h}$. In summer, the designed temperature of the intake water temperature is 30°C and the drainage water temperature is 35°C under the cooling condition; in winter, the designed temperature of the intake water temperature is 7°C and drainage water temperature is 4°C under the heating condition.

The transformation of the old Nanshi Power Plant has made full use of the technology of river WSHP system, which supplies cold and heat source for pavilions of about 15 million m^2 in Zone E of Puxi area during the Expo. and will continue exerting its role after the Expo, when the installed capacity will be further expanded to $41,379 \text{ kW}$, supplying cold and heat sources for the buildings of around $450,000 \text{ m}^2$ through the pipes ranging from 20 to 70 cm in diameter.

(2) Recommendations on Promotion of the ground/water source heat pump

The operating efficiency of GSHP is higher than the conventional air conditioning system by about 40–60 %. In addition, the characteristic of constant ground (water) temperature makes the heat pump more reliable, stable and the overall system maintenance costs is much lower than that of the boiler-refrigerating machine system, ensuring the system's efficiency and economy. Concerning its economy, it depends on many factors, such as different regions, geological conditions, energy structures and prices of energy etc., which will directly affect its economic benefit (Fig. 2.65). According to the experiences of foreign countries, due to the low operating cost of ground-source heat pump, the increased initial investment can be recovered in 3–7 years; the average cost of the ground-source heat pump system in the entire service period will be lower than that of the traditional air conditioning system. Among the Western countries, the United States makes the most intensive efforts in

Fig. 2.65 Application proportion of GSHP technology in different type of buildings (% , survey of 160 projects in 2006)

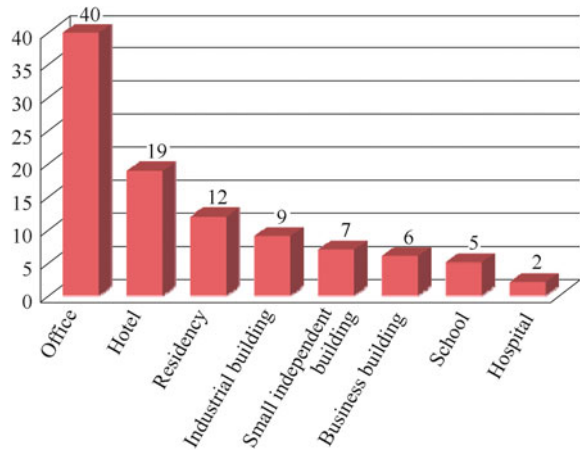


Table 2.3 Installation of ground source heat pump in the world’s major countries (2005)

Country	Total installed capacity (MW)	Annual output of heat (GWh/y)	Total installed number (units)
Austria	275	370	23,000
Germany	560	840	40,000
Canada	435	300	36,000
United States	3,730	3,720	500,000
Sweden	2,000	8,000	200,000
Switzerland	440	660	25,000

promoting GSHP, with all the data higher than those of the rest of the world in terms of the utilization scope. In 1997, 40,000 GSHPs of 12 kW were installed, while in 2000, the number reached 400,000. It is expected to reach 1.5 million in 2010. The main application areas are schools and office buildings. Table 2.3 shows the installation of GSHP in the world’s major countries in 2005.

2.2 Energy Efficient Technologies

2.2.1 Building Energy Efficiency

2.2.1.1 Overview

Building Energy Efficiency (or Energy Saving in Buildings), was initially put forward in developed countries, meaning reducing energy loss in buildings, but the term now universally refers to “improving energy efficiency in buildings.” That is,

utilizing energy in a rational way and improve energy efficiency on conditions of ensuring the basic building functions and maintaining the comfort in buildings.

Specifically, Building Energy Efficiency means that during the process of the planning, design, construction (reconstruction and expansion), transformation and use of the building, energy saving standard should be carried out, energy-saving technologies, process, equipment, materials and products should be used. The purpose is to improve the insulation performance of the exterior protected construction (or building envelope) and the efficiency of the heating, cooling and HAVC system to enhance the operations management of the energy using system of the building, by using the renewable energy sources, reduce the energy consumption in heating consumed, air conditioning, lighting and hot water supplying under the premise of ensuring the quality of the indoor environment.

(1) Significance of Building Energy Efficiency

China is a developing country with a large population and a tremendous numbers of buildings as well. Every year the newly built housing area reaches up to 100 million m^2 , surpassing the total annual construction area of all the developed countries. Building energy consumption has grown rapidly. Energy consumption of buildings refers to the use of energy in buildings, including heating, air conditioning, hot water, lighting, cooking, household appliances, elevators and other energy consumption, among which energy consumption of heating and air conditioning accounts for about 60–70 %. Of 100 million m^2 of existing buildings, only 1 % is the energy-saving buildings, The rest are high energy consumers in terms of exterior protected construction, heating and air conditioning system. Heating energy consumption per unit area equals to twice of that in the developed countries of similar latitude. That is because the heat preservation performance in the exterior protected construction in our country is poor and 67 % of heating energy have been wasted. The new buildings which could really be recognized as “energy efficient” buildings are less than 1 million m^2 . The total amount of energy consumption in buildings accounts for more than 27 % of the total energy consumption in China, which is gradually approaching 30 %.

In regard of the material consumption, China has a higher consumption compared to the developed countries: steel consumption is 10–25 % higher, 80 kg cement more are needed for 1 m^3 of concrete but only 25 % of the sewage is recycled. To achieve a sustainable development of the national economy, the implementation of building energy efficiency is imperative and urgent. At present, severe energy waste in building is founded in our country. Energy consumption in building is growing faster than the production of energy. If the situation of this high-energy consuming construction is allowed to continue, it will be difficult for the country's energy production to meet the demands of such a high energy consumption, which leads to the organization of a large-scale energy-saving renovation of the old houses which will cost more manpower and material resources. To improve energy using efficiency in buildings will greatly ease the situation of the national energy shortage and promote the development of national economy. Therefore, energy efficiency in buildings is an important measure for implementing

sustainable development strategies, realize the objectives of national energy planning and reducing greenhouse gas emissions to be in line with the global trends. Reducing the total energy consumption in the building is one approach to improve the building energy efficiency.

(2) New Energy Efficient Technologies in Buildings

The ideal energy-efficient building should meet the following three requirements based on the minimum energy consumption: firstly, control the solar radiation receiving or preventing in different seasons and different regions; secondly, keep the room comfort in different seasons; thirdly, get the room ventilated whenever needed. Currently, the ways to save energy in construction include minimizing non-renewable energy consumption to improve energy efficiency, reducing energy loss in building envelope and cutting the energy consumption of building facilities. In the above three aspects, high and innovative technologies play a crucial role. Of course, we can also use some traditional building energy-saving technologies but they can be used in modern buildings only after enough demonstration of advanced scientific tests and theoretical analysis.

(i) *Reduce energy consumption and improve energy efficiency*

In order to maintain the environmental quality of the living space, heating is needed to raise the indoor temperature in cold season and cooling is needed to reduce the indoor temperature in hot season. Humidity is needed when the environment is too dry and damp dehumidifier is needed when necessary. Ultimately, energy consumption is needed to achieve all of these. From the perspective of energy efficiency, it is necessary to increase the efficiency of heating/cooling system, which includes the efficiency of the device itself, the network transmission, the measurement of client and indoor environmental controlling devices. All of these require relevant industries to adopt high and new technologies in design, installation, operation, regulation in energy-saving system, equipment, materials, and other aspects of business management. For example, there are three new technologies to save energy in heating systems. ① By using computers, balanced valves and dedicated intelligent instruments, we can allocate the pipe network flow rationally, which not only improves the heating quality, but also saves energy. ② By installing heat distribution meter and the temperature regulating valve on the user's radiator, the users can control the energy consumption to obtain comfort and save energy as well. ③ By using the new thermal insulation material wrapping heating pipes to reduce heat loss in the pipeline. In recent years, low-temperature floor radiant technology has been proved to have good energy efficiency. It adopts cross-linked polyethylene (PEX) pipe as water pipe, spirally twisted in the ground in a double-way. In winter, it supplies low-temperature hot water (from geotherm, solar energy or various waste heat of low-temperature) to the pipe; in summer, cold water to the pipe can reduce the floor temperature (currently only used for heating). Compared with the radiator of thermal convection, this technology has many advantages of even distribution of indoor temperature, comfortable environment, energy saving, easy measurement and easy maintenance.

(2) Reduce energy loss in exterior protected construction of the building

Energy loss in the exterior protected construction of the buildings is mainly caused by three factors: (a) external walls; (b) doors and windows and (c) roofs. The energy efficient technologies in the above three parts draw much attention from the construction industry all over the world. The main development trend is to develop efficient and economical heat insulation materials and practical construction techniques so as to improve the insulation, heat-shielding performance and enclosed-safety of the exterior protected construction.

① Exterior wall energy-saving technology

With regard to energy-saving wall, traditionally, people used to increase the thickness of the walls with single heavy materials to achieve insulation, which can no longer meet the requirement of energy saving and environment protection. The compound wall is becoming the mainstream. Compound wall usually uses block material reinforced concrete as the bear structure, combined with thermal insulation material, or integrating thin wall material with thermal insulation material as the wall in the frame structure. Currently building insulation materials include rock wool, slag wool, glass wool, polystyrene foam, expanded perlite, expanded vermiculite, aerated concrete and polystyrene slurry and other particles. The production of these materials requires special techniques and equipment, which is far beyond the reach of the traditional technology. It is worth mentioning one material called the polystyrene granule mortar, mixed by rubber powder, polystyrene granule lightweight aggregate material and water, plastering on the outer surface of the wall to form a non-cavity insulation layer. Polystyrene granule aggregate uses recycled waste polystyrene board after milled, and rubber powder itself is blended with a lot of fly ash, so this material is waste recycling and energy efficient. There are three kinds of composite wall insulation technologies: inner insulation layer, outer insulation layer and sandwich layer. The third way is widely used in China; In European countries, the common practice is installing the wall with foam polystyrene boards outside. In Germany, the external insulation buildings accounted for 80 % of the total, 70 % of which uses polystyrene foam board. Figure 2.66 shows the external wall insulation system.

② Energy-efficient windows and doors

Doors and windows not only have functions of lighting, ventilation and containment, but also play important roles in art of architectural processing. However, windows and doors are the parts where energy is most likely lost. To enlarge the lighting and ventilation area or highlight the characteristics of the modern architecture, the area of doors and windows of the buildings are designed larger and larger. Sometimes all-glass curtain wall is used, which raises a higher requirement for the structure of external maintenance in energy saving. Currently, the major ways of improving energy efficiency of windows and doors mainly focus on improving the insulation performance of the materials and enhancing the air-sealing property of doors and windows. As for the window materials, some high-tech

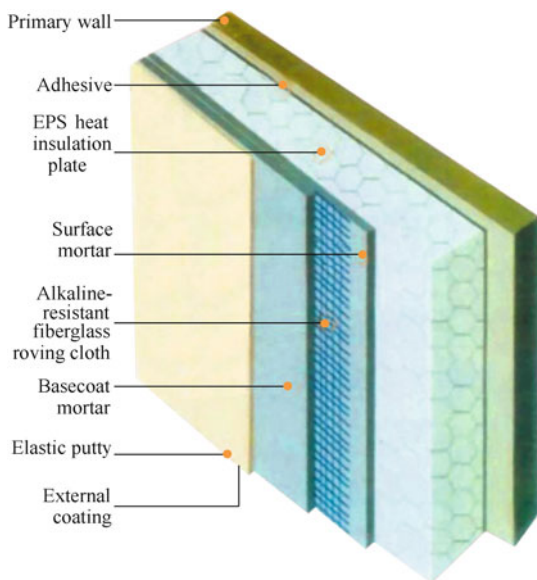
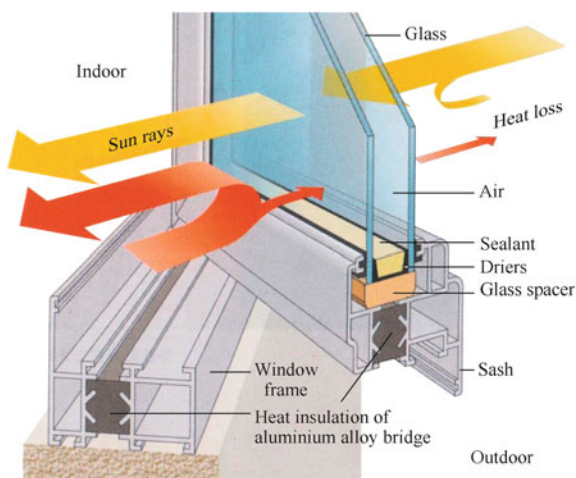


Fig. 2.66 External wall insulation system

energy-saving products have been on the market these years, such as insulating aluminum alloy profile, aluminum wood composite profiles, steel overall profile extrusion, plastic-wood composite profiles, and UPVC plastic profiles. Among them, UPVC plastic profiles is most widely used, which uses polymer materials—rigid PVC as its raw materials. This material has the advantages of not only less energy consumption, no pollution in the production process, but also small thermal conductivity and good sealing with multi-cavity structure and therefore is known to have good thermal insulation properties. UPVC plastic windows and doors have been used in European countries for many years, accounting for 50 % of the total plastic doors and windows installed in Germany. Since 1990s, the amount of plastic doors and windows used in our country has kept increasing, gradually replacing the steel, aluminum alloy and other materials which consumes much energy. To solve the problem of excessive energy loss caused by large-area glass, people use new and advanced technologies to process the ordinary glass into the hollow glass, coated glass (including reflective glass and heat-absorbing glass), and LOW-E high-strength fire-resistant glass (high strength low-E coating film fire-resistant glass), and metallic silver layer glass plated with vacuum magnetron sputtering and most extraordinary smart glass. Smart glass can sense the changes of light in the outside and respond to them with two outcomes: one is photochromic glass, which will turn dark when it senses the light radiation so the light can not penetrate it easily. Once the light irradiation stops the glass will become transparent again so light can penetrate it. Especially, when facing strong sunlight, the glass can block solar heat, while on overcast days, it brightens allowing the sunlight to enter the room.

Fig. 2.67 Energy-efficient windows and doors



The other is electrochromic glass which contains two pieces of glass coated with conductive film and color material. By adjusting the voltage, change the color of the photochromic material to change the incoming sunlight (but due to its high production costs, it cannot go into practical use), all these glasses have good energy saving effects. Figure 2.67 shows the energy-efficient windows and doors.

③ Energy-saving roofs

Roof heat preservation and insulation is one of the key points of the energy-saving in the building envelope. In cold regions, roofs are set with insulation layer to prevent the loss of the indoor heat; in hot regions, cool layer of insulation is set on the roof to prevent the sun's radiation from going through the roof into the house; in regions where it is hot in summer and cold in winter (Yellow River to the Yangtze River region), it should give consideration to both winter and summer in regard of building energy efficiency. The technical measure commonly used in insulation is to install lightweight materials with smaller thermal conductivity under the roof waterproofing layer for insulation, such as perlite, glass wool, etc., or to install polystyrene foam above the waterproof layer of the roof. In the UK there is another approach to make insulation layer, that is, making use of recycled waste paper fiber. This paper fiber consumes little energy and has good insulation performance. After borax retardant treatment, this paper fiber can be fireproof. When in construction, people first make the sandwich layer on the roof with nails and then blow the paper fibers in between the sandwich to form insulating layer. Methods of roof insulation cooling include overhead ventilation, roof water storage or regular water spray, roof greening and so on. The above approaches can meet the requirements of energy-saving of the roof to varying degrees, but the most popular and recommended one is the use of smart technology and eco-technology to achieve the building energy efficiency, such as solar collector roof and controllable ventilation roof etc.

