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Net zero building: A way out to global warming & energy crisis

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Abstract
Emissions of carbon dioxide into the Earth's atmosphere, primarily as a result of burning fossil fuels for energy, are thought to be the cause of rising global temperatures. The scientific evidence to support this assertion has become increasingly compelling in recent years, suggesting a need for urgent and concerted action by all nations to prevent ecological degradation on a massive scale. For the first time in history we face an energy crisis not because we might run out of energy, but because we are using it in the wrong way. Traditional buildings consume 40% of the conventional form of energy. Therefore the western countries, in addition to consuming a major amount of fossil fuel energy are also main contributors of green house gases. Designing buildings in such a manner, so that the consumption of the fossil fuel energy could be minimized is the need of the hour. In this respect, the concept of Zero Energy Building (ZEB), which is a building with zero net energy consumption, was introduced. Zero Energy Building (ZEB) combines state-of-the-art, energy-efficient construction and appliances with commercially available renewable energy systems, such as solar water heating, solar electricity, etc. The combination results in a building that produces as much energy as it uses on an annual basis.

Besides mentioning the various micro-generation technologies such as solar cell, wind turbines for electricity and bio-fuels or solar thermal collectors linked to a seasonal thermal energy storage (STES) for space heating for ZEB, the scope of the principle of piezoelectric effect for the micro-production of electricity in future ZEB has also been pointed out. By optimizing the design features: such as climate specific design, passive solar heating and cooling, energy-efficient constructions and building products/materials, energy efficient appliances and lighting, renewable energy technologies (solar water, solar electric systems etc.). Apart from the above design features; the advantages such as improved comfort, reliability, energy security, environmental sustainability of ZEB over conventional type of buildings have been discussed. To the best of my knowledge this work has not been reported in this manner elsewhere.

Keywords: ZEB, STES, solar electric systems, piezoelectric effect, etc.

Introduction

A Zero Energy building (ZEB), is also known as Zero Net Energy (ZNE) building or Net-Zero Energy Building (NZEB) or Net Zero Building. ZEB is a building with zero net energy consumption. Zero net energy consumption implies that the total amount of energy used by the building on an annual basis is roughly equal to the amount of renewable energy created on the site. Traditional buildings consume 40% of the total fossil fuel energy in the US and European Union and are significant contributors of greenhouse gases. The zero net energy consumption principle is viewed as a means to reduce carbon emissions and reduce dependence on fossil fuel [1, 2]. Most of the ZEB use the electrical grid for energy storage but some are independent of grid. Energy is usually harvested on-site through a combination of energy producing technologies like solar. Wind, geothermal and piezoelectricity. The consumption of energy is minimized by using highly efficient HVAC (Heating, Ventilation and Air-Conditioning), which is the technology of thermal comfort and LEDs for lighting and producing as much energy as it consumes by using geothermal cooling systems and solar energy. The new office of the Grid Corporation of Odisha Ltd. (GRIDCO), in Bhubaneswar is being built as ZEB under the Odisha government's energy department. The building invites direct natural sunlight and screen radiation. It would have photovoltaic glass panels and geothermal cooling systems at strategic places along with its indigenous solar generating systems so that is sustained itself with own energy. The average running cost of energy for a standard building of this capacity amounts to Rs. 10/- per square feet, however, for this green project it will not be more than Rs. 2/- per square feet. Energy Performance Index (EPI) of the building will be roughly 90 KWh/sqm/year. Moreover Malankara Plantations Limited, situated in Kottayam [3], India is also a prominent Net Zero Energy Building of India. The office power consumption consists of 18 tons of air conditioning, followed by water pumps, three packing machines, IT/networking and lighting. It was connected to a private power grid owned by the local maharaja, but the complex experienced frequent blackouts due to power shortages on the electrical grid. With rising energy costs and increased availability of government subsidies, the company decided to install solar panels on the existing roof while preserving the historical integrity of the structure. The 27KW system consists of nine Out Back GVX inverters, seven flex max Charge Controllers and two Mate 3 communication devices.

Design and construction

Most cost-effective steps toward a reduction in a building's energy consumption usually occur during the design process. Successful zero energy building designers typically combine time tested passive solar, or artificial conditioning, principles that work with the on-site assets [4]. Sunlight and solar heat, prevailing breezes, and the cool of the earth below a building, can provide day lighting and stable indoor temperatures with minimum mechanical means.

