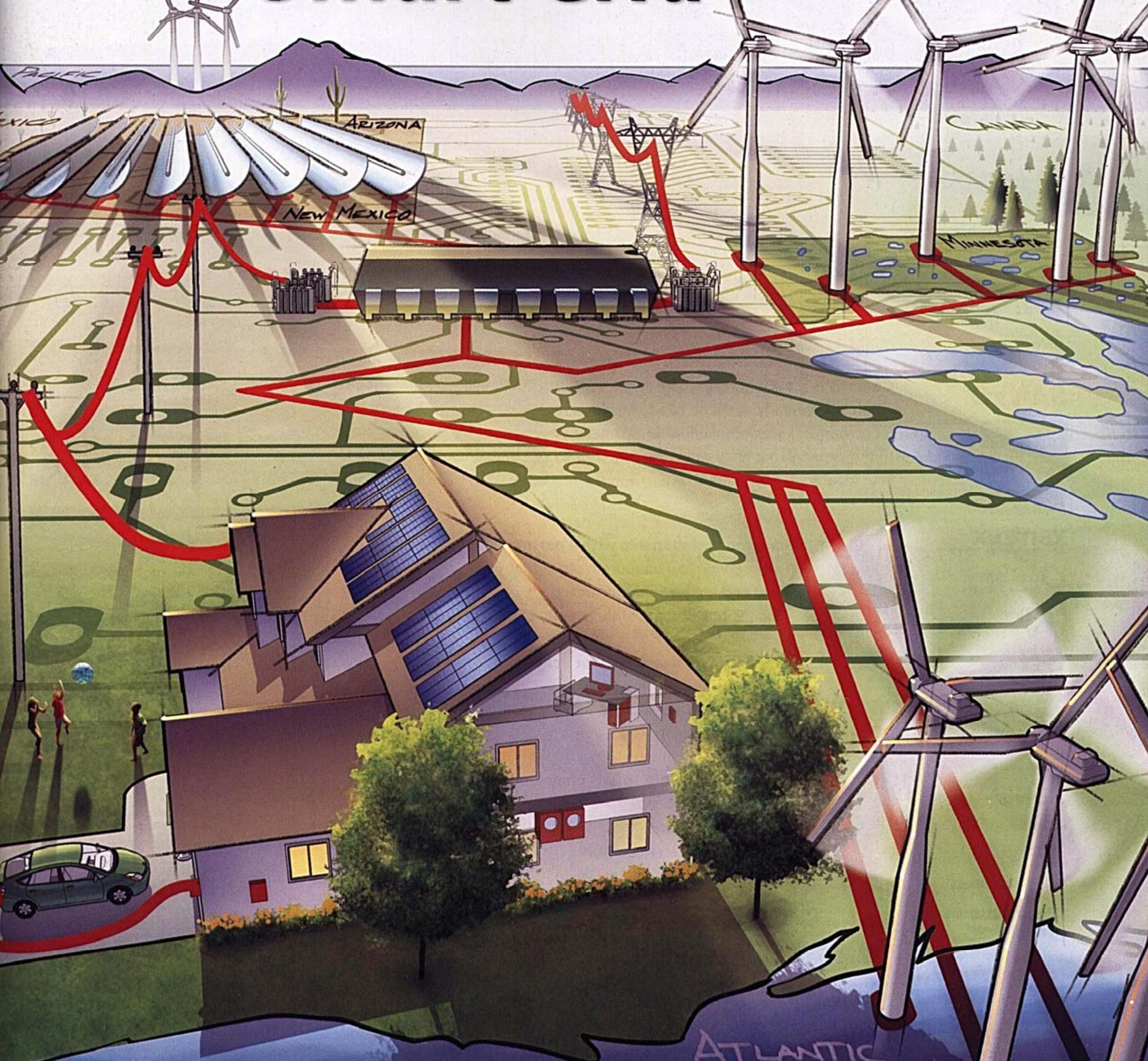
PRODUCTS SHOWCASE ▶ SOLAR 2009 New Products Preview

