Zero-Energy Buildings

A **zero energy building** (**ZEB**) or **net zero energy building** is a general term applied to a building's use with zero net energy consumption and zero carbon emissions annually. Zero energy buildings can be used autonomously from the energy grid supply – energy can be harvested on-site. The net zero design principle is overlaid on the requested comfort of the building occupant. Generally, the more extreme the exposure to the elements the more energy is needed to achieve a comfortable environment of human use.

The zero fossil energy consumption principle is gaining considerable interest as renewable energy harvesting is a means to cut greenhouse gas emissions. Traditional building use consumes 40% of the total fossil energy in the US and European Union. [1] [2] In developing countries many people have to live in zero-energy buildings out of necessity. Many people live in huts, yurts, tents and caves exposed to temperature extremes and without access to electricity. These conditions and the limited size of living quarters would be considered uncomfortable in the developed countries.

The modern evolution of zero-energy buildings

The development of modern zero-energy buildings became possible not only through the progress made in new construction technologies and techniques, but it has also been significantly improved by academic research on traditional and experimental buildings, which collected precise energy performance data. Today's advanced computer models can show the efficacy of engineering design decisions.

Energy use can be measured in different ways (relating to cost, energy, or carbon emissions) and, irrespective of the definition used, different views are taken on the relative importance of energy harvest and energy conservation to achieve a net energy balance. Although zero energy buildings remain uncommon in developed countries, they are gaining in importance and popularity. The zero-energy approach has potential to reduce carbon emissions, and reduce dependence on fossil fuels. Most ZEB definitions do not include the emissions generated in the construction of the building and the embodied energy of the structure. So much energy is used in the construction of a new building that this can dwarf the operational energy savings over its useful life.

A building approaching net zero-energy use may be called a *near-zero energy building* or *ultra-low energy house*. Buildings that produce a surplus of energy during a portion of the year may be known as *energy-plus buildings*.

If the building is located in an area that requires heating or cooling throughout parts of the year, it is easier to achieve net zero-energy consumption when the available living space is kept small.

Definitions

Despite sharing the name **zero energy building**, there are several definitions of what ZEB means in practice, with a particular difference in usage between North America and Europe. [3]

Net zero site energy useIn this type of ZEB, the amount of energy provided by on-site renewable energy sources is equal to the amount of energy used by the building. In the United States, “zero energy building” generally refers to this type of building. Net zero source energy useThis ZEB generates the same amount of energy as is used, including the energy used to transport the energy to the building. This type accounts for losses during electricity transmission. These ZEBs must generate more electricity than net zero site energy buildings.Net zero energy emissionsOutside 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. Others debate whether the carbon emissions of commuting to and from the building should also be included in the calculation.Net zero costIn this type of building, the cost of purchasing energy is balanced by income from sales of electricity to the grid of electricity generated on-site. Such a status depends on how a utility credits net electricity generation and the utility rate structure the building uses.Net off-site zero energy useA building may be considered a ZEB if 100% of the energy it purchases comes from renewable energy sources, even if the energy is generated off the site.Off-the-gridOff-the-grid buildings are stand-alone ZEBs that are not connected to an off-site energy utility facility. They require distributed renewable energy generation and energy storage capability (for when the sun is not shining, wind is not blowing, etc). An energy autarkic house is a building concept where the balance of the own energy consumption and production can be made on an hourly or even smaller basis. Energy autarkic houses can be taken off-the-grid.

Design and construction

The most cost-effective steps toward a reduction in a building's energy consumption usually occurs during the design process. [4] To achieve efficient energy use, zero energy design departs significantly from conventional construction practice. Successful zero energy building designers typically combine time tested passive solar, or natural conditioning, principles that work with the on site assets. Sunlight and solar heat, prevailing breezes, and the cool of the earth below a building, can provide daylighting and stable indoor temperatures with minimum mechanical means. Z.E.B.'s are normally optimized to use passive solar heat gain and shading, combined with thermal mass to stabilize diurnal temperature variations throughout the day, and in most climates are superinsulated. [5] All the technologies needed to create zero energy buildings are available off-the-shelf today. Sophisticated 3D computer simulation tools are available to model how a building will perform with a range of design variables 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 (weatherization), the efficiency of heating, cooling, lighting and other equipment, as well as local climate. These simulations help the designers predict how the building will perform before it is built, and enable them to model the economic and financial implications on building cost benefit analysis, or even more appropriate - life cycle assessment.