④ Reduction of the energy consumption of building facilities

Heating, cooling and lighting are the major energy consuming elements in buildings. So it is very important to reduce the energy consumption of these parts to achieve the energy efficient. A number of successful techniques in this regard are of great value to us. Take UK Building Research Institute (BRE) for example: advanced energy saving control system is installed in the building envelope, while transparent sandwich is used inside the building allowing the natural ventilation. Air comes in through the grille on the back of the building, and exhausts through the grille in the wall on the front ceiling, which forms the natural ventilation through the building. High-performance cold and hot boilers and conventional boilers are used interchangeably controlled by a computer system. Room temperature can be adjusted through the heating and cooling piping systems embedded under the floor. Another technology used in the building for cooling is by pouring cold water into pipes under the floor through the radiator: Step 1, extract the cold water from the ground with pumps from the deep well under the garage to the radiator; Step 2, pour the water back through another recharging well near the building. In order to reduce artificial lighting of the building, a comprehensive daylighting and lighting combination system is used, which is controlled by the building management system; Each unit of the building can receive sunlight where the system can be controlled by users and administrator through monitor. In the 100-seat lecture hall, two forms of lighting systems are installed which guarantees the brightness by using energy-saving fluorescent lamps and incandescent lamps to allow every audience to enjoy the same good visual effects and agreeable temperature.

(3) Development of new energy-efficient building materials

① Exterior insulation and finishing system (EIFS)

EIFS is a type of building exterior wall cladding system that provides exterior walls with an insulated finished surface and waterproofing in an integrated composite material system. This system came into being in the late 1970s when the last energy crisis occurred. It was initially used in commercial buildings and later applied in civil buildings. Today, EIFS system accounts for 17.0 % of use in the commercial building walls, 3.5 % of civil building walls which grows at the rate of 17.0–18.0 % in civilian building walls per year. The system is a multi-layer external wall insulation system which contains the following parts. The main part is made of polystyrene foam insulation board, with the thickness of 30–120 mm. This part is fixed on the external wall by the means of synthetic adhesive or mechanical technology. The middle part is a long-lasting and waterproof primary polymer mortar. This basic layer is mainly used for insulation board to enhance and convey the external forces with glass fiber network. A final topcoat, or finish, is a beautiful and durable surface coating which is a colored, textured paint-like material. In order to prevent fading and cracking the covering material commonly adopts the technology of acrylic acid copolymer coating. A variety of colors and textures are available with strong durability and corrosion resistance.

② Structural Insulated Panels (SIPS)

Applied in both civil and commercial buildings, Structural Insulated Panels (SIPS) are a high performance building material as wall, floor and roof. The core of the board is a polystyrene foam sheet or Poly urethane foam sandwich layer, with a thickness of 120–240 mm. Different flat surfaces can be used on both sides as necessary. For example, the plywood type wood products can be used on both sides in construction projects. Buildings using SIPS will have higher strength, tighter building envelope, and better insulating properties, leading to shorter construction period and low construction cost. Moreover, SIPS-constructed building is energy saving and environmentally friendly. SIPS tend to come in sizes of 1.2 m in width with a maximum of 8 m. There are a series of dimensions for this material. Many factories can also customize the sizes of the product as required by the engineering. Contractors can just assembly this system at the construction site.

③ Insulated Concrete Foams (ICFS)

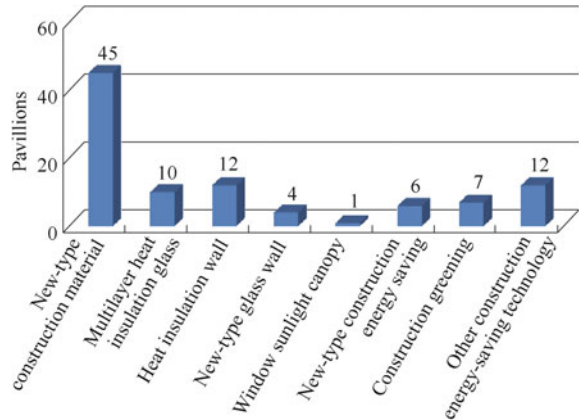
This product is an insulation template system made of recycled polystyrene foams and cement gelled materials, used for pouring in place the concrete walls or the foundation. In construction reinforcement bars are set within the template horizontally or vertically. When the wall is completed, the insulation template will serve as part of the permanent wall, formatting the insulation concrete walls both externally and internally. The template material applied externally on concrete walls meets the requirements of heat preservation, sound insulation and fire protection of the exterior wall.

2.2.1.2 Application of Building Energy Efficient Technologies in Expo 2010

Building energy efficiency refers to the use of new thermal insulation wall materials and heating air conditioning system of high energy efficient ratio in the construction under the premise of ensuring comfortable living, so as to save energy, reduce energy consumption and improve energy utilization efficiency. It involves three aspects such as energy efficiency in architectural materials, building structures and devices.

Building energy-efficient technologies have been widely used in Pavilions of the Expo site. For example, transparent concrete was applied on the external wall of the Italy Pavilion through the deployment of different proportions of the material allowing light to filter through, and thus reducing the use of lamps; German Pavilion used a meshy, breathable architectural fabric on its external wall which can reflect solar radiation to provide shading for the pavilion; In Japan Pavilion, environmental control technology was adopted in the pavilion design, making full use of the light, water, air and other natural resources. The double-layer membrane of high transmittance outside the pavilion light coupled with inner solar cells can take advantage of solar energy resources and realize a high efficient light guiding

Fig. 2.68 Items of building energy-saving technologies applied in Expo site



and power generation. Inside the pavilion the latest technology of circular breathing pores was used. In terms of structure, Japan Pavilion uses an integrated semi-circular light-type structure combining roof with external wall, resulting in less impact on the surrounding environment in construction.

Figure 2.68 shows the items and numbers of energy-saving technologies applied in the Expo site, based on the comprehensive analysis.

(1) Building Energy Efficient Materials

The building energy efficient materials used in the Expo site include new thermal insulation materials, new plates, etc. The new thermal insulation materials include multilayer heat-insulating glass doors and windows, heat-insulating walls and heat-preserving paints, etc.

(i) Energy-Saving Glass Doors and Windows

According to the statistics, all doors and windows used in the World Expo pavilions are made of energy-saving glass. That is to say, the utilization rate of energy-saving glass has reached a full 100 %. Specifically, the types of energy-saving glass used are laminated heat-insulating glass, LOW-E hollow glass, coated glass, ultra white LOW-E glass, sodium metasilicate curtain wall and solar energy glass curtain wall, etc.

China Pavilion uses the LOW-E hollow laminated toughened glass supplied by Xinyi Glass Co. Ltd. As a new type of energy-saving safety glass, it can block most of the heat and ultraviolet in the sunshine, and has excellent performance in sound proofing and safety. The dimension of the LOW-E energy-saving glass in China Pavilion is larger than that of the common energy-saving building glass by 30 %, and its thickness increased by nearly 50 %, which almost reaches the limitation of the sophisticated equipment processing in the world.

The Low-E coated glass (Planibel-G®) offered by Asahi Special Colored Glaze Ltd is applied in Australia Pavilion, Brazil Pavilion, Spain Pavilion, Malaysia Pavilion, and Japan Pavilion, etc. Low-E coated glass is produced in the float

Fig. 2.69 Highly energy-saving doors and windows in Hamburg Pavilion

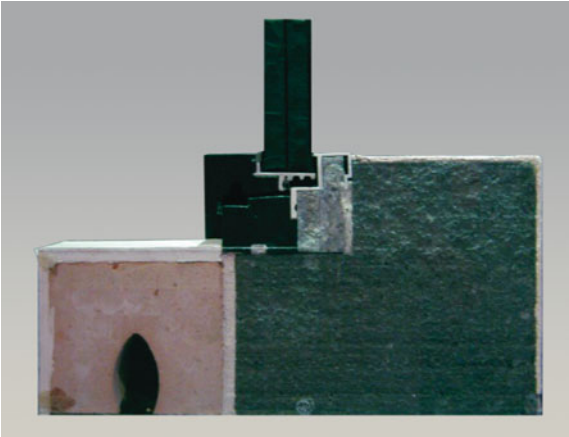


Fig. 2.70 The three-layered window structure exhibited in Broad Pavilion

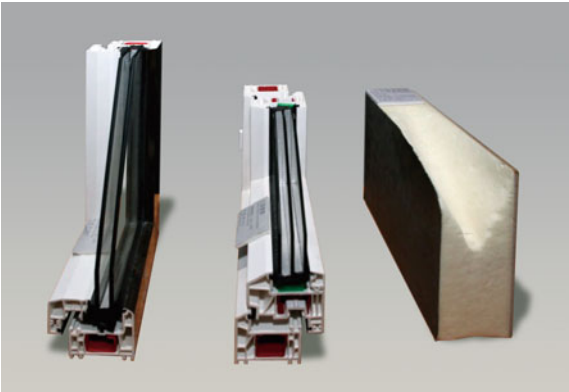


Fig. 2.71 Heat-preserving walls exhibited in Broad Pavilion



processing line, When the glass is still under the high temperature, a layer of low-radioactive metal oxide film is formed on the surface of the glass by using the chemical vapor deposition technology. After annealing, this layer stick to the glass firmly with very good chemical stability, thermal stability and hardness. In freezing winter, the Low-E low-radioactive coat can reflect the heat absorbed by the glass back to the indoor to reduce the heat loss to the outdoor, and thus keeps the indoor room warm. While in hot summer, the Low-E low-radioactive coat can reflect the thermal radiation of the outdoor. In this way, the heat transmission from outdoor to indoor will be reduced so as to keep the indoor cool. Italy pavilion uses the new Low-E energy-saving glass, US pavilion chooses hollow glass made of Low-E coated glass from PPG.

For some other pavilions like the World Cultural Centre, Belgium Pavilion, UAE pavilion, Pavilion of Future, Power Plant in South City and Urban Best Practice Case Pavilion. They chose the low radioactive energy-saving hollow glass of Nanbo Group, which occupied over 70,000 m².

Besides, the Expo Axis, Theme Pavilion, and Performance Center have chosen the ultra-white glass produced by Jingjing Group. It is a high transparent low-iron glass, which is also called low-iron glass or high-transparent glass. With a luminousness rate of over 91 %, this new type of multifunctional high-end glass is characterized by its glittering and translucent design along with its elegant and exquisite taste, renowned as “the Crystal Prince” among the members of glasses family.

The ENERsign highly energy-saving doors and windows system displayed in Hamburg Pavilion (Fig. 2.69) has a window sealing property of 0.65 W/(m²)K.

Hamburg House also displayed a kind of sealing material—Vac organ silicone sealant. Figure 2.70 shows the three-layered window structure exhibited in Broad Pavilion.

(ii) *Thermal Insulating Walls and New Type of insulating Paint*

Thermal insulating walls are adopted in most of the pavilions in the Expo Site to reduce the energy consumption of buildings. Figure 2.71 shows the thermal-insulating wall in Broad Pavilion. Figure 2.72 shows the insulation materials in Broad Pavilion.

Norway Pavilion has applied ElastosprayTM polyurethane spraying foam of BASF to ensure the heat preservation of the roof.

(iii) *New type of plates*

New type of plates have been used extensively in the Expo venues. The exterior wall of the Vanke Pavilion applies the wheat straw planking pressed from wheat straw. It is an environmentally friendly material and has almost zero formaldehyde emission. It features in outstanding nail-holding ability, both inward and outward fineness, and good fire-resistant property, as shown in Fig. 2.73.

Finland Pavilion (with the exterior wall covered with scale-shaped plaque) and China Pavilion (in the third exhibition area) both apply the UPM ProFi wood-plastic composite material. It is a special material, integrating the advantages of

Fig. 2.72 Insulation materials in Broad Pavilion

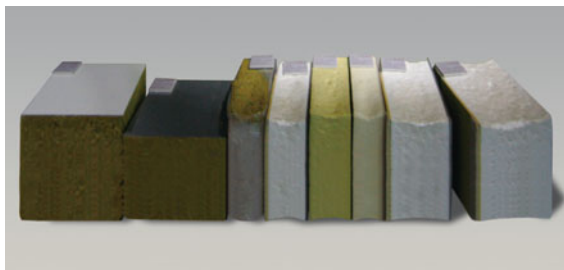


Fig. 2.73 Wheat straw plate on the exterior wall of Vanke Pavilion



both wood fiber and plastic, made from reclaimable material, solid and moisture-proof. The raw material of UPM ProFi comes from the scrap material in the production of sticky label, with the main components as paper and plastic. Therefore, this kind of composite material can either be incinerated or recycled in the process of production. See Fig. 2.74.

Hamburg Pavilion has used the BASF's Neopor in its hollow wall, a heat preserving plate which can increase the heat-preserving rate by 20 %.

The exterior wall of the Portugal Pavilion applies cork wood from Portugal, which mainly features light-weight, large buoyancy, strong elasticity and compression resistance. Besides, it is moisture proof and abrasion proof, and has good impermeability, low conductivity, heat insulating and sound-proofing, and high insulativity. As it is not inflammable, it can slow down the spread of fire and will not lead to allergic reaction, etc. See Fig. 2.75.

The rattan lath outside the exterior wall of Spain Pavilion is sturdy and durable, and at the same time allowing the light and air penetrating in. See Fig. 2.76

Fig. 2.74 Scale-shaped plaque on the exterior wall of Finland Pavilion



Fig. 2.75 Cork exterior wall of Portugal Pavilion



Fig. 2.76 Rattan lath exterior wall of Spain Pavilion



Fig. 2.77 Sun-shading system in Madrid Pavilion



Fig. 2.78 New energy sun-shading device in Shanghai Case Pavilion



(2) Energy Conservation in Building Structure

(i) Sun-Shading System

Sun-shading can effectively block the solar radiation and reduce the workload of air-conditioning in summer. The common sun-shading device includes cornice, visor and external venetian blinds, adjustable awning, external roller shutter, etc. Figure 2.77 shows the sun-shading system outside the Madrid Pavilion in Shanghai Expo, which is made of reeds through pressing and has a good performance in shading sunshine and preventing heat and economical and environmentally friendly as well.

The sun-shading system in Shanghai Case Pavilion can be classified into the following (Fig. 2.78): sun-shading through construction, structural sun-shading, greening sun-shading and sun-shading through new energy components.

Fig. 2.79 Southern afforested wall of Alsace Case Pavilion



(ii) *Construction greening*

The functions of construction greening are as follows:

- a. Ease the heat-island effect: Planting trees or grass on the roof can effectively ease the heat island effect of the city, adjust ambient temperature in the neighboring cities and bring down the indoor temperature. In hot summer, the surface temperature under the vegetation layer on the roof usually ranges from 20 to 25 °C, which is superior to ordinary heat insulating method.
- b. Save energy and protect environment: The green roof matrix has extremely strong water retention. When the roof is afforested, its draining strength can be reduced by 70 %, which not only saves water, but also alleviates the pressure of the city drainage system. Meanwhile, it can cut down the air-conditioning use frequency on the top floor, and thus save a lot more electricity.
- c. Promote ecological balance: The roof greening campaign in urban buildings is a way to return the effective ecological area to the nature, perfect the ecological system, and increase the air humidity as well. It can also add to the city's oxygen content, alleviate air pollution and maintain the balance of carbon against oxygen in the urban air.
- d. Beautify buildings and protect the roof: greening on the roof can beautify the city's environment and the living environment. Moreover, it can protect the building surface from aging or expanding and contracting caused by temperature difference, so as to prevent the roof from leakage caused by the diacalse.

The most typical building greening examples in the Expo site were displayed through London Case Pavilion, Alaska Pavilion (Fig. 2.79), India Pavilion (Fig. 2.80), China Pavilion, Theme Pavilion (Fig. 2.81), Canada Pavilion, Ireland Pavilion (Fig. 2.82), Singapore Pavilion, and Saudi Pavilion.

Fig. 2.80 Afforested roof of India Pavilion



Fig. 2.81 Vertical afforested wall of Theme Pavilion



Through a rainwater collecting system, India Pavilion uses the factory-processed reclaimed water for irrigation.