SOLAR TODAY

LEADING THE RENEWABLE ENERGY REVOLUTION

May 2009
solartoday.org

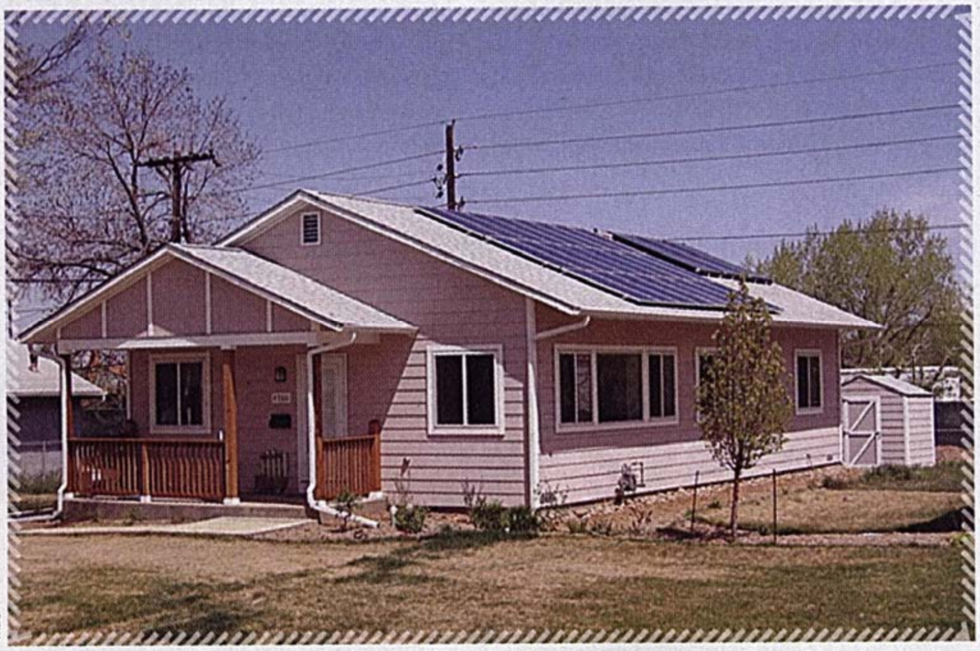
Getting to the Renewable Energy Smart Grid



BUILDING THE SOLAR-READY HOUSE

As we move toward the day when photovoltaics and solar water heating are standard features, the high-efficiency all-electric house is a smart transition strategy.

By COLLIN TOMB



NREL

The small Habitat for Humanity house in Wheat Ridge, Colo., derives much of its heat from electric baseboards, but due to its super-insulated walls and conscientious residents, it is still a net energy producer.

More than 50 years ago, in 1953, Kansas City Power and Light unveiled its all-electric model house in Prairie Village, Kan. Equipped with the latest plastic conveniences, with all-electric heat and water heating, it promoted a life un-dirtied by the wood, gas, oil and coal burned in nearly every furnace and boiler at the time. But it suffered the irony that plagues even modern all-electric houses: Without a renewable electricity supply, they are expensive and environmentally filthy.

As we look to a future powered by renewable energy, the all-electric house is a natural solution. It pairs well with on-site photovoltaic (PV) systems and with the electric utility grid, drawing electricity from the grid and metering energy back from rooftop PV when it's sunny. The catch is that without renewable energy, an all-electric house is running on electricity produced to a large extent from fossil fuels, depending on where you live.

DAN FRUEH PHOTOGRAPHY

Without a renewable energy supply, the 1953 all-electric house and its modern counterparts can be expensive and environmentally filthy to power.

Collin Tomb is an architect and writer in Boulder, Colo., specializing in carbon-neutral design and energy retrofit. Patrick Hughes, director of the Building Technology Research and Integration Center at Oak Ridge National Laboratory, contributed to this article with expertise on heat pumps. Technical assistance was also provided by Walter Grondzik, architectural engineer and professor in the Department of Architecture at Ball State University.

Generating energy from on-site sun resources makes more sense than ever as PV prices continue to drop and incentives increase. Offsetting even a portion of electricity needs with PV can have significant benefits. Yet for builders and architects that have yet to make renewable energy features standard because of cost concerns, offering all-electric houses with solar-ready features is a good interim strategy. The problem is that the 1950s descendents of the first all-electric house, without renewable energy supply, can now cost twice as much to operate as their natural gas-powered neighbors, depending on local electricity and natural gas rates.

Linda Wigington is the special projects director at Affordable Comfort Inc. (affordablecomfort.org), which advocates super-insulated homes and the systems that heat them. "It's sort of obvious that electricity gives you all sorts of flexibility," she says. "I certainly understand the push to get away from fossil fuels. In the meantime, the challenge is the transition strategy." How do we move forward, at a time when fossil fuel remains cheaper than renewables, without making decades-long commitments to gas-burning appliances we'll wish we didn't have when we can get those PV panels on every house?