Zero-Energy Buildings are usually built with significant energy-saving features. The heating and cooling loads are often drastically lowered by using high-efficiency equipment, added insulation, high-efficiency windows, natural ventilation, and other techniques. These features can vary drastically between buildings in different climate zones. Water heating loads can be lowered using water conservation fixtures, heat recovery units on waste water, and by using solar water heating, and high-efficiency water heating equipment. In addition, free solar daylighting with skylites or solartubes can provide 100% of daytime illumination. Nighttime illumination is typically done with fluorescent and LED lighting that use 1/3 or less of the power of incandescent lights, without adding unwanted heat that incandescent lights do. And miscellaneous electric loads can be lessened by choosing efficient appliances and minimizing phantom loads or standby power. Other techniques to reach net zero (dependent on climate) are Earth sheltered building principles, superinsulation walls using straw-bale construction, and exterior landscaping for seasonal shading.

Zero-energy buildings are often designed to make dual use of energy including white goods; for example, use refrigerator exhaust to heat domestic hot water, ventilation air and shower drain heat exchangers, office machines and computer servers, and even body heat from rooms with multiple occupants. These buildings make use of heat energy that conventional buildings typically exhaust outside. They may use heat recovery ventilation, hot water heat recycling, combined heat and power, and absorption chiller units.

Energy harvest

ZEBs harvest available energy to meet their electricity and heating or cooling needs. In the case of individual houses, various microgeneration technologies may be used to provide heat and electricity to the building, using solar cells or wind turbines for electricity, and biofuels or solar collectors linked to seasonal thermal stores for space heating. To cope with fluctuations in demand, zero energy buildings are frequently connected to the electricity grid, export electricity to the grid when there is a surplus, and drawing electricity when not enough electricity is being produced. Other buildings may be fully autonomous.

Energy harvesting is most often more effective (in cost and resource utilization) when done on a local but combined scale, for example, a group of houses, co-housing, local district, village, etc. rather than an individual basis. A benefit of such localized energy harvesting (note localised as opposed to individual) is the elimination of electrical transmission and electricity distribution losses. These losses amount to about 7.2%-7.4% of the energy transferred. [6] Energy harvesting in commercial and industrial applications should benefit from the topography of each location. The production of goods under net zero fossil energy consumption requires locations of Geothermal, Microhydro, Solar, and Wind resources to sustain the concept.

Zero-energy neighborhoods, such as the BedZED development in the United Kingdom, and those that are spreading rapidly in California and China, may use distributed generation schemes. This may in some cases include district heating, community chilled water, shared wind turbines, etc. There are current plans to use ZEB technologies to build entire off-the-grid or net zero energy use cities.

The "energy harvest" versus "energy conservation" debate

One of the key areas of debate in zero energy building design is over the balance between energy conservation and the distributed point-of-use harvesting of renewable energy (solar energy, and wind energy. Most zero energy homes use a combination of the two strategies. [7]

As a result of significant government subsidies for photovoltaic solar electric systems, wind turbines, etc., there are those who suggest that a ZEB is a conventional house with distributed renewable energy harvesting technologies. Entire additions of such homes have appeared in locations such as California [8] and other locations where photovoltaic (PV) subsidies are significant, [9] but many so called "Zero Energy Homes" still have utility bills. This type of energy harvesting without added energy conservation may not be cost effective with the current price of electricity generated with photovoltaic equipment (depending on the local price of power company electricity), [10] and also requires greater embodied energy and greater resources and is thus the lesser ecological approach..

