Modeling Application of Solar Energy for Construction of Buildings in Architecture of Science and Technology Parks in Iran

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Abstract *— Science and technology parks are among human-made structures with a high amount of energy consumption. On the one hand, the constructors of these parks need to provide energy in these spaces and, on the other hand, a huge amount of non-renewable fossil fuels, which are today used for energy generation, are the fuels that will not be left for future generations. The processes involved in fuel to energy conversion will have negative effects on the environment in a long run. Therefore, peace and comfort in the biological environment are affected by energy emissions and energy supply manners. In this regard, some issues should be considered, i.e. energy supply manner as well as form and type of current and future building spaces should be based on the approaches that could fulfill the sense and capability of accountability and responsibility against biological conditions, peace, and comfort as well as maintain the nature and its reserves and operate the potential of renewable energies, especially solar energy. Use of the sun as one of the important energy resources is important, because it is available throughout the world, especially in Iran, and has no destructive environmental effects. Since long ago, it has been used by humans in various methods. So, architectural and urbanization approaches should be based on the design of buildings and sustainable urban spaces so that natural resources can be preserved and various types of renewable energies, especially solar energy, can be widely used and exploited. Following a descriptive-analytical approach, in this paper, the manner of using solar energy in science and technology parks, as buildings with high-energy consumption, is introduced and some examples of buildings designed based on solar energy approach and current buildings equipped with the energy system are mentioned.*

Keywords— Solar energy, Solar systems, Architecture, Science and technology parks.

I. INTRODUCTION

Energy crisis has started since 1960s and motivated countries to have different confrontations with energy issues. The replacement of fossil energies with renewable energies such as solar energy for reducing and saving energy consumption and decreasing the emission of polluting gases has been greatly welcomed. The sun emits $1.1 * 10^{20}$kWh/s energy on average. Out of all the energy emitted by the sun, only about 47% reaches the earth (due to some issues such as the reflection and absorption of a part of the light by aerosols). This means that the earth receives about 60 million BTU/h, i.e. the energy produced by three days of sun radiation to the earth is equal to all the energy caused by the combustion of all the fossil fuels in the earth. Therefore, it can be concluded that, as a result of solar radiation for 40 days, the energy required for a century can be saved [1].

Due to their number of factories and the urbanized-industrialized life system, industrial countries are among the most polluted places in the world. With long-term planning and using various specializations, they attempt to reduce the effects of pollutants in their biological spaces. Among these plans are the construction of cities and towns with zero energy, use of green nature in any space with city and home scales, as well as construction and equipment of buildings based on different solutions and strategies such as use of solar energy. This article is important, since there are no comprehensive plans and strategies in Iran to use and develop industries related to renewable energies at the macro and micro scales; however, through taking minimum measures, it is possible to build clean energy buildings and clean cities.

A. Solar energy and its nature

The origin of all different forms of energieswhich have been identified so far (including fossil fuels stored inside the earth, wind energies, sea waves, geothermal energy, biomass, etc.) on the earth is the sun[2].

The sun is a massive and shining globe, which is located in the center of the solar system and provides light, heat, and other energies for the earth. Most of the energies available on the earth originate from the sun. Only nuclear energy, geothermal energy, and the tide are not supplied by the sun. The sun can be considered a great source of energy, because it emits $1.5 * 10^{18}$ kWh\s energy, while only two-billionth of this amount of energy ($1.5 * 10^{18}$ kWh/y) reaches the outer surface of the earth atmosphere (Iranian Journal of Renewable Energy Organization, 3rd year). Solar energy, similar to other energies, can be converted into other forms of energy, such as heat, electricity, etc., directly or indirectly, but obstacles such as lack of scientific and technical resources in conversion due to lack of knowledge and field experience as well as the variable and intermittent nature of energy due to climatic changes and seasons for the radiation of an extensive distribution range could prevent the appropriate use of this resource [3].

II. SOLAR ENERGY POTENTIAL IN IRAN

In Iran, 5.5 kWh/m^2 solar energy is averagely emitted to the earth surface on a daily basis and there are 300 sunny days in 90% of the land. The area of Iran is approximately 1600000 km^2. Daily solar energy radiation is equal to 1.6 * 5.5 * 10^{12}KWh and the total amount of solar radiation per day is equal to 9000000000 MWh in Iran. If only the solar energy of 1% of the area of Iran is absorbed and the efficiency of energy reception system is only 10%, it is still possible to receive 900000000 MWh energy per day from the sun [3].