The ecological green wall of Theme Pavilion, as large as 5,000 m², can annually hold back 870 tons of dust, achieve 3,175 tons of carbon sequestration, reduce 96 tons of carbon dioxide emissions and saves electricity consumption of air-conditioning in the summer by 125,000 kWh, undoubtedly making itself the “green lung” of the Expo site. In the summer, through the greening exterior wall it blocks the thermal radiation and reduces heat conduction, when the temperature is above 34 °C, the air temperature around the green wall can be reduced to around 31–32 °C, lower by 2–3 °C. Compared to the conventional curtain wall, the ecological green wall lowers its energy consumption by 40 %, resulting in the reduction in the air-conditioning workload by over 15 %. In the winter, the ecological green wall ensures the wall space receiving enough solar radiation heat, and meanwhile it forms an insulation layer on its surface, which reduces the energy consumption from heat supply by 10 %.

Fig. 2.82 Roof and surrounding afforestation of Ireland Pavilion



Fig. 2.83 Roof air caps in London Case Pavilion



(3) Energy-saving Ventilation System

In Shanghai World Expo, many different energy-saving ventilation systems have been applied in different pavilions, among which the air-refreshing equipment in Broad Pavilion and the roof air cap system in London Case Pavilion are typical examples.

A specially structured air cap has been used in London Case Pavilion (Fig. 2.83), which has the function of passive ventilation and heat reclamation.

An air-refreshing equipment with function of air purification has also been displayed in the Broad Pavilion. With 7 types, the equipment can process different levels of air quantities, ranging from 125 to 20,000 m³/h; with the purification rate of fresh air reaching 99 % and heat recovery rate 90 %. The equipment works through either joinable ventilation pipe or straight blow, with the power consumption of 0.7 W/m³. See Fig. 2.84.

Fig. 2.84 Heat-recovery air-refreshing equipment exhibited in Broad Pavilion



2.2.1.3 The Reality of Building Energy Efficiency in China

(1) **The current building energy efficiency level in China is not high, mainly for three reasons:**

- ① limited only to energy saving in the building envelope and equipment;
- ② Imperfection of energy efficiency standards system;
- ③ Building energy audit and energy consumption monitoring have to be improved.

(2) **Suggestions on the promotion of building energy efficient**

- ① Establish energy efficient management system based on energy consumption data of large public buildings;
- ② Conduct the existing energy efficient buildings innovation with the guide of Scientific Outlook on Development;
- ③ Develop green buildings;
- ④ Establish low-carbon demonstration cities.

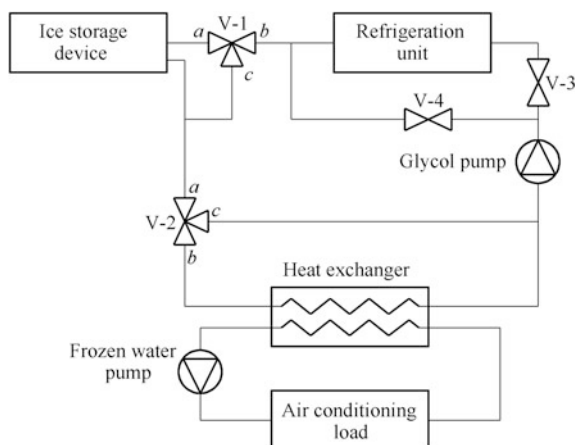
2.2.2 Ice Storage Technology

2.2.2.1 Introduction to Ice Storage Technology

Ice storage technology is a series of technologies of storing cheap electricity during off peak hours at night and release the coolness by melting for use during subsequent daytime peak hours. The system works with refrigerator. Figure 2.85 shows the working principle of ice storage air conditioning system.

Ice storage technology can save the cost of air-conditioning equipment and reduce 30–50 % of the installed capacity of the chiller. For users, the operation costs will be reduced as great as 30–50 %. Besides, it can reduce air pollutants

Fig. 2.85 Working principle for ice storage air-conditioning system



emission around the power plant as well as the CFC and combustion emissions around the buildings. Meanwhile, it can also enhance the power generation efficiency and thus improve energy utilization efficiency, which can achieve “load shifting” of the power, transferring peak power load and balance power supply.

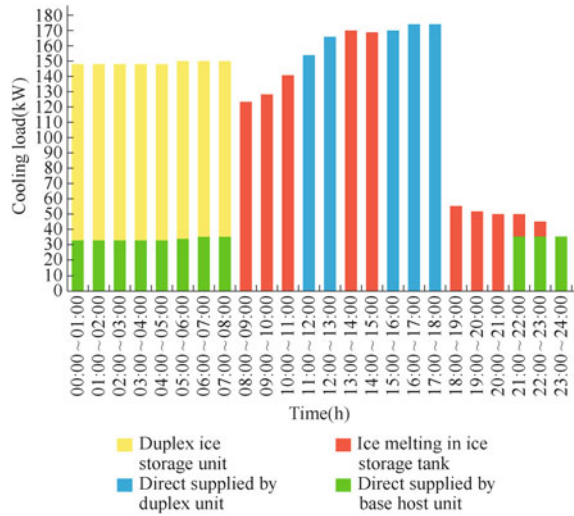
As an efficient means of energy conservation in the twenty-first century, ice storage technology has a great potential for development and benefits mankind, resulting in a positive social effects and economic benefits. It is an important method to increase the electricity load of the grid, improve the overall benefit from investment in power utilities and reduce the emissions of carbon dioxide and sulfides, which is of great significance in environment protection.

2.2.2.2 Ice Storage Technology Utilization in the Shanghai Expo

Ice storage technology has been used in the China Pavilion, also known as “Oriental Crown.” The working mechanism is very simple. That is, place a huge ice storage pool at the bottom of the pavilion, the refrigeration system could make ice during the off peak night time when the power rate is lower, while the ice will melt into cooling water to cool down the pavilion in the daytime. As Shanghai Expo was opening from May to October, covering summer and autumn, which required a large amount of cooling air. This technology can effectively help Shanghai to achieve the electricity “load shifting” during this period. According to a survey, by using the “Ice Storage” and “River Water Source Heat Pump” Technologies, the World Expo pavilions could reduce at least 15–18 % of the energy consumption compared with the conventional air conditioning system.

Apart from the utilization in China Pavilion, Ice storage Technology has also been applied in the permanent building “Four Pavilions along the Central Axis” in the Expo site. In the China Pavilion, 6 sets of Trane host were used, including 3 sets of 830 tons of cold duplex units, and 3 units of 800 tons of base load cooling unit.

Fig. 2.86 Designed daily operation strategy during the Expo



The Art Performing Center have installed 3 sets of 650 tons of duplex status of the cold unit, two 650 tons of cold river WSHP unit and the end device. I

(1) The designed daily operation strategy during the Expo

For the host, maximum cooling storage is 928 kW, the daily ice melting amount is 923 kW. The airborne host, duplex status host and ice storage tank operated in the following five models, shown as Fig. 2.86.

- (i) Duplex status host refrigeration mode (from 24:00 to 8:00 the next day), base host refrigeration;
- (ii) Duplex status single mode of host refrigeration (11:00–13:00 and 15:00–18:00);
- (iii) Ice-storage tank single mode of refrigeration (8:00–13:00 and 15:00–18:00);
- (iv) Base host single mode of refrigeration (23:00–24:00);
- (v) Base host + Ice-storage tank united mode of refrigeration (21:00–23:00).

(2) The daily operation strategy designed when no visits

Maximum cooling storage of the host is 928 kW, the daily ice melting amount is 910 kW. The airborne host, duplex status host and ice storage tank operated in the following three models. See Fig. 2.87.

- (i) Duplex status host refrigeration mode (24:00–8:00 the next day), base host refrigeration;
- (ii) Ice storage single refrigeration mode (8:00–23:00);
- (iii) Base host + ice storage tank united refrigeration mode (21:00–23:00).

It is seen from the above Figs. 2.86 and 2.87 that large-scale units operate efficiently in full load during most of the day time, and the insufficient load of the

Fig. 2.87 The designed daily operation strategy with no visits

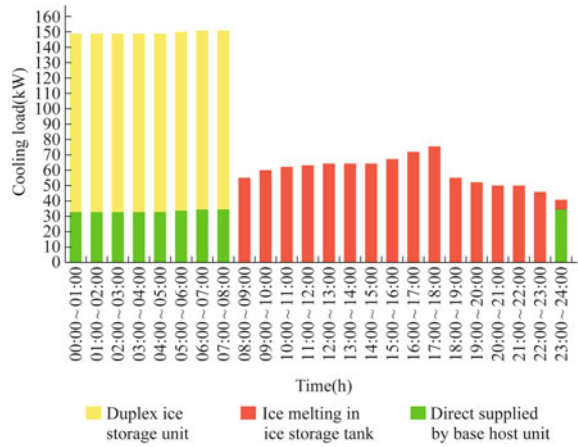
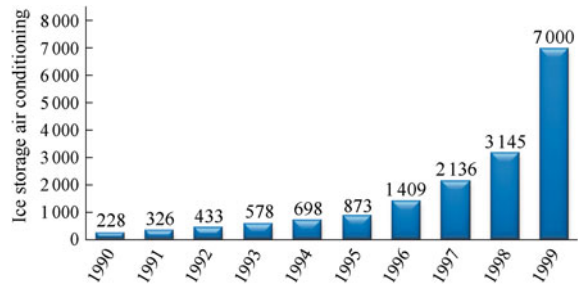


Fig. 2.88 Growth of ice storage air conditioning in Japan in 1990s



air-conditioner is adjusted by the ice storage system and thus increase the operation efficiency of the host while taking advantage of the off peak power rate.

2.2.2.3 Suggestions on the Ice Storage Technology

In the 1970s, due to the global energy crisis, plus the peak electric load growth in summer in the United States, Japan and some European industrial countries and the gap between peak and valley loads is widening at an alarming rate, resulting in a low-load operation of power plants at night. Thus ice storage technology was introduced to the centralized air conditioning system on an experiment basis. Since then the more and more ice storage air conditioning systems have been used in the engineering project. Take Japan for instance, which is among the fast growing countries, in 1990 it had only about 200 of ice storage air conditioning systems, in 1999 the number increased to 7,000 (see Fig. 2.88). In fact the ice storage air conditioning system development in the United States is also growing very fast (remarkably).

Currently the electricity departments in many cities in China have introduced the time-of-use (TOU) price structure and the relevant preferred policies, which will reduce the operating costs of users and thus encourage more people to use ice storage air-conditioners.

Ice storage air conditioning system features a higher technological content over conventional air conditioning system. We believe that it's an inevitable trend to develop ice-storage air conditioning system in China. So far there have been only 109 ice storage air conditioning systems in our country, of which more are in Zhejiang and Beijing, 32 and 27 respectively, accounting for 29.4 and 24.8 % of the total, as in other provinces and cities there are not more than 10 such systems. Table 2.4 shows cold storage air-conditioning applications in China.

2.2.3 Other Energy Saving Technologies

2.2.3.1 LED Technology

- (1) White Light Emitting Diode (LED), also known as light-emitting diode, uses solid semiconductor chip as light-emitting material. When coupled with a forward voltage on both ends of the electrodes, the current carrier across the semiconductor will mix with each other and release excess energy in the form of photon and then emit light. Figure 2.89 is a diagram shows the **schematic diagram** of the light-emitting diode.

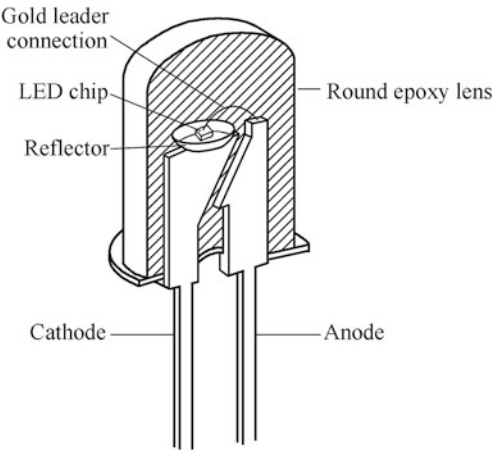
(i) *The Status of White LED development in China*

At present, many domestic enterprises have mastered the manufacturing technology of LED with small power chip. High power LED has high requirement of the epitaxial material. The leading Japanese companies in the industry strictly block the technology. Nichia, a Japanese company, who is known for its cutting-edge research in GaN, has worked with Toyota to develop a device of metal organic chemical vapor deposition (MOCVD). But they don't sell this equipment to foreign countries. Epitaxial wafer and chip manufacturing belong to the technology- and capital-intensive industries, so the entry barriers remain high. At present, the core patent technology is still in the firm grip of large companies, such as NICHIA of Japan, Cree of United States and Osram of German, etc. These companies rely on setting patents bulwark and filing patent litigation to keep other companies from entering the market to compete with them so as to obtain the high monopolistic market interests and form a strong patent alliance. Lack of core technology is a bottleneck in the development of LED in our country. According to statistics, by the end of 2009, China had obtained around 20,000 LED-related patents, but the vast majority confines to the downstream applications, packaging fields. Due to lack of core technology, the development of upstream and downstream development of LED is not balanced. The majority of enterprises are small with low-technology content with irrational industrial structure.

Table 2.4 Cold storage air-conditioning applications in China

Time	1993	1998	2001	2002	2003
Number of users	2	81	177	233	311

Fig. 2.89 Schematic diagram of light-emitting diode



The blue LED chip which can be put into volume production by major Chinese epitaxial wafer and chip manufacturing enterprises has the luminous efficiency of 110 lm/W (lumens/watt), while the luminous efficiency in the world has reached 140 lm/W.

(ii) *Advantages of LED in energy saving*

As a new solid-state light source, LED features small size, high light efficiency, long service time, quick response and high reliability. Now it has been recognized as a major lighting materials of energy saving in the world. Compared with traditional lighting technologies, the most important advantage of LED at present is that it is environmentally friendly and energy efficient.

Cao Dong, general manager of Shanghai Songer Lighting Engineering Co., Ltd, who is responsible for the LED Lighting project in the Expo Park and the theme Pavilion, told the reporters that according to accurate calculation, the 1,700 sets of LED lighting systems in the Expo Park could save 60 % energy compared with the traditional lighting, The white LED lighting system used in the arterial roads and stairs can save up to 75 % of the electricity.

(iii) *Application of monochromatic LED*

LED was first used as the light source for instrument indication. Later a variety of light-colored LED has been widely used in traffic lights and large display screens, producing great economic and social benefits. Take 12-inch red traffic

Fig. 2.90 Night scene of China Pavilion



lights for example, in the United States, people primarily used long life and low-efficiency 140-W incandescent lamp as a light source, which produced 2,000 lm of white light. After going through the red filter, 90 % of the light is lost and only 200 lm of red light is left. In the newly designed lights, however, Lumileds used 18 red LED light sources, including circuit losses, consuming a total power of 14 W but produced the same lighting effect.

Automotive signal lights are also important areas of LED light application. In 1987, China began to install brake light in cars because of the LED's quick response speed (nanosecond grade) which allows the drivers of trailing vehicles know the driving conditions earlier so that they can reduce rear-end accidents.

In addition, LED lights have been applied on red, green, blue full-color display in the outdoor and key chain-type mini flashlight and some other fields.

(2) Applications of the new light source LED technology in the Expo

According to the statistics, currently 1.3 billion pieces of LED chips have been used in the Expo Park, which appeared in indoor-and-outdoor lighting, landscape decoration, direction boards and information display screens. The whole Expo Park becomes the most concentrated area of semiconductor lighting technology demonstration and application. LED green light sources are applied in almost 80 % of the indoor lighting sources in the Expo pavilions, which can save almost 90 % of the electricity compared with incandescent lights.