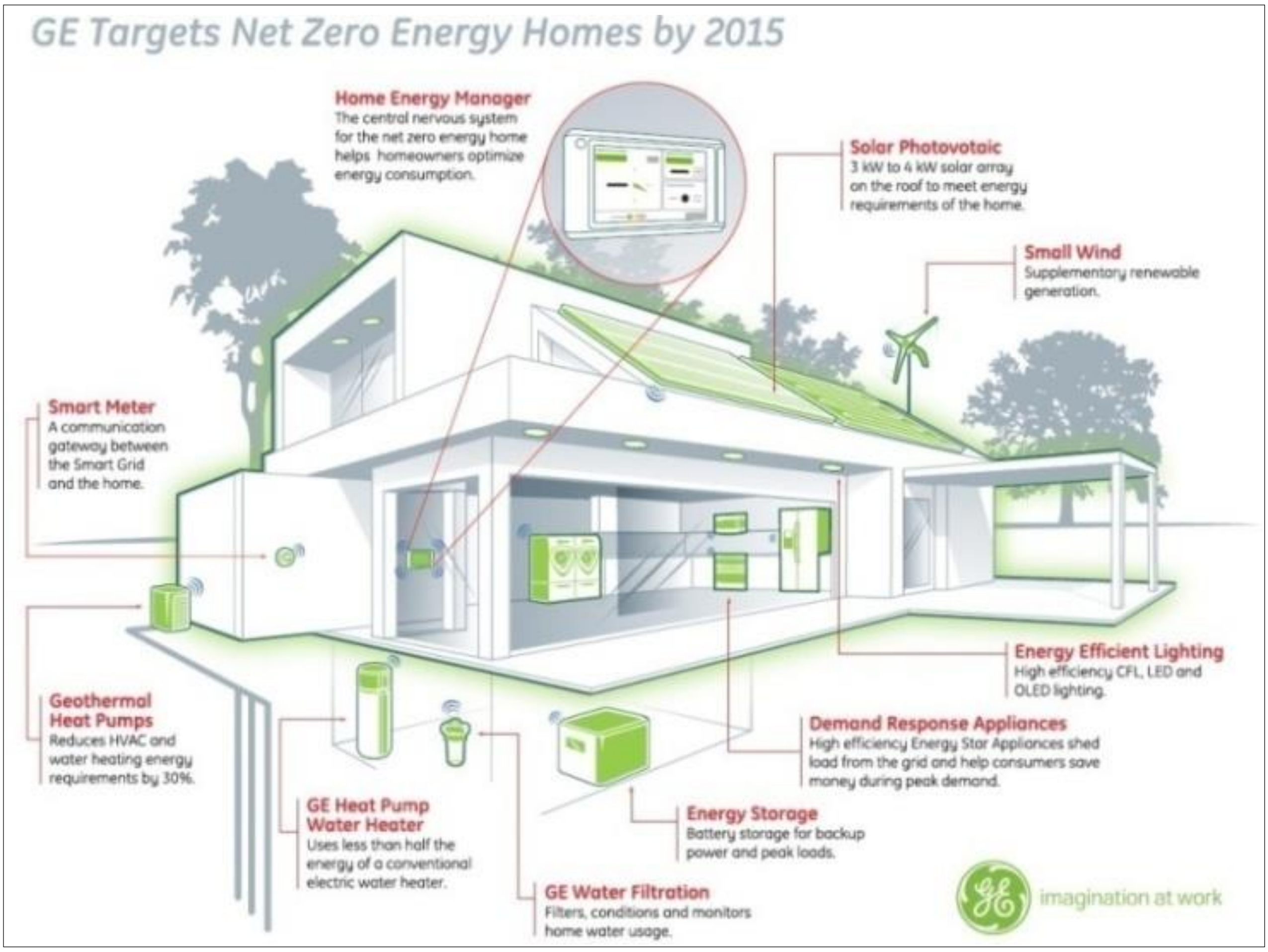

Fig 1: Sketch diagram of a ZEB

Sophisticated building energy simulation tools are available such as building orientation relative to the daily and seasonal position of the sun, window and door type and placement, overhang depth, insulation type and values of the building elements, air tightness, the efficiency of heating, cooling, lighting and other equipment, as well as local climate. Zero-energy buildings are built with significant energy-saving features. The heating and cooling loads are lowered by using high-efficiency equipment, super insulation high-efficiency windows, natural ventilation, and other techniques. These features vary depending on climate zones in which the construction occurs. Water heating loads can be lowered by using water conservation fixtures, heat recovery units on waste water, and by using solar water heating, and high-efficiency water heating equipment. In addition, day lighting with sky lights or solar tubes can provide 100% of daytime illumination within the home. Night time illumination is typically done with fluorescent and lighting that use one third or less power than incandescent lights, without adding unwanted heat and miscellaneous electric loads can be lessened by choosing efficient appliances and minimizing phantom loads or standby power. These buildings make use of heat energy that conventional buildings may exhaust outside.

Zero Energy Building: A Solution to Energy Crisis