A. Radiation map in Iran

Since Iran is located on the world's solar belt, it is one of the countries which enjoy solar radiation with favorable power. Moreover, Iran is a mountainous country, which is located 1000 m above sea level on average. Therefore, since it is proved that, the more the height from the sea level, the higher the reception power of solar radiation would be, Iran has appropriate solar energy potential. The Fig.1 shows map of solar radiation in Iran. Also, Iran can be divided into four following parts in terms of receiving total solar radiation per year [3]:

1. Low radiation area with the radiation of less than 350 cal / cm 2 per day
2. Medium radiation area with radiation between 350 and 390 cal/ cm 2 per day
3. High radiation area with radiation between 390 and 430 cal/ cm 2 per day
4. Very high radiation area with radiation above 430 per day

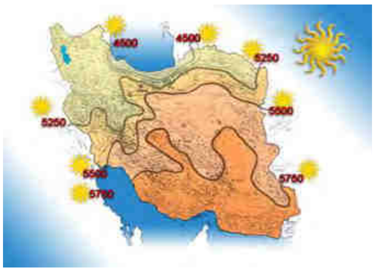


Fig.1:Map of solar radiation in Iran [3]

It means that, at minimum, on 291 out of 295 days of the year, it is sunny and only the intensity of solar radiation is different. Therefore, it is possible to use storage and applied solar energy resources in different parts of the country and it is recommended to use its energy for public and domestic consumption in central and southern areas.

B. History of using solar energy in Iran and the world

Recognition of solar energy and its use for different purposes dates back to the prehistoric era (perhaps the pottery period). In the table 1, some of the most important events related to the solar resource are mentioned.

In the 19th century, solar desalination devices became popular, which could produce about 20000 lit distilled water per day on sunny days [4]. In the 20th century, collectors were greatly considered for generating steam in power plants. The idea of heating buildings with solar energy was stated in 1390s and considerable progress was made in this regard over one decade. Fig. 2 shows the first solar house was built in 1938 in Massachusetts Institute of Technology, America [5].

Fig. 2: The first solar house

III. FIRST SOLAR HOUSE IN AMERICA

Studies on solar energy in Iran have been started since about 35 years ago, almost at the same time at University of Shiraz and Sharif University of Technology. Among the important projects in these centers was the project of 10 MW solar power plants at University of Shiraz as well as the design and development of photoelectric cells [1].Nevertheless, effective practical measures have not been undertaken in this regard and, unfortunately, no progress has been made in terms of technology, technical standards, and architectural aesthetic principles; thus, intellectual, research, and executive investments are still required.

A. Use of solar energy in buildings

Use of solar energy in buildings refers to the better operation of solar radiation for meeting heating and cooling needs and, if necessary, their electricity supply. In the first step, with the use of solar architecture design, which is greatly similar to traditional Iranian architecture, the heating and cooling needs of the buildings are minimized. Table 2 shows Intervened requirements in favorable design in terms of technology and execution in buildings. By applying these parameters, the energy required for these buildings was considerably less than that of a conventional building (with the same foundation) and this percentage depended on using these parameters and climatic conditions of each point.

Since Iran is a country with different climatic areas, the facilities of solar energy are a function of these different climates. Accordingly, to reduce the energy required for a building, its design should be consistent with the area's climate. In all different climates, the buildings manufactured based on climate design principles minimize the necessity for mechanical heating and cooling.

