FESC
Florida Energy Systems Consortium

NET ZERO ENERGY HOMES (ZEHS)

Introduction

Net zero energy homes (ZEHs) and buildings (ZEBs) are "on-grid" structures that produce renewable energy onsite at a value equal to, or greater than, the building's total annual energy consumption. The "net" portion means the building may use energy from the utility grid (electricity and/or natural gas) during some times of the day (such as at night) but supplies renewable energy back to the grid during other times, in a balance that equals out over the course of a year.

There are some variations in the definition of what "net zero" measures such as:

- **Net zero site energy.........*m - r ≤ 0***
  - *m* = end use consumption measured at the building's utility meter(s)
  - *r* = renewable energy produced onsite
- **Net zero source energy....*m + g - r ≤ 0***
  - *m* = end use consumption measured at the building's utility meter(s)
  - *g* = energy losses within the utility grid from the conversion and transmission process
  - *r* = renewable energy produced onsite
- **Net zero cost....................*$m - $r ≤ 0***
  - *$m* = cost of purchased grid-based energy
  - *$r* = income from renewable energy produced onsite
- **Net zero carbon...............$CO_2m - CO_2r \leq 0$**
  - CO_2m = metric tonnes of carbon dioxide equivalent ($MtCO_2e$) emitted from grid-based energy sources
  - CO_2r = metric tonnes of carbon dioxide equivalent ($MtCO_2e$) avoided by on-site carbon neutral sources (e.g., renewables like solar photovoltaic, biomass like wood pellets)

Quick Facts & Impacts

- ZEHs = energy demand reduction (50-70%) + renewable energy supply (30-50%)
- Most estimates project a need for > 80% reduction in greenhouse gas emissions by the year 2050 and ZEHs can help
- ZEH status is difficult but possible for both new and existing buildings

Potential Benefits:

- ↓ living costs and ↑ occupant comfort
- ↓ energy demand through ↑ efficiency
- ↓ greenhouse gas (GHG) emissions
- ↑ renewable energy supply
- Potential for emergency backup with batteries or other storage capacity

In Florida, solar photovoltaics (PV) and solar thermal water heating are the most common renewable energy generation sources of choice. However, ZEHs are not the mere addition of onsite renewable energy to a conventional home. True ZEH status (a federal goal by 2020) is currently a rare occurrence. In the reality of 2010, a ZEH needs approximately 50-70% reduction in site energy use through efficiency measures with the remaining 30-50% in energy needs provided by on-site renewable energy.

Lifestyle & Impacts

In the United States, buildings account for approximately 48% of gross energy consumption with residential dwellings accounting for just over half the total building amount.[1] Since energy use serves as the primary driver of greenhouse gas (GHG) emissions, reducing the total energy consumed by buildings in conjunction with reducing

[1] Based on Architecture 2030 analysis (http://www.architecture2030.org/current_situation/building_sector.html) from EIA data (http://www.eia.doe.gov/overview_hd.html) from the year 2000.

the carbon intensity of the energy produced for building use can play a significant role in helping the U.S. meet its GHG emission reduction goals.[2]

For over a decade, universities within the Florida Energy Systems Consortium (FESC) have partnered with federal agencies on initiatives like the U.S. EPA ENERGY STAR for New Homes (http://www.energystar.gov/) and the U.S. DOE Building America (http://www1.eere.energy.gov/buildings/building_america/) programs to help realize these goals. Much of the research and development of ZEHs has focused on new homes, but the case study in the next section shows how a systems approach can bring ZEH performance within reach for even existing Florida homeowners.

Case Study: A 1950's Concrete Block Home Retrofit

In one example of a residential scale approach to integrating energy efficiency and conservation with renewable energy production, a University of Florida employee and his family improved a single-family detached ranch-style home built in 1959. The family purchased the 1,440 square foot, 3-bedroom, 2-bath home in April 2006 and began installing energy and water efficiency upgrades and living a lower impact lifestyle. These upgrades included compact fluorescent and light emitting diode (LED) bulbs in all but the dimmable light fixtures, high efficiency dual flush toilets, a new dual pane low-E sliding glass door, a programmable thermostat, and ENERGY STAR compliant appliances including: four ceiling fans, a refrigerator, a front-end loading clothes washer, and a whole-house natural gas tankless water heater.

Figure 1. Installation of the 3.85 kW solar photovoltaic (PV) system at the existing home case study. (Source: University of Florida)

The home's energy efficiency was complemented with conservation behaviors such as low energy thermostat set points (78-80 degrees Fahrenheit in the summer and 62-68 degrees Fahrenheit in the winter), using blankets and slippers for comfort in the winter, opening windows and using ceiling fans on mild days, and keeping unnecessary lights and plug loads off or disconnected. However, no modifications were made to the previously installed air conditioning system, the natural gas furnace, the windows, nor the air or thermal barrier of the building envelope, including the attic insulation which the homeowners recognize as "admittedly thin and significantly inadequate."

With these upgrades, this modest 1959 home now consumes approximately 46% less energy (459 kWh per thousand square feet per month) than the Gainesville Regional Utilities (GRU) average (854 kWh per thousand square feet per month).[3] Additionally, the case study family installed a 3.85 kW solar photovoltaic (PV) system on January 30, 2009, becoming possibly the first home in America to generate income ($0.32/kWh) under a European-style solar feed-in-tariff.[4] In its first 362 days of operation the system has generated $1,334 by producing 4,168 kWh (or 11.5 kWh/day), approximately 41% of the average household daily energy use per thousand square feet for all homes in the GRU service territory.