This is astonishing that notwithstanding of having enormous amount of energy in our planet, we always cry that there is a great deficiency of energy. Data analysis show that about two fifth of the fossil fuel energy is being consumed by the traditional type of buildings. Therefore the concept of zero energy building has been introduced to protect ourselves from the energy crisis that we are facing today.

Zero Energy Building: A Solution to Global Warming

Global Warming is the increase of Earth's average surface temperature due to effect of green house gases, such as carbon dioxide emissions from burning fossil fuels or from deforestation, which trap heat that would otherwise escape from Earth. This is a type of greenhouse effect the most significant greenhouse gas is actually water vapor, not something produced directly by humankind in significant amounts. However, even slight increase in atmospheric levels of carbon dioxide can cause a substantial increase in temperature. This is because the concentrations of these gases are not nearly as large as that of oxygen and nitrogen. This is because neither has more than two atoms per molecule, and so they lack the internal vibrational modes that molecules with more than two atoms have. Both water and CO_2, for example, have these "internal vibrational modes" can absorb and reradiate infrared radiation, which causes the greenhouse effect.

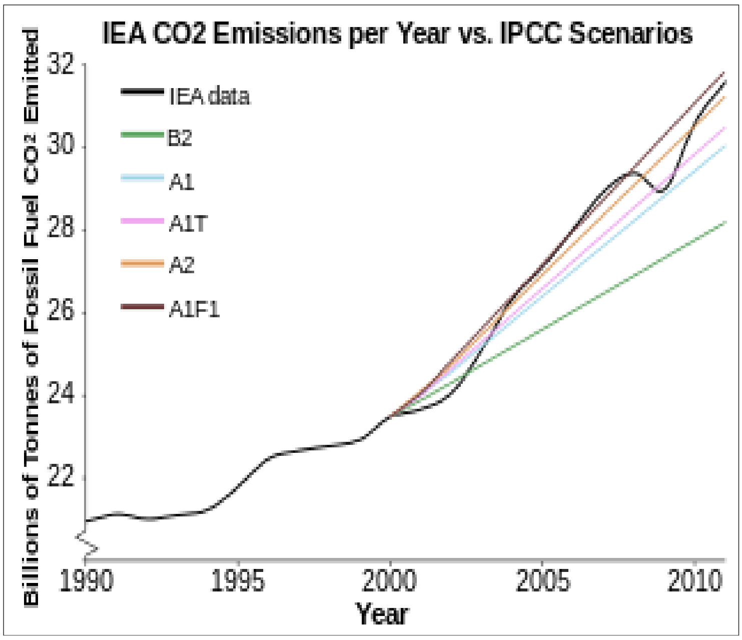

Fig 2: Fossil fuel related CO_2 emissions compared to five of the IPCC's "SRES" emissions.