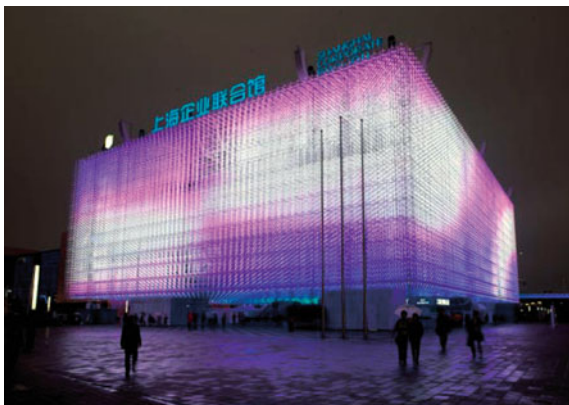
LED has not only been applied to the whole landscape lighting of "Four Pavilions along One Axis" and the city's best practice area, but also used as the LED display screens to exhibit varied video contents, which is worth over 1 billion yuan. The LED lighting application on such a large scale in the Expo Park has a total energy-saving efficiency of over 70 %. LED creates an earthshaking scene with enormous visual impact and helps make a perfect Expo.

Over 2 million LED lights and 90,000 sets of full-colored lamps and light ribbons of different types were used along the 1 km long Expo Axis, which demonstrated the ideas of low-carbon Expo and green Expo.

Fig. 2.91 Night scene of Expo Axis



Fig. 2.92 Night scene of Shanghai Corporate Joint Pavilion



The LED lights also help creating a series of magnificent scenes, such as: the elegance of the Theme Pavilion, the dignity of the Expo Center, the future sense of the Cultural Center as well as the dynamic vigor of the Expo Axis and the shining of “the Chinese Red.” Examples of LED applied in the Expo is seen in Figs. 2.90, 2.91, 2.92, and 2.93.

Take the Sun Valley of the Expo Axis for example, each intersection of the light-steel structure was installed with direct view LED luminous points, and there were some 80,000 such luminous points which can display images and characters with lower resolution through digital control system. Meanwhile, the large-sized tensile membrane on top of the Expo Boulevard also used LED for spot-lighting, which enabled the whole Expo Boulevard to make use of the dynamic changes of the LED full-spectrum to create a lively festive atmosphere.

More than 15,000 LED lights were arranged both inside and outside the “Magic Cube”—the theater. Inside the theater there were 100 spotlights, 100 ultraviolet lamp combinations, 75 digital mobile lights, together with 300 loudspeakers, Outside, 24 seven-kilowatt searchlights, 75 flashing lights, and 150 high-powered

Fig. 2.93 Night scene of Information and Communication Pavilion



loudspeakers were installed. These combinations together make the “Magic Cube” a breathtaking and dreamlike place.

In the Urban Best Practices Area located in Puxi Site, a section of road surface was paved with LED light tiles. When night fell, the LED system was showing different colors and patterns on the ground as time changes.

The “Ball of Energy” in the Energy Source Hall of Germany Pavilion was a great highlight, since the ball was installed with more than 400,000 light-emitting diodes. The ball would turn to one side where the cries are louder and emit dazzling light. In the huge sound wave on site, the Ball of Energy quickly rolled around, perfectly interacting with the audience.

The UK Pavilion at night was like a huge LED dandelion, as shown in Fig. 2.94, thousands of LED lights were “rooted” in some 60,000 Acrylic “tentacles,” with each light guarding a seed. The image of the UK Pavilion thus became the favorite of many photographers.

LED, known as the “green light source of the twenty-first century,” was used as the main lightening body in the Urban Best Practices Area, and it is the first time for LED to be applied in city blocks on a large scale. The creative designs such as “the singing floor,” “ripples coming from standing on water,” and “a plant that quickly flourishes with the increasing number of visitors,” integrated highly effective, humanized and sustainable techniques, allowing the visitors to enjoy the beauty of the lights.

(3) Recommendations on the new lighting source LED technology

Nowadays, as “a Technology to Light the Future,” LED has drawn the attention from more and more countries in the world. The development of the technology in the long-term will grow at a very high rate. It is estimated that the output value of LED all over the world has increased from 12.5 billion US dollars in 2004 to 50 billion US dollars by 2008. It has a huge market potential but faces growing competition as well.

Fig. 2.94 UK Pavilion during the night

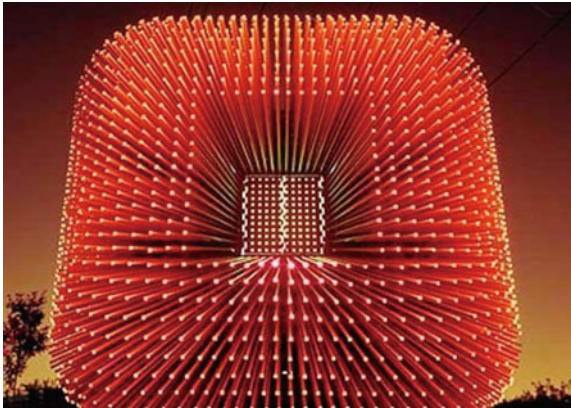


Table 2.5 Development target of the lighting industry in China

Technical index	LED (2010)	LED (2020)	Incandescent lighting	Fluorescent lighting
Luminous efficiency (lm/W)	100	200	20	75
Service life (kh)	50	100	4	10
Luminous flux (lm)	800	1,500	1,200	3,400
Input power (W)	8	7.5	75	40
Unit cost (Yuan)	33.2	24.9	2	14
Cost per mille lumens (Yuan)	41.5	16.6	1.7	4.1
Color Rendering Index (CRI) (Ra)	>80	>80	>95	75
Total cost per million lumens hourly (Yuan)	6.63	3.28	40	7.4

At present, China has become the most important production base of the middle- and down-stream LED products. It is estimated that the LED industry in China will reach 100 billion by the year 2010.

The technological innovation will maintain a sustainable development of LED. The impact of foreign technologies and the progress of domestic LED technologies will be the trend in the future 5–10 years. See Table 2.5, Figs. 2.95 and 2.96.

(i) *Actual status in the industry*

At present, the dominant technical route in producing white light LED both in domestic and overseas markets is still by using blue chip plus yellow phosphor. In the past decade, white LED manufacturing technology has achieved rapid development. Its main technical index, luminous efficiency, has increased by several times. For example, in the conditions of 20 mA, Nichia’s laboratory products have reached 249 lm/W; at 350 mA, Cree’s high-power laboratory products have reached

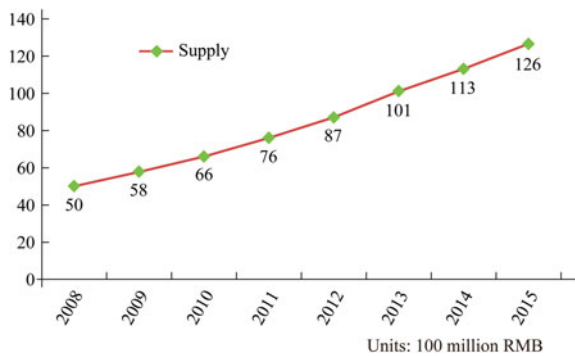


Fig. 2.95 High-power LED lighting products supply and forecast in China in 2008–2015

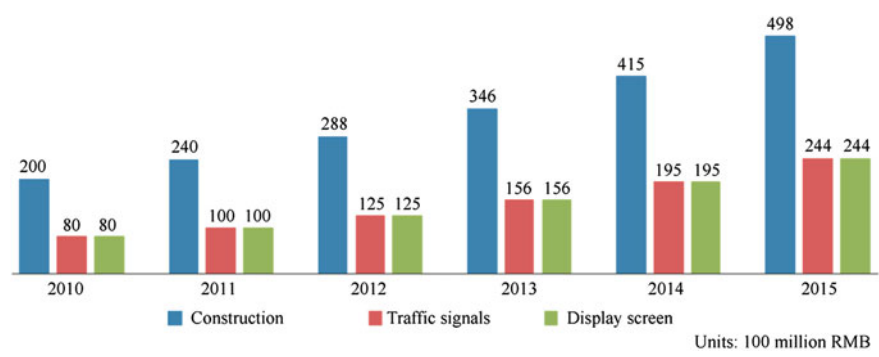


Fig. 2.96 High-power LED lighting market size forecasting in China in 2010–2015

208 lm/W. Cree’s products in commercial production have reached 140 lm/W and are expected to reach 160 lm/W by the end of 2010. With the improvement of LED technology in overseas countries, the performance of domestic high-power white LED products has increased substantially. The luminous efficiency of the product in 2003 was only 30 lm/W, but reached 110 lm/W in 2010. In China, LED has been widely applied in many fields, with the luminous efficiency of white LED far surpassing that of incandescent and fluorescent lamps, close to that of high pressure sodium light and metal halide lights.

(ii) *Development trend*

White LED is an environmentally friendly, energy efficient and long life lighting products, with good prospects for development. The main restrictive factor in the white LED promotion is still t higher cost, e.g. a 7 W LED sphere bulb with the luminous flux same as that of a 40 W incandescent bulb has the manufacturing cost of about 50 yuan. Therefore, the main direction of white light LED development shall start with the basic aspects such as manufacturing equipment, dedicated

materials, packaging technology, light fixture manufacturing and mass production in a bid to further improve the luminous efficiency and further reduce product costs, allowing users to save money while saving electricity.

(iii) *Suggestions for promotion*

- a. The state shall formulate the guidance planning for industrial development and guide the LED lighting industry to develop in the right way.
- b. Government of different levels shall stimulate the innovative enthusiasm of the enterprises with all kinds of projects of science and technology and encourage the joint development of production and research so as to make China's LED lighting technology keep up with the pace of world development.
- c. The initial stage of any emerging strategic industries is inseparable from the government promotion, which requires governments of all levels to provide support through the demonstration project, product subsidies and such forms.
- d. Establish relevant product standard to standardize and coordinate the relationship between the producers and the users.

2.2.3.2 Smart Grid

(1) Overview of Smart Grid

Smart grid, or SPG is an intelligentized electricity network using digital technology, also known as "Power 2.0," which is based on an integrated and high-speed two-way communication network. By the application of advanced technology in sensing and measurement, equipment, controlling methods and decision support system, it achieves the targets of being reliable, safe, economic, efficient, environmentally friendly and safe in use. Smart grid features self-healing, consumer motivation, attack resisting, higher quality power it provides to meet consumers' needs in the twenty-first century as well as power generation options which accommodate different forms of power generation connected to grids, besides, it enables electricity market to flourish and optimizes the assets while minimizing operations cost. The structural diagram of the smart grid is shown as Fig. 2.97.

Smart grid includes intelligent scheduling system that has priority to the access to clean energy, smart metering system with dynamic pricing and intelligent technology systems which optimizes load balancing by adjusting the power generation and electric equipment power. Power flows from the intensive generation stations to grid and from distribution network to the users. Meanwhile there are all sorts of forms of new and clean energies in the electric network, such as solar energy, wind energy, fuel cells and electric vehicles, etc. In addition, high-speed and two-way communication system achieve the information exchange between control center and network devices while advanced analytical tools and decision-making system ensure the security, stability and optimized operation of the smart grid. Figure 2.98 shows the overall planning of intelligent power distribution network.



Fig. 2.97 Smart grid structural diagram

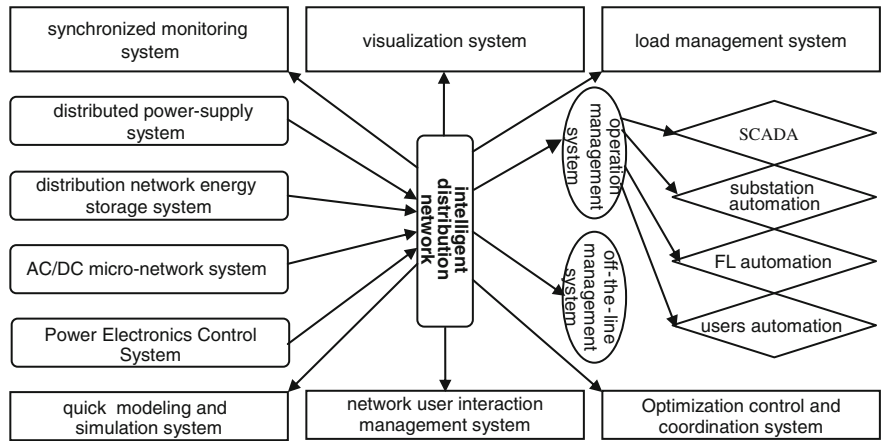


Fig. 2.98 Overall planning of intelligent power distribution network

Since the twenty-first century, the electric power construction in China has undergone rapid development: the installed capacity and electric energy production have been growing continuously and the electricity structure adjustment and technology upgrading have made certain achievements. With the power network scale expanding unceasingly, the power transmission capacity and voltage class being constantly enhanced and the network architecture strengthened, we have initially realized the aim of nationwide power networking. At the same time, we have also made great progress in the development of new energy generating technology. The project of upgrading urban and rural power grids has made remarkable achievement and the reform of the electricity market has achieved initial success. Nevertheless, there still exist the following problems:

- (1) Although the power generating capacity has increased greatly, it still relies on the traditional thermal power as its energy source and the power supply

structure requires urgent adjustment and optimization, which is mainly manifested in the following factors: the insufficient quick adjustment ability of power supply, the unbalance in regulating the peak and off-peak period of the power grid; the immaturity in integrating various kinds of new clean energy into the grid.

- (2) The construction of ultra-high voltage power grids is still in its infancy, with the planning, designing, construction, running, control and some other aspects of extra-high tension line still not developed into a standard system in technology. The synchronism of regional power grids has not been fully realized, the technical means for dynamic monitoring, evaluation, diagnosing, and assisting policy-making of large power network is still not effective, the flexible alternating current transmission technology waits for further application. All the above factors restrict the flexibility of power grid control method, and weaken the disaster response and restoring capability of power transmission network in some extent.
- (3) The grid structure of the distribution network is relatively weak. This is mainly shown in the following: the power supplying ability of the distribution network in some cities is insufficient, the automatic coverage rate of the distribution network remains low, the electricity telecommunication equipment is backward, the losses of the distribution network is excessively high, the problem in power supply reliability and electrical energy quality remains severe. Moreover, the relevant technological and management system demands perfection urgently, the distribution network's bidirectional interactive support for the user is still insufficient and the research on the application of micro electrical network technology is still not mature.
- (4) The load development is not balanced and the informationization degree differs greatly in different areas. The current electrical energy measurement mainly focuses on the electricity bill computation, resulting in an inadequate fineness for the collection of the user's measurement data as well as insufficient in-depth application of these data. The equipment and management level of the urban and rural grid and its directional interaction with the user is not sufficient enough to satisfy the demands of the modern power grid.
- (5) Influenced by the industrialization and urbanization process as well as the improvement of people's living standards, the energy load will continue to grow, thus requiring the further transformation of city power network. Moreover, with the electricity-powered cars and energy-storing equipments being combined into the distribution network, the type and nature of load is also undergoing some change.
- (6) Although the overall technical level of the transformer substation automation system is relatively advanced, its comprehensive utilization efficiency has not been fully realized. The pilot of the digitalized substation has been finished, but has not been widely promoted.
- (7) The construction of advanced dispatch center has started, yet further research is still needed in the operation and control of interconnected UHV power grid, the real-time monitoring and pre-warning of the operating state, the

coordination of dispatching planning and the coordination control of the whole and regional power grid.

- (8) The development of China's electric power communication is unbalanced. In the field of power line communications, we have realized on the whole the application of optical fiber in electric lead passage and the establishment of a data transmission network, and have successfully built a nationwide network of power integrated communications services, but the distribution network is still lack of reliable, economic and practical way of communication.

China has conducted relevant research in the construction and operation management of modern power grid construction and put it into practice, thus providing solid technical support and equipment guarantee for the construction of a unified, strong intelligent power grid. Pilot work on smart grid has already been started. Development on the basic platform of integrated smart grid scheduling-based technical support system has been completed; large customer load management and low voltage power carrier concentrated meter reading system has been taken into application in about 9 million households, research of Power Data Collection System has been in full swing; We have launched the construction of a high-level control center, a unified information platform as well as the pilot program of a user-oriented smart grid. In terms of large-scale renewable energy grid and distributed energy storage, we have carried out in-depth researches of certain key technologies such as the monitoring of PV power generation and grid-connection control, established the simulation platform for the integration of wind power into the power network, set up relevant criteria such as the technical regulation for integrating the wind power substation into the power system, and conducted basic research in frontier topics such as electrochemical energy storage.