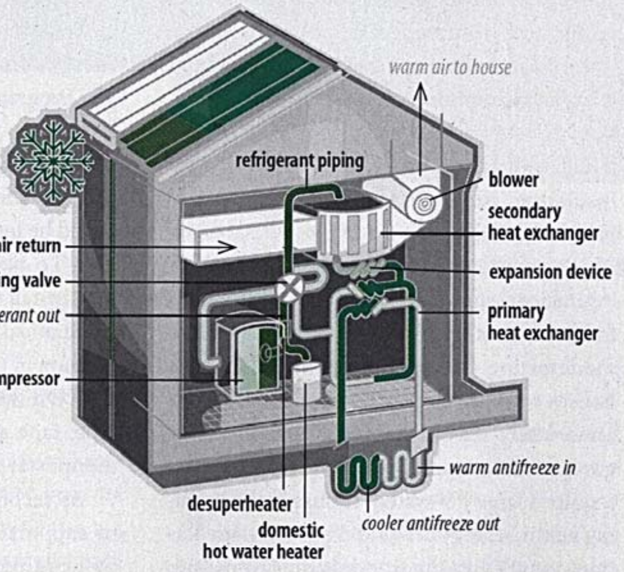
Look to Efficient Heat Pumps

While Kansas City Power and Light's 1953 electric house was mostly noticed for its roundish appliances, automated drapes and the TV hidden behind a sliding picture frame, it boasted a humble but crucial invention: the air-source heat pump.

By exploiting the phase-change properties of a refrigerant, a heat pump moves heat in the opposite direction it would tend to move by conduction or convection — from a cold outdoors to a warm indoors. Reverse the flow of the refrigerant, and you have a cooling system as well. This elemental elegance has been complemented in recent years by efficiencies approaching a coefficient of performance, or COP, of 2 to 4 depending on where you are, averaged over the season. For every watt of electric energy the heat pump draws, it transports 2 to 4 watts of heat in the desired direction. Coincidentally, the heat-to-carbon emissions efficiency of grid electricity used for heating is three times lower on average than burning natural gas — so electric air-source heat pumps with these efficiencies can effectively remove the carbon disadvantage of electric heat versus natural gas. But a ground source heat pump can do even better.

A ground-source, or geothermal, heat pump exchanges heat between the soil and a heating, cooling or water-heating load. This is accomplished using a ground-tempered loop rather than a coil exposed to the ambient air. The even temperature of the earth makes a ground-source heat pump extremely efficient. Studies show that COPs range from 3 to 5 depending on where you are, averaged over the season, and could easily be 6 to 8 if there were a market for this level of efficiency. A ground-source heat pump uses 25 to 50 percent less electricity than conventional HVAC, according to the U.S. Department of Energy.

In climates requiring air conditioning and dehumidification, most homeowners will want a vapor compression machine, and since the incremental cost between an AC-only system and a heat pump is small, it is likely advantageous to use a heat pump rather than gas heat. Although air-source systems have lower initial cost than ground-source systems, in ventilated low-load applications there is little need for a heat pump's compressor to run except when it is very hot or cold. Under these conditions, ground-source systems have significant capacity, efficiency and comfort advantages.



Since water heating accounts for 20 to 40 percent of a typical home's energy requirement, producing it cost effectively is important. Solar water heating is proven for just about any climate, potentially performing well for 20 or 30 years. But backup electric or natural gas water heating is typically required, even with a well-designed system.

Water heating with electric systems alone remains a stumbling block. Electric tankless heaters require 220 volts and generally perform poorly (although their performance improves when paired with solar-heated water). Air-source heat pumps that fit on top of conventional water-heating tanks have COPs of 2 and provide cooling and dehumidification as a byproduct in climates where these are valued. In heating-dominated climates, where these devices effectively raise the house's heating load, locating the devices in basement buffer zones or where they have access to refrigerator waste heat minimizes this effect. By the end of 2009, heat pump water heaters (tank and heat pump as a single integrated device) will be available nationwide under one of the world's strongest appliance brands.

Match Strategy to Energy Load

As society moves beyond bigger-is-better housing, we recognize that electric systems are more logical the smaller the loads they address. We can reduce energy demand through super-insulation, airtight building envelopes, plug-load conservation, heat-recovery ventilation and solar water heating. Daylighting and passive solar contributions are also beneficial. Load reduction is the prerequisite of any all-electric system, not only because it decreases the size of the PV array required to supply or offset the system, but also because by significantly reducing the load, we can change the type of electric system required. We also may be able to eliminate the need for gas on the site. According to Wigington, "There is an increased awareness that the lower the load, the harder it is to justify a gas line when you consider the cost of venting, the line and the service charge."

The basic strategies for energy systems at all-electric houses sort by load size.

Small Energy Demand. If the house is compact, superinsulated and tight, electric resistance baseboards may be enough in climates where no air conditioning and dehumidification is required. Electric appliance resistance "losses" become gains and begin to heat the house. The temperature doesn't drift much during the day, so loads can be shifted to when renewable supply is available or grid energy is abundant.