Table 1. Some of the most important events related to the solar resource

Year	Name	Use of the sun
B.C.	Clergymen of temples	Large and polished golden cups and solar radiation were used to illuminate fireboxes of sanctuaries.
212-287 B.C.	Archimedes	By installing many small squared mirrors next to each other on a moving stand,the solar radiation was focused on Roman ships from far distance and, thus, burned them.
1615 A.C.	SALMON DE CAUM	He published a statement on solar engines and focused the solar radiation, by a number of lenses installed in a frame, on a closed metal cylinder filled in part with water. Solar radiation heated the air inside the cylinder and, as a result of air expansion, the pressure inside the chamber was increased and the water was expelled.
18thcentury	Natura	He built the first solar furnace in France.
1767 A.C.	Susser	He made the first solar cooker, which included a box insulated by a black surface and a lid made of glass pieces. Solar radiation entered the box after passing through the glasses, was absorbed by the black surface, and increased the internal temperature to 88°C.
1794 A.C.	Antoine Lavoisier	As the father of modern chemistry, he had some research on solar furnaces to obtain maximum energy from the purest thermal resource and, in order to form a convex lens, built a furnace consisting of two glass plates; the space between these two plates was filled with alcohol. The liquid lens had the diameter of 130 cm and focal length of 320 cm. Since the refractive power of this liquid lens was not effective to obtain high temperature at the focus, Lavoisier put another small lens in the focus and, by decreasing the effective focal length; the device could even melt platinum at 1760°C.
19thcentury	Bessemer	Some efforts were made to convert solar energy into other forms of energy such as steam generation and use in steam engines. In these years, several steam engines were built and tested.
1878 A.C.	Mushu	He designed the first solar collector with a cone concentrator. The mirrors inside the cone concentrated all the solar rays on the spot in the middle of the truncated cone, in which an absorber was installed. This collector was called oxicone. The first large oxicone consisted of a silver plate with the diameter of 540 cm and area of 18.2 m^2. Its weight with all the moving parts was about 1400 kg and it had the absorption power of 78% of the emitted solar energy. But, since in this project, the solar radiation was focused on a plate, instead of a point, it had less intensity. The generative power of Mush truncated cone was enough to launch a steam machine with the power of 1.5 kW and delivered only 3% of the absorbed energy. However, coal-fired steam machines could deliver 9% to 11% of the absorbed energy. In the following years, the energy obtained from the sun was used in the cases such as providing the power of printing machines or water distillation and desalination.
1880 A.C.	Charles Tilly	He made the first flat solar collector.
1888 A.C.	Westermarck	He proposed the use of solar energy in thermocouples. Therefore, by concentrating solar energy on the thermocouple, using their fundamentals, and developing warm and cold resources, electric energy was generated at both ends of nickel and iron wires.

Table.2: Intervened requirements in favorable design in terms of technology and execution in buildings

Direction of building	Thermal insulation in some areas	Appropriate level of windows
Form of building	Using some inactive solar systems such as Trom be wall, water wall, roof pool or pond, stone storage or floor (thermo siphon), greenhouse method, direct reception method	Double glazing windows, quality of irradiated surfaces, window frames, glass and its substance

IV. TECHNOLOGIES DERIVED FROM SOLAR ENERGY

A. Solar water heater

1. General solar water heaters:

These types of water heaters are installed in all the public places with no natural gas pipeline such as military barracks, health centers, prisons, educational centers, dormitories, and so on.

2. Solar water heaters:

Studies have shown that water and space heating totally consumes more than 80% of energy in buildings; therefore, more than one-third of the world's energy consumption is spent on heating. Also, water heating on average consumes 20-30% of total energy consumption in buildings. Therefore, using solar water heaters, 70% of the energy needed for water heating could be annually provided[6].

B. Heating and cooling of buildings

The first solar building was built in 1939, in which a seasonal heating tank was used for heating during the year. By adding an absorption refrigeration system to solar systems, in addition to consumed hot water and heating, the systems could be used in warm seasons for cooling the buildings.

C. Solar dryer

Drying food materials for storing has been common from long ago and primitive humans have regarded drying as an art. Drying refers to taking some of the water in the food stuff and other products that increases their storage life and prevents the growth of bacteria. In solar dryers, solar energy is directly or indirectly used for drying and the air is flowed naturally or compulsorily, which could accelerate the drying of products. Solar dryers are designed and made in different sizes and designs for various products and applications.

D. Solar heaters

Solar heaters were first made by a person named Nicholas Susser. His stove included an insulated box with a black plate and a lid made of glass pieces. Solar radiation entered this box after passing through these glasses and absorbed by the black surface. Then, the temperature inside the box was increased to 88°C. The working principle of solar stoves was based on collecting direct sun rays at a focal point and temperature rise at that point. Today, there are various designs of these systems, which have been tested in different places such as South Africa and obtained acceptable results. Use of these stoves, especially in the eastern part of Iran which is faced with the problem of fuel shortage, will be very useful.