For three decades, passive solar building design and Passive house has demonstrated heating energy consumption reductions of 70% to 90% in many locations, without using any active energy harvesting systems. With expert design, this can be accomplished with little additional new construction cost for materials over a conventional building. Very few industry experts have the skills or experience to fully capture benefits of the passive design. Such passive solar designs are much more cost effective than adding expensive photovoltaic panels on the roof of a conventional inefficient building. [10] A few kilowatt-hours of photovoltaic panels (costing 2 to 3 dollars per annual kW-hr production, U.S. dollar equivalent) may only reduce external energy requirements by 15% to 30%. A 100,000 BTU (110 MJ) high seasonal energy efficiency ratio 14 conventional air conditioner requires over 7 kW of photovoltaic electricity while it is operating, and that does not include enough for off-the-grid night time operation. Using passive cooling, and superior system engineering techniques, can reduce the air conditioning requirement by 70% to 90%. Photovoltaic generated electricity becomes more cost-effective when the overall demand for electricity is lower.

Occupant behavior

The energy used in a building can vary greatly depending on the behavior of its occupants. The acceptance of what is considered comfortable varies widely. Studies of identical homes in the United States have shown dramatic differences in energy use, with some homes using more than twice the energy of others. [11] Occupant behavior can vary from differences in setting and programming thermostats, varying levels of illumination and hot water, and the amount of miscellaneous electric devices used. [4]

ZEB development efforts

Wide acceptance of zero energy building technology may require more government incentives or building code regulations, the development of recognized standards, or significant increases in the cost of conventional energy.

The Google photovoltaic campus, and the Microsoft 480-kilowatt photovoltaic campus relied on U.S. Federal, and especially California, **subsidies** and financial incentives. California is now providing $3.2 billion USD in subsidies [12] for residential-and-commercial near-zero-energy buildings, due to California's serious electricity shortage, frequent power outages, and air pollution problems. The details of other American states' renewable energy subsidies (up to $5.00 USD per watt) can be found in the Database of State Incentives for Renewables and Efficiency. [13]

The Florida Solar Energy Center has a slide presentation on recent progress in this area. [14]

The **World Business Council for Sustainable Development** [15] has launched a major initiative to support the development of ZEB. Led by the CEO of United Technologies and the Chairman of Lafarge, the organization has both the support of large global companies and the expertise to mobilize the corporate world and governmental support to make ZEB a reality. Their first report, a survey of key players in real estate and construction, indicates that the costs of building green are overestimated by 300 percent. Survey respondents estimated that greenhouse gas emissions by buildings are 19 percent of the worldwide total, in contrast to the actual value of roughly 40 percent. [16]

Influential zero- and low-energy buildings

Those who commissioned construction of Passive Houses and Zero Energy Homes (over the last three decades) were essential to iterative, incremental, cutting-edge, technology innovations. Much has been learned from many significant successes, and a few expensive failures.

The zero energy building concept has been a progressive evolution from other low-energy building designs. Among these, the Canadian R-2000 and the German *passive house* standards have been internationally influential. Collaborative government demonstration projects, such as the superinsulated Saskatchewan House, and the International Energy Agency's

Task 13
, have also played their part.

Advantages and disadvantages of ZEBs
ZEB advantages

- isolation for building owners from future energy price increases
- increased comfort due to more-uniform interior temperatures (this can be demonstrated with comparative isotherm maps)
- reduced requirement for energy austerity
- reduced total cost of ownership due to improved energy efficiency
- reduced total net monthly cost of living
- improved reliability - photovoltaic systems have 25-year warranties - seldom fail during weather problems - the 1982 photovoltaic systems on the Walt Disney World EPCOT Energy Pavilion are still working fine today, after going through 3 recent hurricanes
- extra cost is minimized for new construction compared to an afterthought retrofit
- higher resale value as potential owners demand more ZEBs than available supply
- the value of a ZEB building relative to similar conventional building should increase every time energy costs increase
- future legislative restrictions, and carbon emission taxes/penalties may force expensive retrofits to inefficient buildings