The dips are related to global recessions. in 1998, the Inter governmental Panel on Climate Change (IPCC) was established by the World Meteorological Organization (WMO) and the United Nations Environment Program (UNEP), in recognition of the threat that global warming presents to the world. Zero energy buildings may or may not be considered "green" in all areas, such as reducing waste, using recycled building materials, etc. However, zero energy, or net-zero buildings do tend to have a much lower ecological impact over the life of the building compared with other "green" buildings that require imported energy and/or fossil fuel to be habitable and meet the needs of occupants. Outside the United States and Canada, a ZEB is generally defined as one with zero net energy emissions, also known as a zero carbon building or zero emissions building. Under this definition the carbon emissions generated from on-site or off-site fossil fuel use are balanced by the amount of on-site renewable energy production. Other definitions include not only the carbon emissions generated by the building in use, but also those generated in the construction of the building and the embodied energy of the structure. A crucially important technology will be carbon capture and storage (CCS) [5], which allows for the continued use of fossil fuels in the future energy mix. Coal is widely used to generate electricity in many of the world's largest economies (especially the USA, China and India) and without CCS technology there is little chance that their energy demands can be met whilst at the same time reducing greenhouse gas emissions. It is also important to note that geothermal plants can be installed with the help of special programs that offer low interest rate loans. Electricity generated by geothermal plants saves 83.3 million barrels of fuel each year from being burned world-wide. This prevents 40.2 million tons of CO_2 from being emitted into the atmosphere. It is also important to note here that direct use of geothermal energy prevents 103.6 million barrels of fuel each year from being burned world- wide. This stops 49.6 tons of CO_2 from being emitted into the atmosphere.

Results and Discussions

This is beyond doubt that by constructing Zero Energy Buildings, the problems of energy crisis and global warming can be controlled in a magnificent way. Why renewable sources of energy are important for preventing shortage of traditional sources of energy and emission of green house gases, the comparison between non-renewable sources of energy and renewable sources of energy, which are the very part of the world energy resources, is necessary:-

World energy resources (Non Renewable Energy Resources & Renewable resources)

The world's energy resources can be divided into fossil fuel, nuclear fuel and renewable resources. The estimates for the amount of energy in these resources is given in zettajoules (ZJ), which is 10 [21] joules.

(**A) Non-Renewable Energy Resources (Fossils Fuel & Nuclear fuel**)

(1) Coal: It the most abundant and burned fossil fuel, which launched the industrial revolution and has continued to grow in use. . According to the IEA the proven reserves of coal are around 909 billion tonnes, which could sustain the current production rate for 155 years' [7] although at a 5% growth per annum this would be reduced to 45 years, or until 2051. With the Fischer-Tropsch process it is possible to make liquid fuels such as diesel and jet fuel from coal. In the United States, 49% of electricity generation comes from burning coal [7, 8].

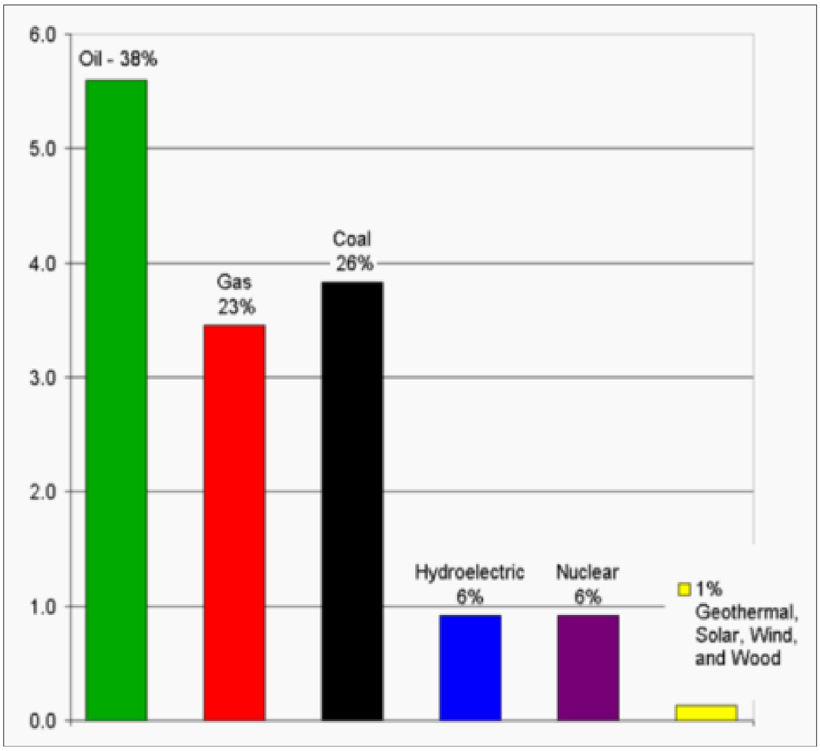

Fig 3: Worldwide Energy Sources graph [6]

(2) Oil: It is estimated that there may be 57 ZJ of oil reserves [9] on Earth (although estimates vary from a low of 8 ZJ, consisting proven and recoverable reserves, to a maximum of 110 ZJ consisting of available.