E. Solar pond

The technology of solar pools is one of the relatively simple technologies for the operation of solar energy, which has been developed to store and use the solar thermal energy and has various applications. For the first time, Egner Rudolf Bloch and Dr. Harry Tabor prepared the design of an industrial saltwater solar pool in 1958 and this technology was implemented in the 70s and 80s. Due to lack of need for the generation of high temperature, the solar heat of pool water has the following features:

1. Collectors without covers can be used.
2. The system's efficiency is very high.

The performance of this system is so that the pool'scold water is pumped, circulated throughout the collector, and heated. The water returns to the pool after being heated.

F. Solar panels

This part is in fact the convertor of solar energy into electric energy without any mechanical mediation. It in fact controls all the system characteristics and also injects and controls the input power of panels based on the design and the need of consumers for load or battery. It should be noted that, in this part, the constituting characteristics and elements are changed considering the needs of electric charges and consumers as well as local weather conditions.

G. Solar lighting systems

Solar systems are optimal and appropriate solutions for the lighting of various areas and are presented based on the need of each project in various designs. Lack of need for paying cabling costs and any kind of maintenance are the most important advantages of these systems. The lighting of the area, warning and flashing lights, warning lights in naval and air navigation systems, and decorative purposes are the cases for the use of solar systems. Fig. 3 shows Lighting systems in parks with energy saving light bulbs [7].

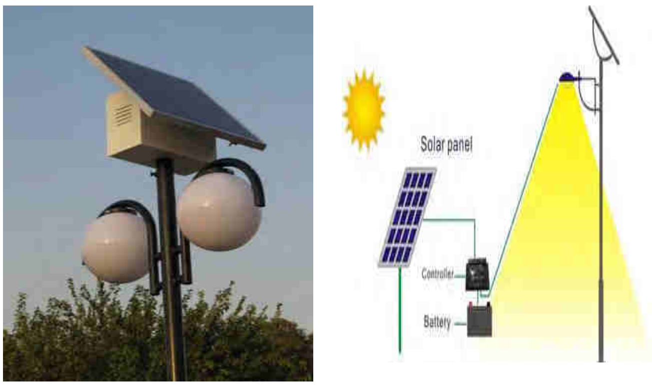
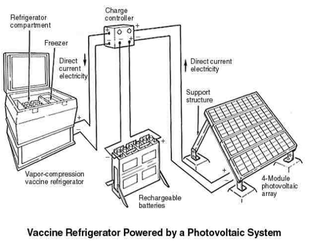


Fig. 3: lighting systems in parks with energy saving light bulbs

H. Solar refrigerators

There are many ways to integrate solar energy with cold generation process. Solar cooling can be generated by both solar heating as a heat resource and photovoltaics as an electric resource. This process can be conducted using absorption and adsorption methods through heating or using a conventional refrigerator, the power of which is supplied by photovoltaics. Solar cooling is used specifically for keeping vaccines cold in the areas where electricity is not available or for cooling the places. Different solar cooling methods including absorption units of porous solids called absorbents can physically and reversibly absorb large amounts of steam called absorption fluid. The main idea of using this phenomenon emerged in the 19^{th} century. The absorption vapor compression inside the solid absorbent depends on the temperature of the pair, i.e. the combination of absorbent and absorbed, as well as steam pressure. If pressure is constant, the absorbed substance can be absorbed or reversed by changing the temperature. This method is the basis for the performance of solar systems that use the cycle of steam absorption. An absorbent–absorbed pair must have the following characteristics for working in a solar refrigerant: 1. Arefrigerant with high latent heat; 2. A working pair with high thermodynamic properties; 3. Low reverse temperature (reversing absorption fluid) in dealing with working pressure and temperature; 4. Low heat capacity of ammonia-water pair which has the widespread use among the available systems and use of more appropriate absorption pairs for solar systems is still being investigated. The efficiency of these systems is limited by condensation temperature and cannot be reduced without using high technologies. For example, cooling and dehumidifier towers are used to produce cold water and condense ammonia at low pressure. Among the inherent disadvantages of ammonia-water pair is the need for pipes and tanks with high thickness, corrosion caused by ammonia, cooling problems, and water-ammonia separation. A few other pairs such as zeolite-water, zeolite-methanol, and methanol-active carbon are being studied, from among which a more appropriate one is selected. So far, methanol-active carbon pair has had the best results. The absorption units of absorption process include moisture absorption by a substance called dehumidifier. Dehumidifiers or absorbents are the substances which could absorb gases or liquids and has special affinity with water. During the absorption, the absorbent undergoes a chemical change via moisture taking; for example, salt which is deformed during moisture absorption and changes from solid into liquid can be mentioned. The dependency of dehumidifiers on moisture has made them useful for separation chemical reactions. Absorption systems are similar to steam air conditioners, but they are different at the pressure level. Generally, an absorbent absorbs the low-pressure part of an evaporated refrigerant fluid. The most widely used liquid compounds include water-lithium bromide, in which water vapor is the coolant, and water ammonia, in which ammonia is the coolant. Solar refrigerators are used for healthcare and nutrition services in remote and impassable areas. The appropriate functioning of solar refrigerators has been to the point that, during the past 5 years, more than 10000 solar refrigerators have been launched for healthcare applications throughout Africa. Fig. 4 shows a solar refrigerator [8].