ZEB disadvantages

- initial costs can be higher - effort required to understand, apply, and qualify for ZEB subsidies
- very few designers or builders have the necessary skills or experience to build ZEBs [17]
- possible declines in future utility company renewable energy costs may lessen the value of capital invested in energy efficiency
- new photovoltaic solar cells equipment technology price has been falling at roughly 17% per year - It will lessen the value of capital invested in a solar electric generating system - Current subsidies will be phased out as photovoltaic mass production lowers future price
- challenge to recover higher initial costs on resale of building - appraisers are uninformed - their models do not consider energy
- climate-specific design may limit future ability to respond to rising-or-falling ambient temperatures (global warming)
- while the individual house may use an average of net zero energy over a year, it may demand energy at the time when peak demand for the grid occurs. In such a case, the capacity of the grid must still provide electricity to all loads. Therefore, a ZEB may not reduce the required power plant capacity.
- without an optimised thermal envelope the embodied energy, heating and cooling energy and resource usage is higher than needed. ZEB by definition do not mandate a minimum heating and cooling performance level thus allowing oversized renewable energy systems to fill the energy gap.
- solar energy capture using the house envelope only works in locations unobstructed from

the South. The solar energy capture cannot be optimized in South facing shade or wooded surroundings.

Zero energy building versus green building

The goal of green building and sustainable architecture is to use resources more efficiently and reduce a building's negative impact on the environment. [18] Zero energy buildings achieve one key green-building goal of completely or very significantly reducing energy use and greenhouse gas emissions for the life of the building. 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.

Because of the design challenges and sensitivity to a site that are required to efficiently meet the energy needs of a building and occupants with renewable energy (solar, wind, geothermal, etc), designers must apply holistic design principles, and take advantage of the free naturally occurring assets available, such as passive solar orientation, natural ventilation, daylighting, thermal mass, and night time cooling.

Many Green building certification programs do not require a building to have net zero energy use, only to reduce energy use a few percentage points below the minimum required by law. The Leadership in Energy and Environmental Design (LEED) certification developed by the U.S. Green Building Council, and Green Globes, involve check lists that are measurement tools, not design tools. Inexperienced designers or architects may cherry-pick points to meet a target certification level, even though those points may not be the best design choices for a specific building or climate.

Zero-energy buildings worldwide

Australia

- The Energised House in Portland Victoria was built to raise awareness and interest in self-reliant & carbon zero housing. The house has a high level of thermal energy efficiency, using passive techniques to reduce its artificial heating and cooling requirements by approximately 95%. The house also uses very efficient appliances, which are powered by a 1.4 kW solar photovoltaic system. Completion was in 2009 and the house is currently occupied by a family of four with regular public open days for inspections. Energised House

Canada

- In Canada the Net-Zero Energy Home Coalition [19] is an industry association promoting net-zero energy home construction and the adoption of a near net-zero energy home (nNZEH), NZEH Ready and NZEH standard.
- The Canada Mortgage and Housing Corporation is sponsoring the EQuilibrium Sustainable Housing Competition [20] that will see the completion of fifteen zero-energy and near-zero-energy demonstration projects across the country starting in 2008.

- The Now House Project, which is a retrofit of a postwar home in Toronto, Ontario.
- The Riverdale project is a duplex near Edmonton, Alberta, completed in 2008. [21]
- The EcoTerra TM House in Eastman, Quebec, is Canada's first nearly net zero-energy housing built through the CMHC EQuilibrium Sustainable Housing Competition. [22] The house was designed by Dr. Masa Noguchi of the Mackintosh School of Architecture for Alouette Homes and engineered by Prof. Dr. Andreas K. Athienitis of Concordia University. [23]

- Alstonvale Net Zero House project, [24] Hudson, Quebec, led by the Montreal-based architect Sevag Pogharian.