Traditional power system includes four sections: generation, transmission, distribution and utilization. The future power system, however, will be intelligent, distributive, visual, controllable, automatic, clean and customer-centered. In the side of power generating, there will be more and more new energy source involved, such as solar power, wind power, energy storage device for large power grid. In the side of the user, there will be distributed energy, micro-network technology, etc. After the application of intelligent power meters, the users will become the supplier of electrical energy instead of just a pure user. Many large commercial users or industrial users will also become managers of the electrical energy.

These changes brings new concept for power systems in the future. Smart grid focuses on power delivery, asset management and customer experience. By using sensor technology and digital communication to manage massive grid data, it makes the power grid visible, controllable, and automatically integrated, thus enhancing reliability and reducing operating costs. At the same time, it can meet the requirement of new energy, distributed electricity power and power storage and reduce the negative impact on the environment.

Whether in the current situation or future development of the smart grid in our country, the integration of new energy and clean energy generators into the power generation system will exert deep influence on the current power supply structure.

The transmission system mainly covers such aspects as wide dynamic monitoring, real-time online alarming, fault diagnosis and analysis, etc. The distribution system mainly includes upgrading of the distribution network's voltage class, synchronous detection of the distribution network, visualization and load management system, fast simulation system and the optimal control and coordination systems; the user system mainly focuses on intelligent marketing system, smart metering system and user's optimization management system; the load system mostly includes the development of new energy storage devices, access of distributed power source, design of user-friendly electrical appliances and the research and development of new electric cars. The construction of intelligent substation is a combination of technologies such as intelligent network communication, information sharing and integration and intelligent real-time protection system; the intelligent dispatching center relies on the visualization technology, coordination and optimization technology of operation, intelligent pre-warning control and scheduling safety technology to realize the optimization, coordinated operation and safe scheduling of the power grid.

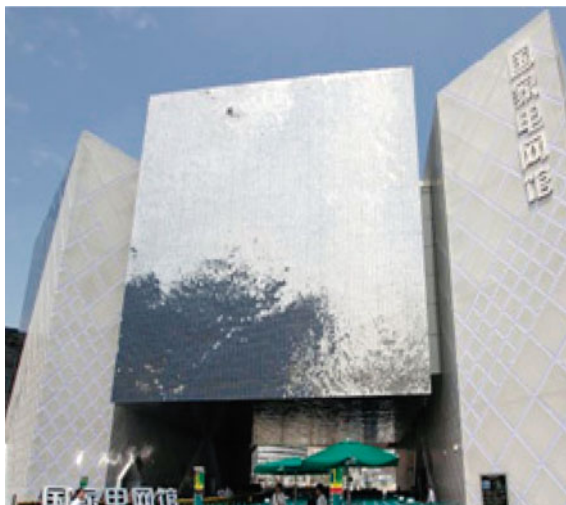
To conclude, the development of China's smart grid requires scientific planning of the development layout of the power grid. We should lay emphasis on both development of distributed power and the construction of large energy base, and combine the construction of ultra-high voltage transmission grid with the upgrading of distribution networks, the dynamic monitoring management of the whole network with the development of new energy storage devices, the intelligent transformer substation with the construction of integrated dispatching center and information collection system of power grid, so as to achieve the goal of secure, safe-healing, compatible, efficient and high-quality operation of grid in China.

(2) Application of Smart Grid Technology in the Shanghai Expo

It is known that the smart grid applied in the Shanghai Expo is the first demonstration project of its field in China. This smart grid project includes 9 sub-projects, which include new energy access (East China Sea Bridge wind farm, Chongming solar PV, solar PV Expo venues), energy storage systems, intelligent substation, distribution automation, troubleshooting management system (TCM), power quality monitoring, electric information acquisition, intelligent buildings and intelligent home electric, electric vehicle charging and discharging and connecting into the grid. A number of records were set in this project, including 650 Ah sodium-sulfur battery with world's largest single capacity, China's first electric vehicle charging and discharging station, China's first set of TCM in the power industry. The East China Sea Bridge Offshore Wind Farm (100 MW) is Asia's first grid-connected offshore wind power project and Shanghai Chongming Island Vanguard Village PV power plant (1 MW) is the first PV feed-in demonstration project in China.

The Expo smart grid demonstration area included nine model projects and four demonstration projects. The nine model projects were contained in the smart grid of the Expo and four demonstration projects were open to visitors who could to learn the smart grid closely and visually at multi-angle. Especially in the basement of the

Fig. 2.99 State Grid Pavilion in the Expo



State Grid Pavilion (Fig. 2.99), through the large glass windows, visitors can see how a 110 kV substation operates. As the first Intelligent Substation served for the Expo, known as the “heart of energy” of the Expo Puxi site, all processes such as information collection, transmission, processing and output adopted digital and intelligent workflow after it was put into operation.

Four large PV power stations in the Expo Park corresponding to China Pavilion, Theme Pavilion, Expo Center Pavilion and the Pavilion of Future were connected to the grid, with the total capacity of 4.687 MW, of which the Theme Pavilion had a PV generating capacity of 2,825 kW, becoming the largest single BIPV power station in Asia. During the World Expo, the generating capacity in Shanghai from grid-connected clean energy reached 146.4 MW, including 139.4 MW by wind power, 7 MW by PV power, which can provide one-third of electricity consumed in the Expo site.

For the demonstrated electric vehicle charging and discharging stations and the interactive system between electric vehicles and the grid in the Expo area, the controlled two-way flow of energy can be achieved between the electric vehicles and the grid. Dynamic response can be obtained based on the grid running condition and the control command, which displayed the application potential of electric vehicles as distributed mobile energy storage.

The significance of constructing a smart grid demonstration area in the Expo site is to promote the concept of energy-saving and facilitate the application of relevant high-techs. The smart grid technology, with ultra-high voltage grids as its main frame, greatly helped the intensive development, long-distance transmission and highly efficient utilization of those clean energies like wind power and solar power, so as to achieve the standardization of distributive powers, power storage devices and the connection of power devices to grids as well as to achieve the intelligence of grid operating controls. At the same time, it greatly reduced the power loss in the

long-distance transmission and therefore occupied a commanding height of the new economic growth.

It's a good start for smart grid in the Expo to withstand the test of high temperature, thunder and lightning. It's expected that by 2020, in a strong smart grid scenario, the power loss of the whole society can be reduced by 18.95 billion Yuan.

(3) Suggestions on Smart Grid Technology

According to statistics of China Electricity Council, in 2008, China's total investment in electricity infrastructure was 576.329 billion Yuan, an increase of 1.52 % year on year, among which investment in power source was 287.873 billion Yuan, down by 10.78 % year on year, the amount of power grid investment reached 288.456 billion Yuan, an increase of 17.69 % yoy. The proportion of the power grid infrastructure investment reached 50 % of the total electric investment for the first time. At the same time, with the help of 4 trillion investment plan in 2009, the construction of power grid will be the focus of investment in the future, with the proportion of grid investment expected to increase by 10 %. But the proportion of smart grid is also rather small.

The National Grid recently announced for the first time the phase targets of smart grid, as follows:

- ① 2009–2010—planning and pilot phase. During this period, focus on establishing smart grid development plan, formulating technical and management standards, conducting research and development of key technologies and equipment as well as pilots in various stages.
- ② 2011–2015—overall construction phase. During this period, the construction of ultra-high voltage power grid and urban-rural distribution network will be speed up to achieve the initial formation of the smart grid system operation control and interactive services, and to make major breakthroughs and wide applications of key technology and equipment.
- ③ 2016–2020—lifting phase. The aim at this stage is to establish a unified fully integrated smart grid, ensuring that the resource allocation capacity, safety level and operating efficiency of the grid and the interactivity between the grid, power supply and users will increase significantly, with technology and equipment reaching the international advanced level.

2.2.3.3 Non-electric Air-Conditioning Technology

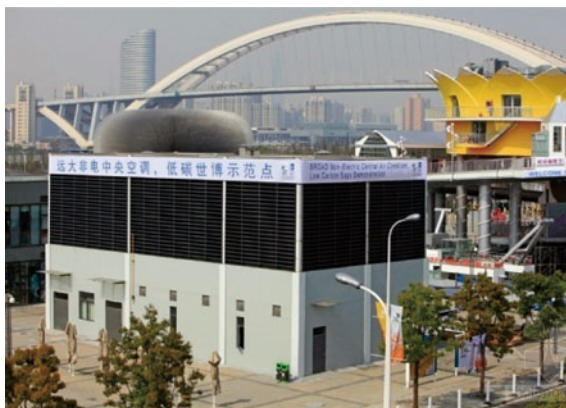
(1) Introduction to Non-electric Air-Conditioning

Non-electric air-conditioning is to achieve refrigeration directly with thermal energy. Traditionally, a cooling process of an electric air-conditioning has to go through a series of energy conversion process from thermal to mechanical energy, then to electric energy, and finally back to mechanical energy before the cooling is made. The five energy conversions involved in this process inevitably results in energy loss, and the amount of carbon dioxide emissions from coal-powered

Fig. 2.100 Non-electric air conditioning unit in Broad Pavilion



Fig. 2.101 Broad non-electric air conditioning unit used in the Expo site



air-conditioning are five times as large as that of the non-electric ones. Therefore, non-electric air-conditioning can not only save primary energy, but also effectively reduce the carbon dioxide emissions by four times. To sum up, the feature of a non-electric air-conditioning is it is powered by natural gas, waste-heat power, or solar energy instead of electricity and that makes it the cleanest air-conditioning.

(2) Applications of Non-electric Air-Conditioning in the Expo

It is reported that Broad Non-electric Air-conditioning has been applied in all the pavilions in the Shanghai Expo (Figs. 2.100 and 2.101). Besides, the world's leading energy-saving mode of air-conditioning was introduced. 22 energy centers was built in the Expo site, with 14 in Pudong and 8 in Puxi, distributed in each area to provide air-conditioning service for over 200 pavilions, resulted in the reduction of 73,000 tons of CO₂ emissions, equal to the amount absorbed by 4 million trees in half a year, or the forest coverage of 8 Shanghai World Expo sites. By doing this, the Shanghai Expo met its goal of being a "Low-Carbon Expo" in a real sense.

(3) Promotion of non-electric air-conditioning technology

In addition to the difference that non-electric air-conditioning uses natural gas as the energy source, a non-electric air-conditioning uses lithium bromide as the refrigerant instead of Freon. Lithium bromide is a kind of saline material extracted from seawater, with good water absorption. When heated, lithium bromide solution will release vapor, which will be condensed into water, which is sprayed over the copper tubes for cooling. This is how cooling is made. Water takes away the heat of the air conditioning system and becomes vapor again, which is absorbed by lithium bromide solution, and the diluted lithium bromide solution is heated and water vapor is regenerated to repeat this cooling cycle. Non-electric air-conditioning is not completely free from the use of electricity, but its consumption of electricity is only 10 % as much as that of the common electric air-conditioning.

For most of us, non-electric air-conditioning is new term. At present, the majority of people are taking a wait-and-see attitude in deciding whether to give up the traditional air-conditioning and use a non-electric one. The reasons for this hesitation are the traditional air-conditioning is more convenient and technically mature. Anyway, people need time to accept new things. Another reason is the concern for the costs.

The key factor in popularizing the non-electric air-conditioning into thousands of households lies in the change of people's concepts. In spite of its higher cost than traditional air-conditioning, non-electric air-conditioning will save much more electricity from the perspective of the whole society. In addition to the electricity bills it saves, the application of non-electric air-conditioning will reduce carbon emissions, and thus reduce the potential costs of the nation's environment management and dealing with the side effects caused by environmental deterioration. However, it takes time for people to foster a low-carbon concept of environmental protection. Therefore, there will definitely be a long way ahead before every one can abandon his or her old lifestyle and embrace the new lifestyle of low-carbon.

2.3 Low-Carbon Transportation

2.3.1 Low-Carbon in Transportation

2.3.1.1 Introduction to Low-Carbon Transportation

The low-carbon transportation includes three parts: control of the pavement noise, increase of the driving skill and the road material improvement.

In terms of driving technique, one must have good driving habits, make slow acceleration when starting, maintaining a smooth driving on the road, with stable and smooth movements. And a correct judgment on the traffics on the road is necessary. Second, pay attention to maintain a good condition of your car, including warming up the vehicle properly before driving it, accelerate after stable driving

1–2 km and regular cleaning air filter, ensure that the vehicle is in good condition and therefore be fuel-efficient.

Try to use public transport as much as possible. More walking, bicycle riding or light railway and subway, and less drive.

Low-carbon road involves three aspects: the first is to improve the quality of road construction and road management so as to extend the service life of the road; Second, to develop low-carbon construction and the road surface materials; third, to recycle the waste road materials.

2.3.1.2 Application of Low-Carbon Transport in the Expo

The application of low-carbon transport in the Expo is mainly reflected in the road material. 60 % of the city demolition wastes are used as the road materials, which turned the waste into things of value while putting low-carbon concept into practice.

2.3.2 New Energy Vehicles

2.3.2.1 Introduction

The *Management Rules for New Energy Automobile Manufacturing Companies and Product Access* (the Rules) was carried out officially on July 1, 2009. The Rules emphasizes that new energy vehicles use unconventional fuels as a power source (or use conventional fuels but apply new car power plant). By integrating the advanced technology in vehicle's power control and drive, these cars are made with advanced technical principles featuring new technology and new structure. New energy vehicles include Alternative Fuel vehicles (AFV), Hybrid electric vehicles (HEV), pure electric vehicles (PEV) and solar vehicles. AFV further consist of Methanol Fuel vehicles (MFV), Compressed Natural Gas Fuel vehicles (CNGV) and hydrogen engine vehicles.

With the increase of the vehicle population in China, the proportion of demand for petrol and diesel consumed by vehicles is rising. It is estimated that, by 2020, the petrol needed by vehicles will account for over 50 % of the total oil consumption. Therefore, in order to ease the pressure in oil import and environmental protection, it is of great significance for us to advance the research and promotion of fuel cell vehicles.

(1) Alternative Fuel Vehicles

At present, there are mainly two types of alternative fuel cell vehicles. One is direct fuel cell vehicle (DFCV). In the cell of DFCV, the fuel, which could be hydrogen or methanol, will be oxidized directly by electrochemistry. Another is called processed fuel cell vehicle (PFCV). In the system of PFCV, the fuel, which could be gasoline, methanol or propane, will be first converted to hydrogen by means of a fuel processor. Then the hydrogen will be conveyed to the cell to generate electricity. Currently what has attracted more global concern is the

PEMFCs that directly use hydrogen as its fuel, and there are more successful examples both in the lab and in application.

Methanol vehicles use methanol fuel as the power instead of petroleum fuel. This kind of vehicles has been applied in other countries for years and very mature in its control system technology. In recent years, due to the shortage of petroleum resource and the intensified diversification of automobile fuel, methanol vehicles again have been listed as one of the major alternatives.

Compressed Natural Gas (CNG) vehicles use CNG, Liquefied Petroleum Gas (LPG) and Liquefied Natural Gas (LNG) as the fuel. For the past few years, governments of different countries all have actively been seeking to solve this problem and started to adjust the automobile fuel structure. Because of its good performance in discharge, ability to adjust automobile fuel structure, low operating cost, mature technology and stability, the CNG vehicles are universally acknowledged as the optimal AFV.