(3) Nuclear fission: The International Atomic Energy Agency estimates the remaining uranium resources to be equal to 2500 ZJ [10]. This assumes the use of breeder reactors, which are able to create more fissile material than they consume. IPCC estimated currently proved economically recoverable uranium deposits for once-through fuel cycles reactors to be only 2 ZJ. The ultimately recoverable uranium is estimated to be 17 ZJ for once-through reactors and 1000 ZJ with reprocessing and fast breeder reactors.

(4) Nuclear fusion: Fusion is the source of energy for the sun and other stars. It generates large quantities of heat by fusing the nuclei of hydrogen or helium isotopes, which may be derived from seawater. The heat can theoretically be harnessed to generate electricity. The temperatures and pressures needed to sustain fusion make it a very difficult process to control. Fusion is theoretically able to supply vast quantities of energy, with relatively little pollution.

(B)Renewable resources

(1) Solar energy: Radiant energy from the sun is being harnessed by humans since ancient times, using a range of ever-evolving technologies. Solar energy technologies include solar heating, solar photovoltaic, solar thermal electricity, solar architecture and artificial photosynthesis, which can make considerable contributions to solving some of the most urgent energy problems the world now faces. Renewable energy sources are even larger than the traditional fossil fuels and in theory can easily supply the world's energy needs. 89 PW [11] of solar power falls on the planet's surface. While it is not possible to capture all, or even most, of this energy, capturing less than 0.02% would be enough to meet the current energy needs. Barriers to further solar generation include the high price of making solar cells and reliance on weather patterns to generate electricity. Also, current solar generation does not produce electricity at night, which is a particular problem in high northern and southern latitude countries; energy demand is highest in winter, while availability of solar energy is lowest. This could be overcome by buying power from countries closer to the equator during winter months, and may also be addressed with technological developments such as the development of inexpensive energy storage. Globally, solar generation is the fastest growing source of energy, seeing an annual average growth of 35% over the past few years. Japan, Europe, China, U.S and India are the major growing investors in solar energy. Solar energy is converted into electrical energy by a solar cell or photovoltaic cell, which works on the principle of photoelectric effect. In contrast, a solar thermal collector supplies heat by absorbing sunlight, for the purpose of either direct heating or indirect electrical power generation from heat. India is densely populated and has high solar insolation (solar irradiation), an ideal combination for using solar power in India.

(2) Wind power: The available wind energy estimates range from 300 TW to 870 TW [12]. Using the lower estimate, just 5% of the available wind energy would supply the current worldwide energy needs. Most of this wind energy is available over the open ocean. The oceans cover 71% of the planet and wind tends to blow more strongly over open water because there are fewer obstructions.

(3) Wave and tidal power: At the end of 2005, 0.3 GW of electricity was produced by tidal power. Due to the tidal forces created by the Moon (68%) and the Sun (32%), and the Earth's relative rotation with respect to Moon and Sun, there are fluctuating tides. These tidal fluctuations result in dissipation at an average rate of about 3.7 TW. Another physical limitation is the energy available in the tidal fluctuations of the oceans, which is about 0.6 EJ (exajoule). Note this is only a tiny fraction of the total rotational energy of the Earth. Waves are derived from wind, which in turn is derived from solar energy, and at each conversion there is a drop of about two orders of magnitude in available energy. The total power of waves that wash against our shores add up to 3 TW.

(4) Geothermal: Geothermal energy is thermal energy generated and stored in the Earth. Thermal energy is the energy that determines the temperatures of matter. The geothermal energy of the Earth's crust originates from the original formation of the planet (20%) and from radioactive decay of minerals (80%). The geothermal gradient, which is the difference in temperature between the core of the planet and its surface, drives a continuous conduction of thermal energy in the form of heat from the core to the surface. Earth's internal heat is thermal energy generated from radioactive decay and continual heat loss from Earth's formation. Temperatures at the core –mantle boundary may reach over 4000 °C [13]. The high temperature and pressure in Earth's interior cause some rock to melt and solid mantle to behave plastically, resulting in portions of mantle – convecting upward since it is lighter than the surrounding rock. Rock and water is heated in the crust, sometimes up to 370 °C [14]**.** According to a 1999 study, it was thought that this might amount to between 65 and 138 GW of electrical generation capacity 'using enhanced technology'. Other estimates range from 35 to 2000 GW of electrical generation capacity, with a further potential for 140 EJ/year of direct use. Geothermal Heat Pumps produces 4 times the energy that they consume. Initially costs more to install, but its maintenance cost is 1/3 of the cost for a typical conventional heating system and it decreases electric bill. This means that geothermal space heating will save the consumer money.