China

- One example of the new generation of zero energy office buildings is the 71-story Pearl River Tower, which is scheduled to open in 2009, as the Guangdong Company headquarters. It uses both modest energy efficiency, and a big distributed renewable energy generation from both solar and wind. Designed by Skidmore Owings Merrill LLP in Guangzhou, China, [25] the tower is receiving economic support from government subsidies that are now funding many significant conventional fossil-fuel (and nuclear energy) energy reduction efforts.

- Dongtan Eco-City near Shanghai

Germany

- Technische Universität Darmstadt won first place in the international zero energy design 2007 Solar Decathlon competition, with a passivhaus design (Passive house) + renewables, scoring highest in the Architecture, Lighting, and Engineering contests [26]
- *Self-Sufficient Solar House* Fraunhofer Institute for Solar Energy Systems (ISE), Freiburg im Breisgau

Ireland

In 2005 *Scandinavian Homes* [27] launched the worlds first standardised passive house in Ireland, this concept makes the design and construction of passive house a standardised process. Conventional low energy construction techniques have been refined and modelled on the PHPP (Passive House Design Package) to create the standardised passive house. Building offsite allows high precision techniques to be utilised and reduces the possibility of errors in

construction.
In 2009 the same company started a project to use 23,000 liters of water in a *seasonal storage tank* , [28] heated up by evacuated solar tubes throughout the year, with the aim to provide the house with enough heat throughout the winter months thus eliminating the need for any electrical heat to keep the house comfortably warm. The system is monitored and documented by a research team from The University of Ulster and the results will be included in part of a PhD thesis.

Malaysia

In October 2007, the Malaysia Energy Centre (PTM) successfully completed the development and construction of the PTM Zero Energy Office (ZEO) Building. The building has been designed to be a super-energy-efficient building using only 286 kW·h/day. The renewable energy - photovoltaic combination is expected to result in a net zero energy requirement from the grid. The building is currently undergoing a fine tuning process by the local energy management team. Findings are expected to be published in a year. [29]

Norway

In February 2009, the Research Council of Norway assigned The Faculty of Architecture and Fine Art at the Norwegian University of Science and Technology to host the Research Centre on Zero Emission Buildings (ZEB), which is one of eight new national Centres for Environment-friendly Energy Research (FME). The main objective of the FME-centres is to contribute to the development of good technologies for environmentally friendly energy and to raise the level of Norwegian expertise in this area. In addition, they should help to generate new industrial activity and new jobs. Over the next eight years, the FME-Centre ZEB will develop competitive products and solutions for existing and new buildings that will lead to market penetration of zero emission buildings related to their production, operation and demolition.

- The Research Centre on Zero Emission Buildings, Norway

Singapore

Singapore's First Zero Energy Building Launched at the Inaugural Singapore Green Building Week

http://www.bca.gov.sg/Newsroom/others/SGBWb_ZEB_Media_release_non.pdf

United Arab Emirates

- Masdar City in Abu Dhabi

United Kingdom

Further information: Energy efficiency in British housing

In the English region of the United Kingdom, in December 2006 the government announced that by 2016 all new homes will be zero energy buildings. To encourage this, an exemption from Stamp Duty Land Tax is planned. In Wales the plan is for the standard to be met earlier in 2011, although it is looking more likely that the actual implementation date will be 2012.

- BedZED development
- The Hockerton Housing Project

United States

In the U.S., ZEB research is currently being supported by the US Department of Energy (DOE) Building America Program [30] , including industry-based consortia and researcher organizations at the National Renewable Energy Laboratory (NREL), the Florida Solar Energy Center (FSEC), Lawrence Berkeley National Laboratory (LBNL), and Oak Ridge National Laboratory (ORNL). From fiscal year 2008 to 2012, DOE plans to award $40 million to four Building America teams, the Building Science Corporation; IBACOS; the Consortium of Advanced Residential Buildings; and the Building Industry Research Alliance, as well as a consortium of academic and building industry leaders. The funds will be used to develop net-zero-energy homes that consume at 50% to 70% less energy than conventional homes. [31]

DOE is also awarding $4.1 million to two regional building technology application centers that will accelerate the adoption of new and developing energy-efficient technologies. The two centers, located at the University of Central Florida and Washington State University , will serve 17 states, providing information and training on commercially available energy-efficient technologies. [31]

The U.S. Energy Independence and Security Act of 2007 [32] created 2008 through 2012 funding for a new solar air conditioning research and development program, which should soon demonstrate multiple new technology innovations and mass production economies of scale.