Hydrogen Fuel Cell Vehicles use hydrogen as the fuel; in fuel-cell conversion, the hydrogen is turned into electricity through chemical reaction which then powers electric motors. The energy of the cell is generated via the chemical action between hydrogen and oxide instead of combustion and directly converts to electric energy. This process produces no hazardous substance thus hydrogen fuel cell vehicles are pollution-free automobiles. Since the energy conversion efficiency of hydrogen fuel cell is 2–3 times higher than internal-combustion engine, hydrogen fuel cell vehicles are the ideal ones on the aspect of energy utilization and environmental protection. At present, the most attractive application orientation for hydrogen fuel cell is to be the power supply for low-discharge and diversified electric automobiles. Large automobile manufacturers like Toyota, Honda, General Motors and Daimler Chrysler have successively made tremendous investments in developing hydrogen fuel cell vehicles. Take General Motors for instance, it has made the investment of 1 billion US dollars in a research and develop project of Cell Electric Automobile. Although the manufacturers are enthusiastically hoping that hydrogen fuel cell vehicles will enter the market within a few years, none of them actually reaches the stage of commercialization. Constrained by various conditions, problems in the hydrogen fuel cell vehicles are as follows:

- As the main fuel for the cells, Hydrogen (H_2) does not exist solely in the natural world and difficult to be transported. Therefore, it is widely acknowledged that the preparation and transportation of hydrogen can be the biggest problem in promoting this technology.
- Currently, the hydrogen cells have to be catalyzed by a large amount of platinum, which is a kind of the precious metal and is limited in its reserves. Based on the researches at the moment, the amount of platinum utilization cannot drop in a short period. This is also a technical problem that we have encountered.
- The manufacturing cost for hydrogen fuel cell is relatively higher so that ordinary clients may hardly afford it. Take the unit power cost of the engine for example, the current cost of fuel cells is about US \$500 per kW, while the cost

of internal combustion engine is only US \$11–27 per kW. The cost of utilization at present is unbearable for most people thus becoming another problem.

- Suppose that fuel cells will replace the internal combustion engines in the future, all the combustion engine plants will have to be closed. This indicates that promoting fuel cell vehicles on a large scale requires an adjustment and a new overall arrangement in a wide scope. The replacement could affect not only gas station worldwide but also many industries such as petrochemical industry, power industry, machinery industry and electronics industry. It will negatively affect those industries while create some new opportunities and finally generate a huge impact on the world political and economic structure.

(2) Hybrid-Electric Vehicles

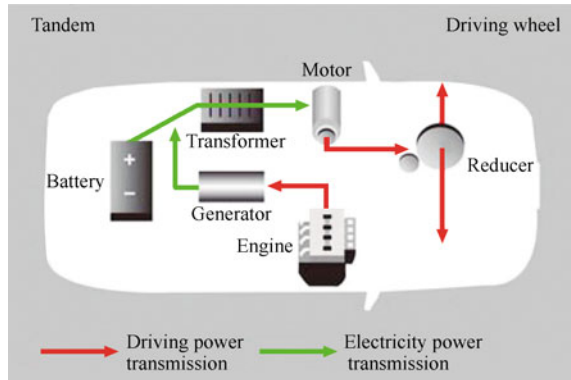
HEV refers to vehicles that consume traditional fuels and are supported by motors/engines to improve low rates of power output and fuel consumption. Based on different fuel types, HEVs can be divided into gasoline hybrid-vehicles and diesel hybrid ones. At present, the former dominates the domestic market, while the latter are also developing fast in the international market. Figure 2.102 shows the working mechanism of a tandem hybrid electric vehicle.

(i) Historical development

Currently, the commonly used fuel-driven motor vehicles have many demerits. The statistics show that on more than 80 % of roads, an ordinary car only uses 40 % of its power capacity. In urban areas, the figure will even fall to 25 %. More seriously, its emissions will pose threats to the environment. Since the 1990s, the call of world for environmental protection has been growing louder and a variety of electric vehicles have been emerging. Although it is generally believed that electric vehicles will dominate the future vehicle market, problems with the current battery technology have hindered the use and spread of electric vehicles. As the power density of battery is about a hundred times less than that of gasoline, which is far from the required value, experts estimate that within 10 years electric vehicles will not replace fuel electric ones (unless there is a major breakthrough in non-fuel battery technology).

Engineers have been forced to develop a vehicle called HEV, which combines merits of both hybrid and electric vehicles. The so-called hybrid-electric device refers to the combined application of a motor and an APU to one car as the driving force; the APU is a small fuel engine or a set of electric generators. To put it simple and vivid, engineers try to make the conventional engine smaller so that part of the power can be generated by the battery-motor system. This device not only gives a full play to the traditional engine that can work continuously for long hours and function well in terms of power generation, but also has the advantages of the electric motor that is pollution-free and producing little noise. Both are mutually collaborative and supportive, and therefore the thermal efficiency of the vehicle can increase by more than 10 % and its emissions can be reduced by more than 30 %.

Fig. 2.102 Working principle of hybrid electric vehicle



(ii) Advantages

- a. With the hybrid-electric power, we can determine the maximum power of the combustion engine according to the power acquired in daily use. At this point, the engine is working with low fuel consumption and less pollution. If the power generated by the high-power internal combustion engine is less than required, the battery can provide the rest. When the load is low, the surplus power can generate electricity to charge the battery. The internal combustion engine can work continuously and the battery can be charged simultaneously, so the HEVs can travel as far as the ordinary ones.
- b. With the battery, it can be very easy to recollect the energy generated in the operations of braking, going to the downhill and idling.
- c. In the downtown areas, we can shut down the internal combustion engine, so the vehicle will only be driven by the battery so as to achieve “zero” emissions.
- d. With the internal combustion engine, it can be very convenient to solve problems encountered by PEV, such as the energy-consuming air-conditioning, heating, defrosting, etc.
- e. The vehicle can be refueled in existing gas stations on which there is no need to invest more.
- f. The battery can work in good condition without such problems as over-charge and over-discharge, so its life can be prolonged and costs reduced.

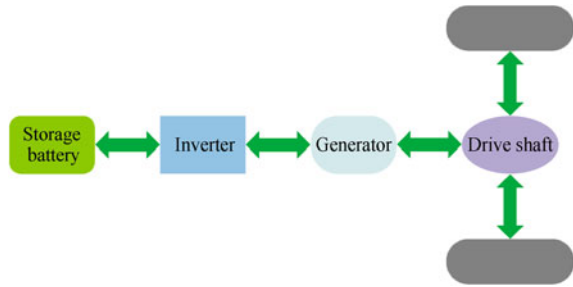
(iii) Disadvantages

Basically, it can not save fuel in long-distance travel with a high speed. That is to say, its energy saving effect is not obvious.

(3) **Pure electric vehicles**

Electric vehicles are those mainly driven by electric power (super capacitor vehicles belong to this category as well). Most vehicles are directly driven by electric engines; with some, electric engines are installed in the engine compartment; there are still some that have their wheels as the rotor of the four engines.

Fig. 2.103 Schematic diagram of a pure electric vehicle



The difficulty lies in the electricity storage technology. The fact that the electric power can be obtained from a variety of primary energy resources such as coal, nuclear, water, wind, light, heat, etc. can lift people out of an increasing concern over the decreasing oil resources. Figure 2.103 shows the schematic diagram of a pure electric vehicle.

Advantages: Electric vehicles can make the best use of surplus electric power in the off-peak hours in the evening, so that the power generation equipment can be used throughout the whole day, thus bringing great economic benefits. Research shows that when the crude oil undergoes the process of being refined and sent to the power plants for generating electricity which is then charged into the battery to drive the battery-powered vehicles, it has a higher energy utility efficiency than the same crude oil that is refined into gasoline which is consumed in the engines to drive the vehicles. Therefore, it helps greatly save energy and reduce carbon dioxide emissions.

Disadvantages: At present the energy stored per unit weight of the storage battery is fairly low, due to the high price of batteries for electric vehicles and no economic scale, the vehicles are expensive. As to the cost to use, some trial results show that electric vehicles cost more than ordinary ones, while some cost only 1/3 of the ordinary vehicles, which depends on the service life of batteries and prices of local oil and electricity.

(4) Solar vehicles

Solar vehicles are a type of vehicle powered by solar energy (Fig. 2.104). Compared with the traditional engine-driven vehicles, solar vehicles have truly achieved zero emissions. Due to its characteristics of environmental friendly, it has been advocated and promoted in many countries around the world, leading to the booming of the solar vehicle industry. With the solar energy vehicles, photoelectricity replaces oil gasoline to provide the needed power so as to save the limited oil resources. In the daytime, the solar batteries transform the solar energy into electricity that is automatically stored in the power batteries. At night, the batteries can be charged making use of the off-peak hours (220 V). So far, solar energy technology applied in vehicles includes two aspects, one is as the driving force and the other is used as the source of energy for the vehicle supplementary devices.

Fig. 2.104 Solar vehicle

The advantages of the solar vehicle are that it produces no noise or pollution. As solar vehicle does not consume gasoline, no harmful gas is discharged into the atmosphere. Also because it does not install internal combustion engine, no rumbles from the working engine of a traditional vehicle will be heard. A solar vehicle is simple in structure with no such parts and components as internal combustion engine, clutch, mechanical transmission, transmission shaft, radiator and exhaust pipe. As a result, it is easier to manufacture than traditional vehicles.

2.3.2.2 Application of New Energy Vehicles in the Shanghai Expo

Numerous clean energy bus lines were available in and around the Expo site, which corresponded with the goal of “zero emission inside the Expo site and low emission in the neighboring area.” The hydrogen refueling station replaced the traditional gas station to serve the clean energy vehicles. The number of such vehicles actually applied amounted over 1,000, including ultra capacitor vehicles, fuel cell vehicles, PEV, hybrid vehicles, and solar vehicles, etc.

(1) Applications in the Expo Site

Figure 2.105 illustrates the amount of different new energy vehicles applied in the Expo Site.

Various kinds of new energy vehicles serving as the shuttles took visitors to any part in the Expo site and across the Huangpu River. As one of the first experimental cities in promoting and demonstrating the energy-saving and new energy vehicles, Shanghai has cooperated with the National Science and Technology Department to carry out the demonstrational operation involving 1,017 various kinds of new energy vehicles during the Expo.

New energy vehicles applied in the Expo site are classified as: sightseeing, garbage collection, patrol, public transport, VIP reception, etc. See below the pictures of different types of vehicles in Figs. 2.106, 2.107, 2.108, 2.109, 2.110, and 2.111.

The electric vehicles are also equipped with special charging station (pillar). The most common ones seen in the Expo Site are the charging stations for electric

Fig. 2.105 New energy vehicles in the Expo by classified statistics

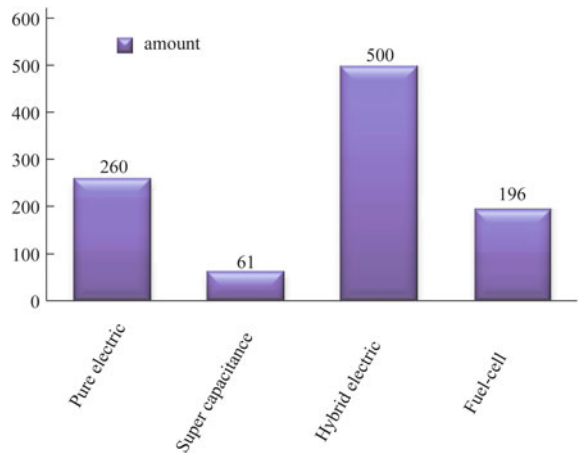


Fig. 2.106 Ultra-capacitor bus in the Expo site



Fig. 2.107 Fuel cell sight-seeing cars



Fig. 2.108 VIP reception car with hybrid electric system



Fig. 2.109 Pure electric car between pavilions



Fig. 2.110 Cleaning truck with full-electric system



cleaning trucks (Fig. 2.112) and 5 kW AC charging stations for electric cars (Fig. 2.113). Such charging stations have an output voltage of 220 V AC, with a maximum current of 22 A. It has the following features:

Fig. 2.111 Four electric patrol car in the Expo site



Fig. 2.112 Charging station for electric cleaning truck



1. It is easy to operate; 2. It is flexible in choosing the charging method; 3. It can cater to the need of commercial operation, with self-lock device and emergency stop button, the charge can be finished unattended; 4. It can ensure charging security due to its function of electrical connection confirmation with the vehicles; 5. It can indicate information about voltage and electric current and mode during charging.

(2) Demonstrations in the pavilions

The information of different types of new energy vehicles displayed in the pavilions is shown in Table 2.6.

Figure 2.114 shows Roewe E1 electric mini-car displayed in China Pavilion. Figure 2.115 shows Smartfortwo electric car exhibited in Switzerland Pavilion.

Fig. 2.113 5 kW AC charging station for electric vehicles



Table 2.6 Different types of new energy vehicles displayed in the pavilions

Pavilions	Types	Features
Switzerland Pavilion, Pavilion of Urban Planet, Austria Pavilion	Smartfortwo Electric cars	Electro-motor of 40 hp,a max speed of 100 km/h
Japan Pavilion	Pure electric vehicles	Pure electric-driven, Toyota RAV4, estimated to be launched on the market in 2012
Portugal Pavilion		METROBuddy mini pure electric vehicle, continuous travel distance is120 km
France Pavilion		This pint-sized car is only 2.5 m long, which can hold four people
Sweden Pavilion	Volvo hybrid vehicles	Parallel hybrid technology
Monaco Pavilion	VenturiVolage latest high-end concept car	Electric vehicle, Quattro technology plus active suspension technology
China Pavilion	Roewe E1 mini electric car	

Figure 2.116 shows Toyota pure electric car displayed in Japan Pavilion. Figure 2.117 shows Buddy mini pure electric car in Portugal Pavilion. Figure 2.118 shows Volvo Hybrid electric City bus displayed in Sweden Pavilion.

Fig. 2.114 Roewe E1 electric mini-car displayed in China Pavilion



Fig. 2.115 Smartfortwo electric car exhibited in Switzerland Pavilion



2.3.2.3 Review and Analysis of New Energy Vehicles Application in the Expo

The quick charging device installed on the top of the super capacitor bus in the Expo site takes advantage of the interval when passengers get on and off the bus to complete its charge. According to the vehicle maintenance engineer, it only takes about 2 min to finish the charge which can sustain its driving for 3–5 km.

At the beginning of the Expo, there were altogether 36 super capacitor buses, 120 electric cars and 70 fuel cell sightseeing cars put into use in the Expo site for

Fig. 2.116 Toyota pure electric car displayed in Japan Pavilion



Fig. 2.117 Buddy mini pure electric car in Portugal Pavilion



Fig. 2.118 Volvo hybrid electric City bus displayed in Sweden Pavilion



trial operation. However, as the number of passenger increased, more cars were needed. The organizer was quick in responding to this issue, on one hand, they continued to put more new energy automobiles into use, on the other hand, they brought together over 10 suppliers specializing in the research and development of pure electric automobiles to solve a lot of technical problems in a joint effort. As hot season arrived, nearly a thousand of such new-energy automobiles have passed the preliminary test posed by hot days, with a serviceability rate of 99.73 %, and work ratio of 99.59 %.

With thousands of new energy vehicles running in the Expo site, it is estimated to save about 10,000 tons of traditional fuel during the 6-month Expo. Besides, they also helped reduce the emissions of harmful substance by about 118 tons and greenhouse gases (mainly carbon dioxide) by about 28,400 tons. Among all these different types of new energy vehicles, the fuel cell car is completely free from the use of fuel, and is regarded as the trend of sustainable development of auto industry in the future and one of the most ideal solutions for the problems of global energy and global warming due to its zero emission, high efficiency and extensive fuel sources.

2.3.2.4 Current Status of New-Energy Vehicles

The key point of the new energy vehicles lies in its battery. According to a report, nickel-hydrogen batteries have taken up a 99 % market share among all the existing types of hybrid batteries, and the most commercialized is Toyota Prius. At present, the main manufacturers of automobile batteries around the world are PEVE and Sanyo from Japan. PEVE accounts for 85 % of the nickel-hydrogen batteries used in Hybrid automobiles. Currently, the main commercialized automobiles such as Prius, Alphard, Estima of Toyota, and Civic, and Insight of Honda have all adopted the PEVE nickel-hydrogen battery pack.