(5) Biomass: Production of biomass and biofuels are growing industries as interest in sustainable fuel sources is growing. Utilizing waste products avoids a food vs food trade-off, and burning gas reduces greenhouse gas emissions, because even though it releases carbon dioxide, carbon dioxide is 23 times less of a greenhouse gas than is methane. Biofuels represent a sustainable partial replacement for fossil fuels, but their net impact on greenhouse gas emissions depends on the agricultural practices used to grow the plants used as feedstock to create the fuels. While it is widely believed that biofuels can be carbon-neutral, there is evidence that biofuels produced by current farming methods are substantial net carbon emitters. Geothermal and biomass are the only two renewable energy sources that require careful management to avoid local depletion.

(6) Hydropower: In 2005, hydroelectric power supplied 16.4% of world electricity, down from 21.0% in 1973, but only 2.2% of the world's energy.

(7) Piezoelectricity: Nowadays most of the research in the energy field is to develop sources of energy for future with all resources being over tapped and eventually bound to end. It is time to find renewal source of energy for the future. Piezoelectric effect materials are being more and more studied as they turn out to be very unsual materials with very specific and interesting properties. In fact, these materials have the ability to produce electrical energy from mechanical energy. While recent experiments have shown that there materials could be used as power generators, the amount of energy produced is very low hence the necessity to optimize it. Quartz (SiO_2) Quartz shows a strong piezoelectric effect perpendicularly to the prism axis. Applying pressure on a quartz crystal generates an electrical polarization along the pressure direction. Alternatively, applying an electrical tension leads to a mechanical deformation of the crystal. Other piezoelectric materials are $AlPO_4$, $GaPO_4$, AlN, Lithium tantalite, Lanthanum gallium silicate, Potassium sodium tartrate, $BaTiO_3$, $KNbO_3$, $Ba_2NaNb_5O_5$, $LiNbO_3$, $SrTiO_3$, Pb $(ZrTi)O_3$, $Pb_2KNb_5O_{15}$, $LiTaO_3$, $BiFeO_3$ [15]. Recently, it has been reported that polyvinylidene fluoride flu (PVDF) [16] (transparent, semi-crystalline, thermoplastic fluoroplastic) as a piezoelectric element. Piezoelectric polymer is fully integrated in the footwear. When the people walk the piezoelectric polymer gets compressed and the energy is generated. An electronic circuit which includes Schottky diodes is used to generate dc voltage. An electrostatic generator is also included in order to increase energy harvesting. To provide the required energy value to the load a lithium battery has been used.

This is quite obvious from the above description that to counter energy crisis, we will have to develop the techniques to harvest renewable sources of energy so that efficient ZEB could be made.

Conclusions

Residential and commercial buildings consume about forty percent of the primary energy and seventy percent of the total electricity in the world. That is a huge burden on the electrical system, energy resource availability, emissions, and economic viability. The decisions we make on design teams will influence the energy future of the world. We have the potential to change how buildings use energy, to the point of creating ZEBs in the coming decades. As a profession, we all need to strive to achieve this goal and help facilitate decisions that are economically responsible, environmentally sound, aesthetically pleasing, and occupant friendly. As a starting point, we need to strive to create low-energy buildings. Constructing market-viable buildings that use substantially less energy is possible today. Many times it involves careful planning and creating an engineered sys-tem-something that requires the entire design team early in the process. The developed countries along with large developing countries such as China, India, Russia and Brazil must adopt a common position on climate change, focused on reducing greenhouse gas emissions through an effective cross-border market and technology transfer mechanism. Moreover Despite of having some disadvantages like higher initial costs and lessening the values of capital invested in energy efficiency due to possible declines in future utility company renewable energy costs, the advantages like integration of renewable energy resource and plug-in electric vehicles, reduced total cost of ownership due to improved energy efficiency, reduced total net monthly cost of living, isolation for building owners from future energy price increases, reduced carbon emission and improved reliability as photovoltaic systems have 25-year warranties.

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