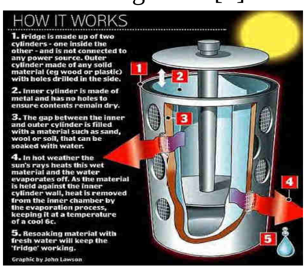


Fig.4: Solar refrigerator

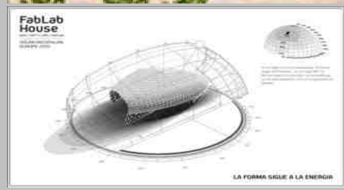
V.STUDYING CASE STUDIES IN THE WORLD

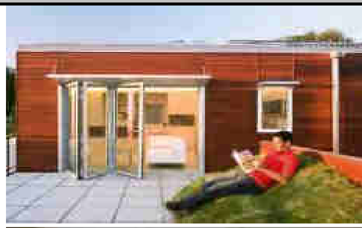
By studying the works built around the world and their adaptation with the current situations in Iran, the available knowledge in this industry can be used in the design and construction of science and technology parks. In the table 3, some examples of these projects along with the required explanations are presented. As can be seen, solar energy can be used in different forms. Due to the structural type of buildings, the buildings used in science and technology parks, which are the symbol of progress and development of every country and provide the inspiration and model for other parts, should gain maximum benefit from solar energy by using different ideas in the their construction, the area of space and design, harmony between form and photovoltaic cells and materials, and also in insulation that can be synchronized with climate conditions in different climatic areas, the use of solar energy should be considered.

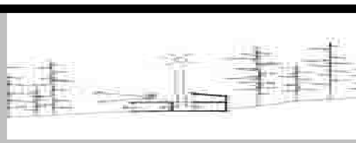
VI. SUMMARY AND CONCLUSION

Architecture is not just the construction of buildings by concrete, metal, and brick. Owing to its creative and innovative nature, architecture is the most beautiful event which is developed by humans. The existence of multiple factors in architecture makes it a unique expertise and responding to these factors makes architecture an unmatched phenomenon. Architecture which seeks to meet human needs establishes a structure that not only provides a shelter and protects from the wind, rain, and atmospheric agents, but also brings safety and comfort as well as self-actualization and transcendence opportunities for humans. Architecture is the spirit of spaces and, by getting involved in the environmental and climatic conditions, awards identity and peace for the building. In order to establish a comfortable life for the residents of the living spaces, the effective parameters for and factors influencing architecture should be considered, the most important of which are to provide energy as well as heating and cooling conditions in that space. Considering the increasing development of technology in the world, in order to achieve the most favorable conditions in the living spaces, their applications should be examined in every country to understand the negative and positive effects and consequences of any thought and technology and use the most appropriate ones in the buildings.This issue is particularly important in providing energy and comfortable living conditions as well as using clean and renewable energies. The building examples in this article are selected to introduce the technologies and thoughts with the mentioned approach in order to provide the possibility for modeling based on climate in Iran, after studying the similar examples. In order to achieve this result, more articles and works with closer precision are needed.