Arizona

- Zero Energy House developed by the NAHB Research Center and John Wesley Miller Companies, Tucson.

California

- One of the first zero-energy commercial buildings in the United States is Integrated Design Associates Z-Squared Design Facility.

- Googleplex, Google's headquarters in Mountain View, California, completed a 1.6 megawatt photovoltaic campus-wide renewable power generation system. Google (and others) have developed advanced technology for major reductions in computer-server energy consumption (which is becoming a major portion of modern zero-energy commercial building design, along with daylighting and efficient electrical lighting systems).

- The [[Audubon Center at Debs Park]] is an example of an off-the-grid zero energy building that relies on extensive energy efficiency strategies combined with solar thermal and photovoltaic renewable energy systems to supply its energy needs.
- Palo Alto Net Zero Energy House - The Palo Alto Net Zero House is the green renovation of a home in Palo Alto, California. Completed in June 2009, the house is net zero energy.

Colorado

- Van Geet Off-Grid Home [33]
- NREL/Habitat for Humanity Net-Zero Energy Demonstration Home, Wheat Ridge, CO. [34]

Florida

The 1999 side-by-side Florida Solar Energy Center Lakeland Florida demonstration project [35] was called the "Zero Energy Home." It was a first-generation university effort that significantly influenced the creation of the U.S. Department of Energy, Energy Efficiency and Renewable Energy, Zero Energy Home program. George Bush's Solar America Initiative is funding research and development into widespread near-future development of cost-effective Zero Energy Homes in the amount of $148 million in 2008. [36]

[37]

New Jersey

- The 31 Tannery Project , located in Branchburg, New Jersey, serves as the corporate headquarters for Ferreira Construction, the Ferreira Group, and Noveda Technologies. The 42,000-square-foot (3,900 m^2) office and shop building was constructed in 2006 and is the 1st building in the state of New Jersey to meet New Jersey's Executive Order 54. The building is also the first Net Zero Electric Commercial Building in the United States.

New York

- Hudson Valley Clean Energy in Rhinebeck, NY has proven it is zero net energy. 15 kW of solar pv, geothermal heating and cooling and air tight construction allow this building to generate more energy than it consumes to heat, cool and power the building. After one year of operation the unassuming metal building generated more than 110% of total energy consumption.

North Carolina

- Habitat for Humanity/ Appalachian State University house , Hickory.

Vermont

- The Putney School's net zero Field house was opened October 10, 2009.

- The Charlotte house located in Charlotte Vermont was designed by Pill-Maharam Architects , it has documented zero net energy use since it was built in 2007. It is a modern farmhouse which uses passive solar design, super insulation and a ground source heat pump. The house produces all of its energy with a 10 kW wind turbine.

Wisconsin

- The Aldo Leopold Legacy Center in Baraboo, WI, is a 12,000 square-foot complex by The Kubala Washatko Architects (TKWA), completed in 2007. It earned a LEED Platinum rating. [38]

See also

- Category: Low-energy building
- Autonomous buildings
- Building-integrated photovoltaics
- Earthship
- Ecocities
- Energy conservation
- Energy Neutral Design
- Environmental design
- Environmental economics
- Green building
- Home energy monitor
- Life cycle analysis
- List of low-energy building techniques
- Low-energy house
- Natural Building
- Off-the-grid
- Passive cooling
- Passive house (Passivhaus standard)
- Passive solar building design
- Passive solar
- Peak oil
- Sustainable design

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External links

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- Oak Ridge National Laboratory Building Technologies and Integration Center

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