As an example, the Habitat for Humanity house in Wheat Ridge, Colo., derives much of its heat from electric baseboards, but due to its triple-stud superinsulated walls and conscientious residents, it is still a net producer of energy. This house is emblematic of the gas-electric dichotomy: It is a hybrid. It has a natural gas water heater and a small gas heater in the main space, which minimized the size of the PV array required for offset and brought the house into Habitat's price range. In fact, but for cost, an all-electric system was the design team's preference for its "philosophical simplicity," says Paul Norton, who was on the sponsoring design team at the National Renewable Energy Laboratory. "You read the meter and you know if you're net-zero or not."


DAN BIHN

Next West House, the first LEED-Platinum house in Colorado, is a relatively large all-electric house with a ground-source heat pump and desuperheater, with air-source water-heating backup. Instead of a gas line, it has an alcohol-burning fireplace and induction stove.

As discussed, in climates requiring air conditioning and dehumidification, ground-source heat pumps offer advantages over AC-only or air-source heat pump systems.

Medium Energy Demand. If the house is too large for baseboards but small enough to need no ductwork, a few air-source heat pump units ("ductless mini-splits") can do the job. Baseboard heaters can supply areas not exposed to the heat pumps. R. Carter Scott's net-zero-energy home in Massachusetts makes use of a mini-split to great effect: The lower cost of this system relative to a conventional, ducted system offsets the cost of the increased envelope efficiency he needed. The ground-source equivalent of this system uses multiple indoor heat pump consoles and has the same benefits as noted above. Scott also greatly reduced electricity demand at the house through solar water heating and PV. (See "The Net-Zero-Energy Home Challenge," November/December issue.)

Large Energy Demand. Large houses tend to have enough loads to justify a ground-source heat pump. These systems often contain an accessory (a desuperheater) that taps the refrigerant to heat water as well.

The first LEED-Platinum house in Colorado (the Next West House, featured in "Back to the Future," March *SOLAR TODAY*) is an all-electric house with a ground-source heat pump and desuperheater, with air-source water-heating backup. Instead of a gas line, it has an alcohol-burning fireplace and induction stove. Next West is relatively small for a high-end home, and it is encapsulated by insulating concrete forms and urethane-packed framing.

The problem of all-electric systems with insufficient renewable supply comes into sharp focus in existing housing. Whether you're modernizing one of the original all-electric houses or going electric in a multifamily situation where retrofit-venting a high-efficiency gas appliance would be costly, it often would require a large PV system to supply the building's entire energy demand. Poor solar orientation, complex rooflines and shading by mature trees are common challenges. This is another case where ground-source heat pump systems may make the most sense. Sometimes offsetting a portion of energy needs through PV and solar water-heating systems also makes sense. These modular systems can be expanded over time to further reduce loads.

Plan Solar into the Design

Perhaps the most valuable thing a builder or architect can do to prepare for a shift to renewable energy is to design all-electric houses to use ground-source heating/cooling and for solar readiness. Low-load houses can be conditioned largely by way of their ventilation systems in mild weather, and the ultra-efficient, renewable ground-source heat pump will be there during extreme weather, when it is needed most. Low-cost ground-source systems for new homes with low loads are emerging (but that is a topic for a future story). Siting and constructing buildings in ways that make it easier to add solar systems later to power the heat pump and other energy needs can greatly reduce the eventual cost of the system and maximize performance.

To work efficiently, a solar system needs open roof space with good sun. The main roof surface should be oriented within 30 degrees of due south and have a slope of latitude minus 15 degrees for year-round optimum performance. Inside, the basement or utility room should have room to accommodate a PV system inverter or water tanks for the solar water-heating system.

Wisconsin Focus on Energy (focusonenergy.com) and the Wisconsin Energy Star Program suggest a few simple solar-ready features:

- Install half-inch conduit from the utility panel to the attic near where the PV system would be installed.
- To plan for a solar water-heating system, install two type L copper pipes from the mechanical room to the future installation location in the attic.
- On the outside of the insulated copper pipe, tape a four- or six-conductor stranded thermostat control wire.

As technologies, prices and policies align to support movement to a renewable energy economy, the solar systems needed to power these houses will be readily available and affordable. New legislation in Colorado would require homebuilders to offer solar as an option, and Hawaii already requires that new homes include solar water heating. We may soon see the day when a solar electric system is at last standard, something we can take for granted. In the meantime, all-electric, solar-ready strategies are smart planning and can pay dividends in energy savings and buyer appeal. **ST**