Speaking of the development of new energy automobiles, the Nickel-hydrogen battery is considered the most mature technology. During the next 3 years, new energy automobiles will remain as the mainstream, and after that the market will be divided among batteries of nickel-hydrogen, lithium-ion and hydrogen fuel. And in 5 years, nickel-hydrogen batteries will gradually be replaced by fuel cells. Nowadays, more and more auto manufacturers choose lithium battery for the new energy automobile. Lithium cell has the advantages of small volume, light weight, high working voltage, long life circle, zero pollution, and security, etc. Many world's well-known auto manufacturers such as Ford, Kreisler, Toyota, Hyundai, Courreges, Ventury, etc., are committed to the development of new energy automobiles using lithium cell. Meanwhile, some domestic car manufacturers also aim to develop hybrid automobiles and pure electric automobiles coupled with lithium cell batteries.

2.4 Technologies in Water Treatment

2.4.1 Water Purification

2.4.1.1 Overview of Water Purification

As most of the water bodies in the world are seriously polluted, human beings are facing increasingly shortage of water resource. Conventional water treatment method can not ensure the high quality drinking water. Moreover, secondary pollution exists in the municipal water supply, such as water tank in the high-rise, long line of pipes for tap water may cause the potential rust, scale and micro contamination. To meet the demand for clean water, various brands of water purifiers have thus been invented.

Based on the water treatment method, the purifiers are involved in the following 11 methods:

- (1) **Softening:** is to remove or reduce the hardness (mainly calcium and magnesium ions) of the water. Soften only makes water soft but can not improve water quality.
- (2) **Distillation:** it refers to boiling the water to produce water vapor. The vapor contacts a cool surface where it condenses as a liquid. Distilled water is very safe drinking water. Because distilled water contains no minerals, those who criticize it point that this may speed up the process of aging. Besides, distillation method has the disadvantages of high cost, high energy consumption and hard to remove the volatile substance in the water.
- (3) **Boiling:** an ancient purification method and widely used domestically. Water is heated hot enough and long enough to kill micro-organisms that normally live in water at room temperature. But boiling does not remove chemical substances or heavy metals in the water even the content is very low. Therefore, it's not safe for drinking.
- (4) **Magnetization:** treat water taking advantage of magnetic field effect. So far, magnetization treatment of water in China has been still in the initial stage of practice and research. There is no requirement for magnetization in the purifiers in other countries as this is not in the scope of purification but medical treatment.
- (5) **Mineralization:** is to add the beneficial mineral elements (e.g., calcium, zinc, etc.) to the purified water with the purpose of strengthen the health benefit of mineral water. The purifiers on the market normally add medical stone into the water to achieve the mineralization. But this is still controversial as for the effect.
- (6) **Ozone and ultraviolet disinfection:** They only kill the organisms but can not remove the heavy metals and chemicals in the water. The killed bacterium remains are still left in the water to become the pyrogen.
- (7) **Electrolysis and Activation:** This is a new invention in Japan. Water is purified first and then electrolyzed and activated. After this process, the water

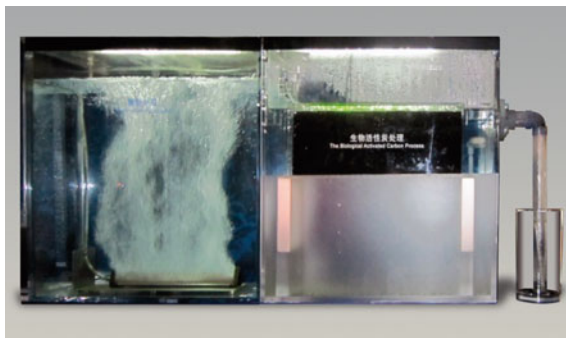
corresponds with the PH inside the body of human beings and therefore has a health function. For the purifier, the effect requires further research.

- (8) **Activated carbon absorption:** including three forms:
- Granular activated carbon: commonly used
 - Silver activated carbon combination: with the effect of both absorption of organic contaminants and sterilization.
 - Fiber activated carbon: with great microscopic bore structure, huge specific surface area and numerous functional groups.
- (9) **Reverse osmosis membrane:** a membrane separation technology. Mechanical pressure is applied to an impure solution to force pure water through a semi-permeable membrane. While pollutants are removed. Reverse osmosis is theoretically the most thorough method of large scale water purification available, although perfect semi-permeable membranes are difficult to create. This system cost much and requires much routine service, such as monitoring and membrane change.
- (10) **Microfiltration and ultrafiltration:** Microfiltration uses cellulose or high polymer material as the microfiltration membrane to hold back the particles, organisms and colloid in the water by using its uniform microscopic bore. Both microfiltration and ultrafiltration are membrane separation technology, with no distinct limit.
- (11) **Compound technology**

When one technique can hardly remove the harmful substances from the water, two or more techniques are adopted, this is called compound technology, which involves some of the above technologies. The purifiers with membrane composite technology proves to have good performance, which is very efficient in filtering out the micro organisms. Some of the quality ones are very popular among the consumers.

From the above classification of the water purifiers it is easy to conclude that household water purifier is actually a miniaturized deep water treatment device. The process consists of pre-filtration (coarse filtration), absorption, fine filtration (micro-filtration, ultra-filtration and reverse osmosis), of which absorption and fine filtration are the major means of removing the organic matter and odor and color in water. Household purifier aims at millions of households, but the current situation is, the regional water quality and water pressure vary widely, and users usually lack the necessary operation knowledge, plus the current product design can not cope with the ever-changing situation. So the water purifier manufacturers should take into consideration how to educate users with certain knowledge, proper installation and operation of water purifier, so as to achieve the desired water quality, and thus reassure the users.

Fig. 2.119 Water treatment device in Japan Pavilion



2.4.1.2 Application of Water Purification in the Shanghai Expo

Japan Pavilion exhibited a water treatment device known as MBR technology shown in Fig. 2.119, which is one of the most advanced water treatment technologies in the world. Unlike before when the reclaimed water from sewage could only be used for toilet flushing, plant watering and car-washing, this technology is upgraded to provide drinking water. Inside the Osaka Pavilion of the UBPA, tourists have an interesting experience of converting sewage into purified water by just pedaling a specially designed bicycle.

Faced with the water shortage as Japan is, Singapore has also made great efforts in water treatment. In Singapore, there are 15 reservoirs and one water-collecting system that can defend flood in case of rainstorm. With the completion of Punggol reservoir and Serangoon reservoir in 2011, the catchment area, currently accounting for half of Singapore's land, will be enlarged to take up 2/3 of the whole country's area. Now they are promoting a technology which can turn the wastewater into drinking water directly. Moreover, there is also a widespread water-saving proposal in Singapore to convince people to use water in a rational way. At present, the per capita daily consumption of domestic water in Singapore has been cut down from 165 L in 2003 to 155 L, and with an aim to lower the amount to 140 by the year of 2030.

In the happy street of Netherlands Pavilion, the world's smallest water purification system is displayed (Fig. 2.120). It is about 1 m wide and 2 m high. Though the activated carbon technology, it can produce the highest-level drinking water, and serve the tourists with its purified water, the source of which is from Huangpu River.

Norway Pavilion exhibited a solar-powered water purification device (Fig. 2.121), which converts the contaminated rain water into the safe purified drinking water. This device can remove all the contaminants in the water, including bacteria, viruses, parasites and so on. In the purification process, no environmentally hazardous substance is used. The system can be loaded into the standard-sized containers for transport.

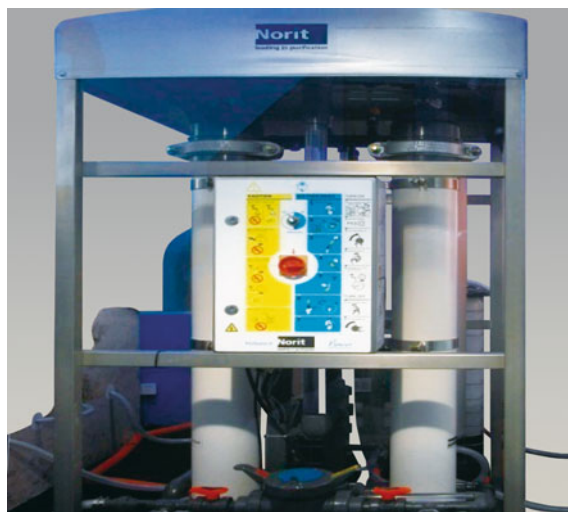


Fig. 2.120 Water treatment device in Netherlands Pavilion

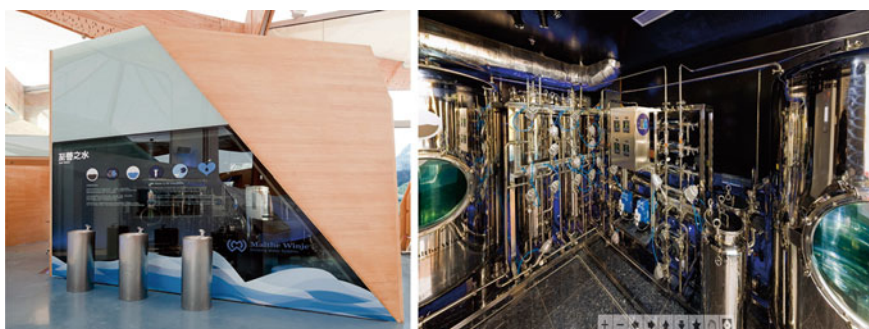


Fig. 2.121 Water treatment device in Norway Pavilion

At present, the drinking water supplied in the Expo site is the direct drinking water system independently developed by our own country, which uses the “Activated Carbon + PVC (polyvinyl chloride) alloy ultrafiltration membrane + UV” combination treatment technology. Among the multiprocessing procedures and over 200 criteria, membrane technology has the highest technical content. Besides, the recycling project for domestic water and rainwater in Pavilion of Future, with a scale of 120 tons per day, adopts the world’s advanced alloy ultrafiltration membrane bioreactor. The device has a very high performance and price ratio, with an annual water treatment capacity of over 40,000 tons. All the reclaimed water after treatment is used for toilet flushing and plants watering. Figure 2.122 shows the water purification device in the Expo. Figure 2.123 shows the cup cleaner water-saving toilet in United Nations Pavilion.

Fig. 2.122 Drinking water purification device in the Expo site

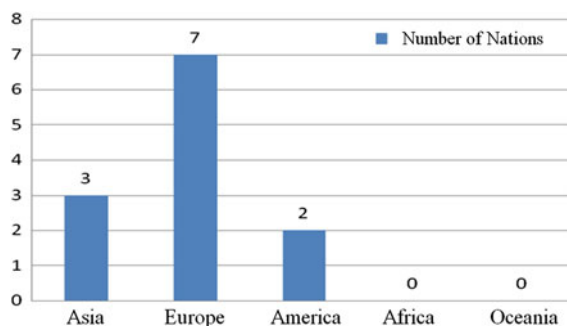


Fig. 2.123 The cup cleaner water-saving toilet in United Nations Pavilion



Water saving and recycling is another theme of the World Expo. The sanitary ware and irrigation equipment are all water-saving devices. The permeable floor in the Expo site can effectively reduce the runoff and pollution efflux to the pipe network of urban rainwater. The permanent pavilions such as Expo Center, Performance Center, Theme Pavilion and China Pavilion, together with the Expo Axis have all resorted to a roof rainwater utilization system, by which the rainwater and sewage collection and processing rate can reach a full 100 %, with an estimated water-saving amount of over 1 million m^3 . Figure 2.124 shows water treatment application in the Expo site (statistics by continent).

Fig. 2.124 Water treatment application in the Expo site (statistics by continent)



2.4.2 Rainwater Treatment

2.4.2.1 Brief Introduction

Rainwater treatment is the purification process for Surface runoff water in the urban area (rainwater, snow water and irrigating water). Based on the different pipe system drainage system (separate or confluent system), rainwater treatment can be processed independently or combined with the domestic sewage and industrial wastes. When treated independently, the rainwater catchment and sedimentation pond is needed, with grilling in front and filter pond in the back. Water flow rate in the pool should be less than 0.01 m/s, for a period of not less than 1–2 h. After treatment, the biological oxygen demand (BOD) can be reduced by 50–70 %. In the latter case (combined treatment), the water amount in the grilling and sand setting pond is calculated based on the total amount of water. The residence time in the sedimentation pond shall not be less than 1 h. If the rainwater after treatment is used for as the industrial circulating water, the processing requirement should be calculated by the circulating water. The discharge port can be placed on the water bank as needed.

2.4.2.2 Rainwater Treatment Application in the Shanghai Expo

(1) Collection and Application of Roof Rainwater

Located in the core area of the Expo, the four permanent pavilions like Expo Center, Cultural Center, the Theme Pavilion and the China National Pavilion, together with the Expo Axis and Shanghai Corporate Pavilion, have all engaged in the collection and application of roof rainwater.

The roof rainwater from the Expo Center will be reclaimed for road cleaning and plants and lawns watering (Fig. 2.125).

As for the rainwater harvesting system in the Expo Cultural Center (Fig. 2.126), it collects and further process the coagulated water from air-conditioning and roof rainwater, so that they can be used for road cleaning and plants irrigation.



Fig. 2.125 Expo center

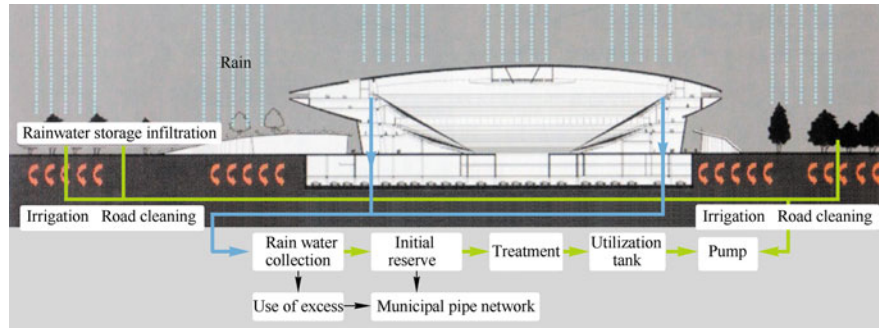


Fig. 2.126 Rainwater collection and utilization system in Expo Culture Center

By adopting the programmed control of spray and drip irrigation, the utility rate of water resources can be significantly improved.

Large amount of rainwater from the Expo Axis is stored in its basement. After being filtered, the rainwater can not only be used for itself, but also for irrigation and cleaning in the pavilions around. The roof of China Pavilion is equipped with a rainwater collecting system, from which the collected natural rainwater will also be applied in irrigation and road cleaning. By introducing the technology of small-scaled constructed wetland in the south landscape design of Region Pavilion, with the self-cleaning capability of the artificial wetland, an ecological wetland is created in the city center without covering a large number of land area.

Shanghai Corporate Pavilion chooses the environmentally friendly building materials (Fig. 2.127), adopts the world’s latest solar power technology, and also equips itself with the rainwater collecting system. The collected rainwater will be

Fig. 2.127 Rainwater collection system in Shanghai Corporate Joint Pavilion

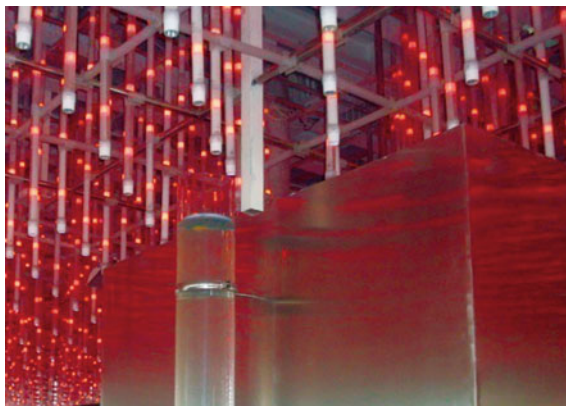
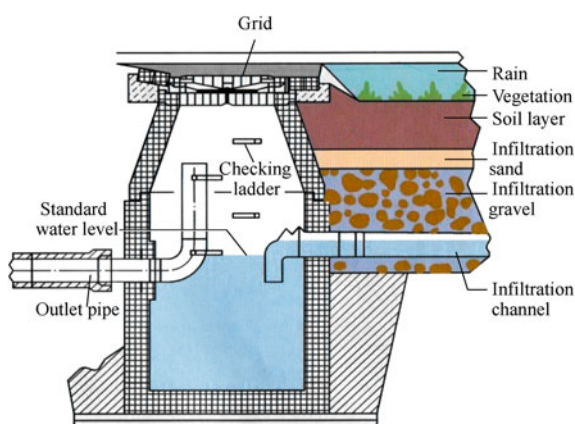


Fig. 2.128 Rainwater storage and infiltration solution for low green land and underground drainage system



recycled, and after being deposited, filtered and stored, they can satisfy the daily water consumption as one of the water sources in the pavilion.

