Zero-Energy Retrofit

Sean Geiger

Retrofitting an Existing House

by Sean Geiger

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Residential structures account for over 20% of U.S. energy consumption. Very few of the existing 110 million U.S. households generate any significant fraction of the energy they consume, but if they were retrofitted to do so, U.S. greenhouse gas emissions would be reduced considerably. My goal was to retrofit my typical 1990 house to consume net "zero-energy" averaged over a year.

Conservation and Planning

A home energy audit was money well spent, identifying where I was losing energy and how to make fixes. Most of the house's energy consumption was from burning natural gas—partly for heating domestic hot water (DHW), but mostly for winter space-heating via forced-air furnace. Old gas utility bills gave an idea just how much heat energy the old 80% efficiency furnace put into the house every month in the winter, and additional calculations/modeling of the house roughly confirmed these numbers.

Hot Water

I addressed DHW needs with two 4'x8' flat-plate solar thermal collectors (enough for a family of four) feeding solar-heated water into a 110-gallon reservoir tank. Using pure water as a circulating liquid in a "drain-back" system achieved the highest efficiency and reliability with no scheduled maintenance. A fully modulating tankless electric backup/supplemental water heater takes preheated water from the reservoir tank and adds more heat to the water if needed.

Heating and Cooling

After analyzing many system and cost trade-offs, I found a 3-ton (36,000 BTU/hour) electrically-powered geothermal loop heat pump system that would act as a space-heating source, with its high winter electricity use to be offset by the year-round electricity generation from a large photovoltaic (PV) system. The benefit of geothermal-source heat pumps is that every unit of electrical energy used to run the pumps and compressor results in the collection of another two to four units of heat energy out of the ground. Heat from the heat pump can be transferred both to radiant flooring and heat exchanger coils (an air handler) mounted in the existing ductwork. An evaporative cooler accomplishes summer cooling.

Electricity

Although the house is dependent upon the electrical grid for a constant supply of electricity, 4.7kW of PV electricity generation offsets that electricity used. An exclusively grid-tied PV system (without battery backup) was chosen because of lower cost for installation and higher DC-AC efficiency.

I tried to keep costs down by doing much of the design and installation myself, with help from family and friends (thank you!). Some systems needed to be designed or installed by contractors. The bulk of the installation work spanned eight months, including about four man-months of my time. A "green" home equity loan covered most upfront purchases. Final cost totals are pending.

Solar and geothermal energy make it possible to migrate away from oil and natural gas as heating sources. Oil prices have increased dramatically, and natural gas may follow as the proven natural gas reserves in North America deplete in the next few decades. Geothermal and solar thermal can have larger up-front costs, but these are known and controllable, and the technology is renewable.

I will post more information I've collected and generated at www.zeroenergyretrofit.org, if you'd like to learn more from my experiences and hopefully improve on them!

Year Built, Remodeled:
1990, 2006–2008

Home Size: 1,650 sq. ft.

Contractors:

- Self-installed (PV-2nd system, radiant flooring, forced air, thermostat control, solar thermal DHW)
- Namaste Solar Electric (PV-1st system) (see ad on page 5)
- Next Generation Energy (Solar thermal, PV vendor and sage)
- PK Geothermal, LLC (Geothermal System)

Energy Features

- Energy audit
- 4.7 kW grid-tied PV system
- Flat-plate solar collector for domestic water heating with tankless high-efficiency electric boiler for backup
- Ground source heat pump
- Evaporative cooler
- CFLs
- Programmable thermostats
- Separable upstairs/downstairs zoned heating
- ENERGY STAR appliances: refrigerator, clothes washer
- Use of clotheslines for drying
- Ceiling fan in the living room

Green Features

- Low-VOC floor finish
- Planned use of clover in lawn and legumes in garden for nitrogen fixing in soil to avoid fertilizers

Water Features

- Drip irrigation
- Smart irrigation controller
- Soil amendments
- Hydro-zoning
- Trees planted for summer grass shading
- Check-valves in irrigation system
- Low-flow plumbing fixtures

Re-Use/Salvage Features

- Solar hot water tank and several pumps were salvaged from two dismantled solar hot water systems