Table 3. some examples of projects along with the required explanations

No.	Building name	Construction year	Designer	Special features of the building	Project images
1	**FabLab House**	This building was designed in 2010 Solar Decathlon Europe Competition. In this annual competition, the best European projects are presented for solar buildings. This house could win the event's public choice award in 2010.	Of Adonsend	FabLab is not just a building equipped with solar panels on the roof, but it is a completely self-supporting prefabricated structure that can produce twice as much of the energy it consumes. It is a completely biological building which is made of wood and natural materials with the coating of photovoltaic panels. This House is like a giant fish and its indoor furniture is made of wood, just like its outdoor surface. Its flooring is made of plant fiber linoleum and its lighting system is provided by LED lamps.	 
2	**Solar home in Switzerland**	Thisproject received the award for European Solar Energy in 1995.		On the roof of this building, 276 solar panels are formed that are connected to a massive tank of healthy water. These panels can provide the hot water and indoor heat of its8 furnished apartments. The roof panels can heat 205000 lit water in a tank with 17 m height. The solar power plant of this house costs about 300000 Swiss franc and is equal to 10% of the total cost of the building. Using this power plant, the residents of the building can annually save 3000 lit oil for the house and healthy water heating.	
3	**Refract House**	U.S. Dept. of Energy Solar Decathlon 2009	SCU + CCA Californian Team	This project is announced as the winner for two reasons: 1. Indoor and outdoor harmony 2. High-quality of the project. The area of this building is 700 m², which includes a large central courtyard and an open area that connects the living space to an open area. The roof windows and large sliding doors bring the natural daylight light into the house and minimize the electric charge. The form of the building is bent, due to the use of sunlight along the sunrise to sunset direction. The central courtyard, in addition to providing a small garden with edible plants, is an open space in harmony with the ecosystem and climate of California. The house has a gray water	  

				filtration system, bamboo beams, and a storage pool. All the systems are designed compatible with the environment.	
4	**Solar House**	In a competition held by Department of Energy Research at Cornell University, this house won the first award as the most affordable home.	SubZero Energy Architects Home	It has a bedroom and a bathroom, and is equipped with a photovoltaic system, which is a kind of lighting generating power system. It should be noted that this structure has a solar thermal system. It is also equipped with rainwater recycling system and its internal valves completely save the water consumption. All around the house is surrounded by a beautiful green space. The indoor space is designed and decorated in such a way that you will easily access whatever you need. The most considerable aspect of this house is its outdoor davenport.	 
5	**Solar Umbrella**	In1953, it was made with an inspiration by Paul Rudolph's Umbrella House.	Brooks + Scarpa	Using active and inactive methods has led to making a solar building with 100% natural energy and also 180° displacement to the original axis has allowed architects to use the southern light. The solar canopy protects the building against the southern heating of California. The solar shell absorbs the sunlight and converts it into usable energies. The acoustic panels are made of recyclable newspapers.	 
6	**ORDOS Villa**	It was designedin 2008 and built in 2009.	Michael Meredith, Hilary Sample	The house is designed according to traditional Chinese houses which have courtyards. In the design of this house, solar windows and chimneys are found to be appropriate solutions for the outside weather of this area with warm summers and cold winters. In winter, the solar radiation angle is low, these windows let in the sunlight, and the sun's rays are saved by a stone wall and floor to transfer the heat to the indoor space. In summer when sunlight angle is high, the warm air rises from the chimney and cold air is replaced. The structure's wall and floor reducethe rate of sunlight to the house.	 
7	**Villa Nyberg**		KjellgrenKaminsky Architecture	Thisproject is aimed to make the building compatible with the environment. The energy simulation in this building shows that the energy consumption in this villa is only about 25 kwh/m^2. This villa is built between the lake	

				and the forest. During the day, by moving from one room to another, various landscapes of the lake and forest can be seen.	
8	**The Meridian First Light House**	2011	Team Victoria University of Wellington	This house is constructed with the inspiration from Kiwi Bach traditional holiday home. The 3-layer skylight and large door illuminate the central part of the house. The outer coating of the building is made of red cedar wood that is naturally durable, light in weight, and stable in a variety of weather conditions. The canopy is one of the key features of the project.	 
9	**Solar House**	2011	Studio Albori	The wooden frames are used to support the structure. The solar energy in this building is used in 3 ways:1. Directly through south-facing windows, 2. Saving energy by mineral salts in PCM (phase-change material) by the panels in the view,3. Converting the electric energy by the photovoltaic panels established on the roof.	 
10	**Totally Solar**	It wonmany awards in the late 1990s in Germany.	Rolf Disch	This building is known as the Solar City and designed based on three points: 1. Energy conversion, 2. Using renewable energies, instead of fossil fuels, and 3. Understating the indigenous energy facilities. This building produces more energy than its own energy consumption. The buildings can be rotated to receive more light. This building shows that the buildings with photovoltaic panels can be beautiful, economical, comfortable, and superior to conventional buildings.	 

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