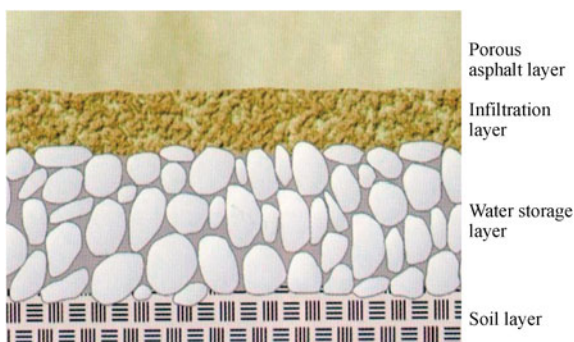
(2) Application of Rainwater Storage and Infiltration

The rainwater storage and infiltration technology is typically applied in grass infiltration swales, lower green land, permeable road surface, potential infiltration wells and infiltration trench, etc. Among them, green land is a natural infiltration facility, which has good water permeability, saves investment and facilitates the absorption of rainwater. Figure 2.128 shows rainwater storage and infiltration solution for low green land and underground Drainage system. Figure 2.129 shows permeable pavement in the Expo site. Figure 2.130 shows typical structure of permeable pavement in the Expo site.

Fig. 2.129 Permeable pavement in the Expo site



Fig. 2.130 Typical structure of permeable pavement in the Expo site

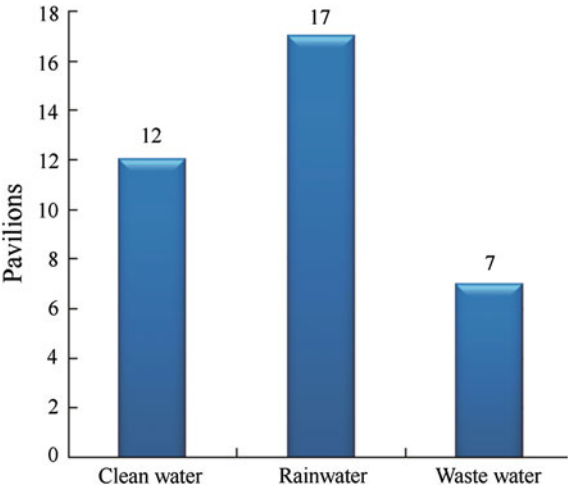


2.4.3 Waste Water Treatment

Advanced water treatment technologies such as reverse osmosis and ultrafiltration membrane technology have been used in many of the Shanghai Expo pavilions. For example, ultrafiltration membrane is used in the direct drinking water device as its terminal purification unit to thoroughly remove the secondary pollution in the water pipeline transport. In the Pavilion of Future, hollow fiber membrane bioreactor with the PVC alloy ultrafiltration membrane as the material is applied in the sewage recycling demonstration project. It is a new movable sewage treatment device, which collects the sewage from discharge and rainwater from the roof for reuse.

The research worked out the number of cases of the water purification, water collection and other applications of the water treatment in the Expo site, as shown in Fig. 2.131.

Fig. 2.131 Water treatment technologies applied in the Expo site



2.4.4 Summary of Water Treatment Technologies Applied in the Shanghai Expo

2.4.4.1 Current Status of Water Treatment Technologies in the Shanghai Expo

Shanghai Expo has given a full play to its concept of water saving, separate collection, assorting treatment and recycle in the process of water treatment and reclamation. It has adopted the foreign advanced technology of comprehensive rainwater harvesting system, and displayed successful cases of biochemical and advanced sewage treatment, in which the technology of membrane filtration, ultrafiltration membrane bioreactor, activated carbon adsorption, ultraviolet disinfection are applied. Nowadays, people have grasped the technical principles and practices of these advanced technologies, but problems such as high production cost, difficulty in regeneration, secondary pollution and short life circle have seriously hindered the promotion and application of these advanced technologies.

Due to the space limit of the Expo site, there are very little exhibitions for some special treatment of industrial sewage (especially the complex sewage that is difficult to be degraded), such as physicochemical pretreatment, biochemical intensified treatment, advanced treatment and water reclamation technologies. Along with the development of industry and people’s greater awareness and requirements for environmental protection, a number of new technologies, innovative equipment and process have emerged for treating the industrial waste water that is difficult to be degraded.

2.4.4.2 Developmental Trend of Water Treatment Technology in the Expo

The concept of water saving and sewage reduction, separate collection, assorting treatment and recycle is the overall direction for carrying out the development of water treatment. For a long period of time in the near future, we should mainly focus on the combination of existing routine technologies and at the same time, perfect the existing advanced technologies. In response to the acute contradiction between increasingly serious problems of environmental pollution and people's improving requirements for protecting environment, we should place an emphasis on the development of new technologies for treating industrial sewage, in particular, the difficult-to-degrade mixed wastewater. And this will be the guiding direction for us to make efforts in the future water treatment.

2.4.4.3 Suggestions for Promoting Water Treatment Technologies in the Expo

Firstly, some relevant policies and rules should be formulated at a state level, so as to lead and help the development of new technologies in the industry and render great service to the society.

Secondly, the establishment of technical norms and standards should be set up in treating industrial wastewater, especially the difficult-to-degrade mixed wastewater.

2.5 Solid Wastes Disposal

The problem of solid waste is a growing concern in the development of the city and also the hot spot in resource recycling. The Shanghai Expo has focused on the demonstration of new technologies in the treatment and disposal of the engineering waste and urban solid waste, transforming the organic and inorganic garbage in the building and operation of the Expo Park into the construction materials, organic fertilizer and methane, etc. to achieve the harmlessness and recycling of garbage disposal.

2.5.1 Introduction to Solid Waste Disposal

Solid waste is the solid and semi-solid substances that we consume and discard in our daily life, production and other activities, more commonly known as trash or garbage. It consists of solid particles, trash, furnace slag, sludge, discarded goods, worn appliances, spoil, food scraps, human feces, etc. Some countries also classify the waste acid, alkali, oil and waste organic solvent into the solid waste.

2.5.1.1 Classifications of Solid Wastes

According to the Law of the People's Republic of China on Prevention of Environmental Pollution Caused by solid Waste, solid wastes consist of urban solid wastes, industrial solid wastes and harmful wastes. Based on the sources of the solid wastes, it is divided into the municipal solid wastes (MSW), industrial solid wastes and agricultural solid wastes.

- (1) **Municipal solid waste (MSW)** commonly known as trash or garbage, is a waste type consisting of everyday items we consume and discard. It predominantly includes household waste, hospital trash, commercial wastes, building wastes (trash). Generally speaking, the daily trash generated amount per person is 1–2 kg, depending on the living standard, habit how they the discarded goods are recycled and municipal construction, etc. It is estimated that in 2025, 60 % of the global residents will live in the city or its neighboring area, the pollution caused by the MSW will become one of the serious problems. Normally, the higher the living standard, the more trash amount. In a industrialized city, the daily generated trash is 1 kg per person.
- (2) **Industrial solid waste** is a type of waste produced by industrial activity, such as that of factories, mills and mines. Much industrial waste is neither hazardous nor toxic, such as waste fiber produced by agriculture and logging.

Based on its sources and physical properties, industrial waste is divided into six types. Based on the toxicity of the waste residue, it is divided into toxic waste and non-toxic solid waste.

Toxic waste, chemical waste, Industrial solid waste and MSW are designations of industrial waste. Sewage treatment can be used to clean water tainted with industrial waste. The wastes containing fluorine, mercury, arsenic, chromium, lead, and cyanogens elements or their chemicals and phenol, radioactive substances are toxic waste.

- (3) **Agricultural waste** is also called agricultural garbage, mainly coming from feces and plants straw.

Solid waste disposal usually refers to physical, chemical, biological, physico-chemical and biochemical methods used to convert the solid waste into another form which is suitable for transportation, storage and utilization. The goal of solid waste disposal is harmlessness, minimization and reclamation. Some people think that solid waste is the most difficult to dispose among the “three wastes,” because it contains rather complicated elements, with its physical properties (size, liquidity, uniformity, crushing degree, moisture, heating value, etc.) variable, making it hard to achieve the goal. Currently the main methods for proposal include compaction, crushing, sorting, curing, incineration and biological treatment.

Today the disposal of wastes by land filling or land spreading is the ultimate fate of all solid wastes, whether they are residential wastes collected and transported directly to a landfill site, residual materials from materials recovery facilities (MRFs), residue from the combustion of solid waste, compost or other substances

from various solid waste processing facilities. A modern sanitary landfill is not a dump; it is an engineered facility used for disposing of solid wastes on land without creating nuisances or hazards to public health or safety, such as the breeding of insects and the contamination of ground water.

A landfill may offer a cheap solution to large amounts of trash, but incineration can quickly reduce the volume. An efficient and environmentally sound incinerator does not simply burn whatever trash there is lying around. Some incinerators recycle and reuse refuse as fuel to burn non-recyclable materials.

Modern incinerators are designed to destroy at least 99.9 % of the organic waste material they handle. Numerous thermal processes recover energy from solid waste. Companies burn in-plant wastes in conventional incinerators to produce steam. Pyrolysis, a process of chemical decomposition, produces a variety of gases and inert ash. Garbage burned in incinerators has poisoned air, soil, and water, which is one of the disadvantages.

2.5.2 Applications of Solid Waste Disposal Technologies in the Shanghai Expo

In the Expo site, set up an advanced infrastructure and services on solid waste collection by classification, transportation, processing and utilization of renewable energy, to achieve the recycling and utilization of the solid waste treatment.

In the core area of “One Axis and Four Pavilions” in Putong, the advanced foreign technology for pneumatic conveying was introduced and applied in large exhibition hall and municipal roads (Fig. 2.132). It mainly provided service to the “One Axis and Four Pavilions” (World Expo Axis, China Pavilion, Theme Pavilion, Expo Center, Performance Center) and the surrounding main roads.

Fig. 2.132 Pneumatic conveying trash bin in the Expo site



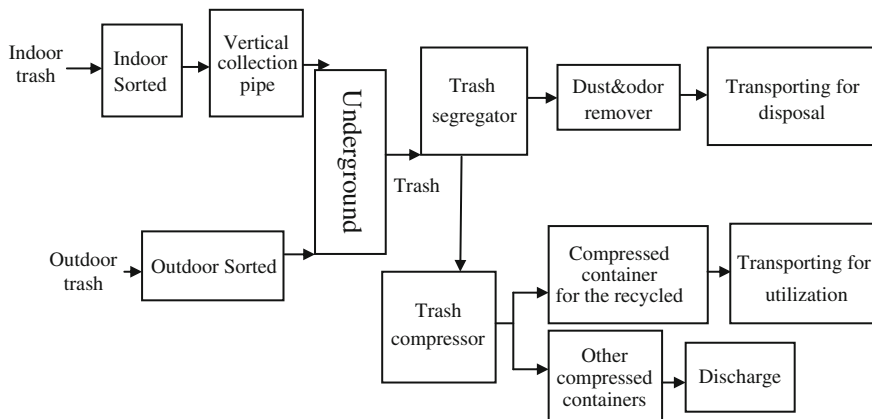


Fig. 2.133 Flowchart for pneumatic conveying trash system

This system is a closed pneumatic system for trash transmission and the whole collecting procedure is pre-programmed by the computer. The transportation of trash is completed in a totally closed status without any manual operation. The sanitation workers can avoid the direct contact with trash so as to ensure that the trash disposal process emit no smell or overflows. Figure 2.133 shows flowchart for pneumatic conveying trash system.

2.5.2.1 Case Demonstration

In Basel, Geneva and Zurich United Case Pavilion, one can see the very fine sorting of trash. Even the glass bottles are subdivided into several groups like brown, green and colorless ones, which contributes to the recycle and disposal of trash. In Sweden, the residents have the obligation to recycle waste, for example, diving enthusiasts will go to the Rhine River in search of wastes every year, the students are organized every year to do some environmental protection work within their power, such as picking up litter or garbage sorting.

While the Porto Alegre Pavilion demonstrates a creative way to transform trash into things of value—to extract fiber from PET bottle to make bedspreads and pillows—this brings income and job opportunity for women from 20 poor families. And this project also improves the living quality for more than 90,000 people in need.

The exhibiting project in Cairo Pavilion involves the transformation of an 80-acre dump of the 1980s into a park.

Taipei Case Pavilion shows their approach in proper classification and recycling of trash, to not only reduce the amount of trash but also realize “zero landfill.” In 2000, the daily amount of trash produced by all households in Taipei was 2,970 tons; while in 2009, the number was reduced to 1,009. In other words, the

Fig. 2.134 Work schematic for Sysav garbage power plant



amount was reduced by 2/3 within only 9 years, the success of which can be attributed to the policy of “no trash on the floor.” There’s much in their practice that we can learn and draw experience from, and it is advisable to promote this kind of practice in mainland China.

Speaking of the four-floor small building of Shanghai Pavilion, we can see that the constructional materials of this building are actually made of town refuse. During the reconstruction of some old buildings in the city of Shanghai, about 150,000 pieces of bricks and some structural steels were left over, which are now re-used in the construction of the walls and stair treads of this building, and are re-welded into its steel stairs.

Malmö Case Pavilion of Sweden demonstrated how Sysav Trash Disposal Company makes flexible utilization of the wastes to convert them into source of energy. Every year the company has to dispose the MSW and industrial waste in a city of 620,000 residents. It collects the flammable garbage of up to 400,000 tons a year in the southern area of Sweden, after combustion to produce 1,000 GWh (1 billion kWh) of electricity, equivalent to 300,000 tons of standard coal production. The latest production line generates 135 GWh of electricity and 540 GWh of hot water for district heating, which meet the heating demand for 40 % of Malmö and Burlöv area (300,000 residents) and electricity demand for 170,000 households. The new production line is capable of handling 200,000 tons of combustible wastes per year, running 24 h a day, 365 days a year. Figure 2.134 shows work schematic for Sysav garbage power plant.

2.5.2.2 Conveying Trash Out for Disposal and Utilization

(1) Landfill of Household Trash

The seepage-proof system with high safety is applied to prevent the waste from leaking. The seepage-proof system of landfill site has used foundation, woven geotextile, metalling, nonwoven geotextile, rough-surfaced geomembrane of 1.5 mm thick, and many other materials to ensure its excellent performance, so that trash and underground water is completely insulated without even the smallest gap in between.

(2) Incineration of Household Trash

The factory for incineration of household trash spent 70 % of their total investment on the gas control system. The world's most advanced technology of "lime + activated carbon + bag filter" is applied in the gas purification process.

(3) Utilization of Building Trash

Over 60 % of the road surface in the Expo is made from building trash and slag. And most of the pavilions in the Expo have adopted recyclable building materials.

The construction wastes in the Expo site is first classified according to their uses, of which 10 % is of higher economic value to be sold off, the remaining 90 % is waste concrete, waste plastics and waste timbers. What is the destination of these construction wastes? The answer is: construction waste residue with high water resistant strength is used as the road base in the Expo site; construction wastes recycled aggregate as roadbed construction; waste concrete is processed into pavior bricks; waste wood and plastics is used as inspection well lid, inside and outside the Expo site. The smooth implementation of the project has given people an inspiration. In the urban construction, is there any possibility of establishing such a large-scale "Logistics Transformation Center" for the construction wastes?

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