However, the important take-home message from this retrofit case study is that the combined $3,000 in energy efficiency improvements and essentially free conservation behaviors resulted in 64% more greenhouse gas emissions reductions through electricity and natural gas use avoided than the reductions via the electricity produced

[2] Federal legislation currently under consideration within the U.S. Congress aims to reduce GHG emissions to 83% less than their 2005 levels by the year 2050.

[3] The utility average and the case study home are normalized per thousand square feet (ksf) with natural gas converted into kWh equivalents using the average from calendar year 2006 through 2009 data for both the GRU community and the case study home.

[4] For more information on the GRU solar feed-in-tariff program, visit: http://www.gru.com/OurCommunity/Environment/GreenEnergy/solar.jsp

by the $26,000 solar PV system (and this doesn't even account for the greenhouse gas emissions reductions from switching the water heating from electricity to natural gas).[5]

This suggests the importance of maximizing energy efficiency and promoting conservation behaviors over simply providing enough solar energy to power the modern McMansion at an installed cost of more than $63 per square foot.[6] This case study reinforces why the U.S. Department of Energy Building Technologies Program aims to create a pathway for marketable net zero energy homes by 2020 (and commercial buildings by 2025) by reducing energy consumption (and/or shrinking home size) by 50-70% while leaving the other 30-50% to be offset by onsite renewable energy.[7]

Additional Information on Improving the Energy Efficiency in Homes

Florida Energy Systems Consortium (FESC) – Energy/Climate Awareness Fact Sheets
http://www.floridaenergy.ufl.edu/?page_id=273

Florida Solar Energy Center (FSEC) – Home Energy Ratings
http://www.fsec.ucf.edu/en/consumer/buildings/homes/ratings/index.htm

Next Steps

Though much progress has been made to date, there are many integrated fields of research that are working to further accelerate and improve the potential for ZEHs. The table below summarizes key ZEH features, the timeframe of a feature's market maturity in cost effectiveness and/or technological efficacy, and their related research threads within and beyond FESC.

ZEH Feature	Timeframe*	FESC: Linked Threads
Passive solar designs (orientation, daylighting, climate specific design/materials)	Yesterday	Urban design
Super efficient building envelope (air and thermal barriers)	Yesterday	Thermal management; materials and polymers
Super efficient heating/air conditioning/ventilation systems	Yesterday	Materials and polymers
Energy modeling and commissioning	Today	Life cycle assessment
Solar water heating	Today	Solar thermal; thermal management
Solar photovoltaic (PV)	Today	Coatings; distributed power generation; materials and polymers; nanotechnology
Efficient appliances	Today	ENERGY STAR
Efficient lighting	Today	LED; OLED
Innovative financing strategies	Today	Feed-in-tariffs (FITs); energy conservation districts; energy efficient mortgages (EEMs)
Conservation behaviors of occupants	Today	Community-based social marketing; social norms and neighbor feedback; energy conservation
Off-peak appliance and plug-load management	Tomorrow	Smart grid; transmission; energy policy
Vehicle-to-grid interface	Tomorrow	Electric/hybrid vehicles
Emergency energy back-up	Tomorrow	Batteries and capacitors
District/community heating and cooling	Tomorrow	Thermal management; transmission
Zero energy communities (integrating shelter and mobility issues)	Tomorrow	Urban design; electric/hybrid vehicles

***Note**: "Yesterday" = practiced for many years; "Today" = being currently implemented and refined; "Tomorrow" = in development for a better future.

[5] The energy efficiency/conservation resulted in 569 kWh/month (395 kWh/ksf/month × 1.44 to correct for the home size of 1,440 square feet) of electricity saved over the GRU community average as compared to the 347 kWh/month of electricity produced by the solar PV system.

[6] According to the NAHB (http://www.npr.org/templates/story/story.php?storyId=5525283), the average American new single-family home size has grown from 983 square feet in 1950 to 2,349 square feet in 2004. A modern home of this size consuming the GRU energy average (854 kWh/ksf/month) would need a 22 kW solar PV system (to offset 24,073 kWh/yr of consumption) at a cost of $148,500 (assuming $6.75/watt installed cost and production of 3 kWh/day per kW of installed capacity) to achieve net zero energy status.

[7] See http://www1.eere.energy.gov/buildings/goals.html

References and Resources

See the following publications for more information about ZEHs and examples in the field:

ASHRAE Transactions – Early Performance of a Green Academic Building
http://www.oberlin.edu/physics/Scofield/pdf_files/ashrae-2002.pdf

Florida Solar Energy Center (FSEC) – Zero Energy Buildings & Case Studies
http://www.fsec.ucf.edu/en/research/buildings/zero_energy/index.htm

Passive House Institute U.S.
http://www.passivehouse.us/

ToolBase Services – The Zero Energy Homes Project
http://www.toolbase.org/Home-Building-Topics/zero-energy-homes/zero-energy-home-project

Southface – Zero Energy Homes Project
http://www.southface.org/solar/solar-roadmap/zero-energy/zero-energy-menu.htm

U.S. DOE | Energy Efficiency & Renewable Energy – Zero Energy Home Design
http://www.energysavers.gov/your_home/designing_remodeling/index.cfm/mytopic=10360

U.S. DOE | Energy Efficiency & Renewable Energy – Building America
http://www1.eere.energy.gov/buildings/building_america/

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