A Hybrid Approach to Carbon Reductions in Existing Homes: Deep Efficiency and Renewables

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ABSTRACT

Existing homes are responsible for 20% of America's energy consumption and more than 10% of worldwide energy consumption. Over the last several years, many homeowners have spent thousands of dollars to install Solar Photovoltaics (PV) to produce their own electricity and reduce their carbon footprint. However, this renewable alone is not the most economical or sustainable solution. The least expensive and most effective way to provide additional energy throughout the world is to make existing homes use less energy.

This session will introduce the audience to Home Performance solutions – an innovative whole-house approach to diagnosing and upgrading the components of a home that are responsible for excessive energy consumption. This session will also demonstrate the benefit of installing renewable energy solutions after a home's energy efficiency has been maximized rather than installing renewables on an unimproved home.

Keywords: energy efficiency, home performance, solar, renewable energy, carbon footprint

1 INTRODUCTION

Home Performance solutions are based on building science and treat the home as a whole system to pinpoint the sources of excessive energy use as well as common comfort and health related issues. Home Performance improvements have been proven to reduce the energy demands of a home by anywhere from 25% to 50% or even more while making the home more sustainable.

More sustainable homes will also increase adoption of renewable energy solutions. After a home's efficiency has been maximized and thus the energy loads minimized, renewable solutions such as solar PV, combined heat and power (CHP) furnaces, and geothermal will have a lower initial and long-term cost since the size of the renewable energy equipment required is significantly smaller.

Though Home Performance is effective in all climate zones, this session will focus on a cooling climate such as Sacramento, CA since Solar PV has a relatively high prevalence in this region of the U.S.

2 HOME PERFORMANCE

Home Performance uses applied building science to analyze a home as a completely integrated system. Certified building analysts use advanced tools and technology to quickly identify the structural, heating and cooling, thermal, electrical, and solar components of the home that are negatively impacting efficient energy consumption, comfort, health, and safety. Using Home Performance solutions – including sealing air leaks, super insulating the home, installing high efficiency air conditioners and furnaces, sealing ducts, upgrading to more efficient lighting, and in some cases addressing window deficiencies – to provide deep efficiency improvements will reduce the energy load of a home by a minimum of 25% and often significantly higher. Not only is this surplus energy now available to the grid – thereby reducing the need for new power plants – the transformed home is more sustainable with a much lower carbon footprint.

2.1 Diagnostics

There are numerous architectural housing styles across America. A few examples include cape cods, bi-levels, tri-levels, ranches, and colonials. Each of these have numerous variations that make them unique, including the age of the home, exterior wall configurations, and quality of the original construction.

Based on all of these unique configurations, Home Performance solutions always begin with a comprehensive assessment to diagnose and identify all the sources of excessive energy use. Advisors, specifically trained and certified in Home Performance, use a blower door and manometer to de-pressurize the home and measure the amount of air that is leaking back inside through holes, cracks, and crevices. Infrared cameras are used to identify missing insulation and air flow patterns. Carbon monoxide testing is performed on all combustion equipment, such as furnaces, stoves, and water heaters, to ensure they are operating at safe levels and venting properly. The furnace, air conditioner, duct work, lighting, windows, water heater, and appliances are all thoroughly inspected to determine their current energy efficiency and performance ratings. Lastly, visual inspections are completed on the crawl space/basement, shell, living space, attic, and roof.

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Once the Home Performance assessment is complete and data analyzed, a customized set of home upgrade recommendations can be made that will provide the deepest energy reductions and greatest comfort improvements.

2.2 Air Sealing

Because of a lack of proper detailing, most homes — regardless of age — leak like sieves (Fig. 1), resulting in excessive energy consumption, drafts, rooms that are hot in the summer and cold in the winter, and other energy and comfort issues. Sealing the "envelope" of the home — its outer walls, ceiling, windows, doors, and floors — is often the most cost effective way to improve energy efficiency.

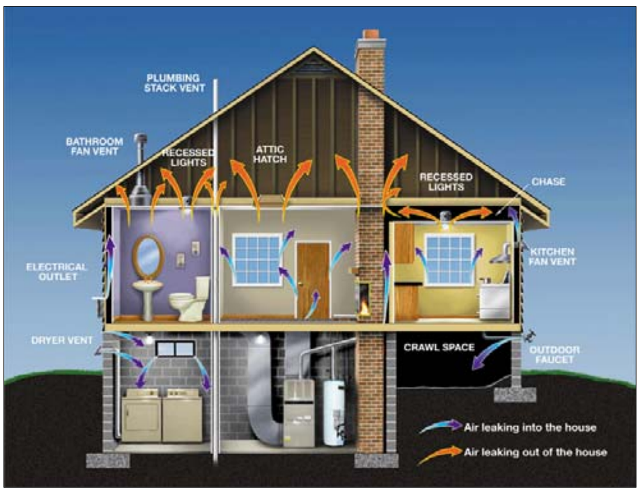

Fig. 1 Common Sources of Air Infiltration
Source: U.S. Environmental Protection Agency

Many air leaks and drafts are easy to find because they are easy to feel — like those around windows and doors. But holes hidden in attics, basements, and crawlspaces are often bigger problems. In fact, these defects can allow as much air in as an open window. Sealing these leaks with caulk, foam board, and spray foam can dramatically reduce energy use in both the summer and winter [1].

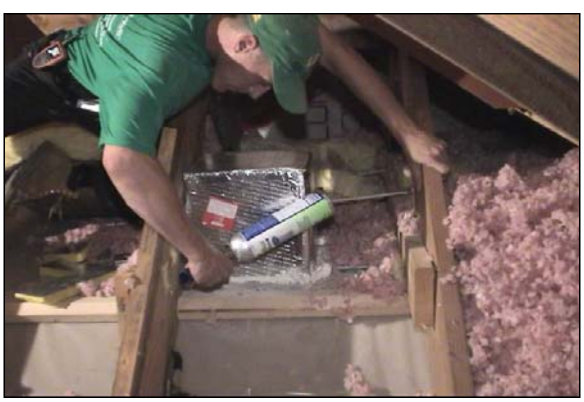

Fig. 2 Air Sealing an Insulated Box over a Recessed Can Light

For example, in the summer, by sealing the air infiltration points in the home (Fig. 2), the cooling system is not constantly fighting against the hot summer air — including superheated air from the attic — that is drawn in through leaks.

2.3 Insulation

Once comprehensive air sealing is performed, installing cellulose with an insulation level of at least R-38 will keep the hot attic air from conducting down into the living space under the attic and stops heat loss to the attic in the winter (Fig. 3).

Fig. 3 Super Insulating the Attic

This is critical because the summer attic temperature is often 50 degrees (F) or more hotter than the outside air temperature. This heat is constantly conducting and radiating from the attic to the living space below. It may even be carried to the living space by convection induced by air leakage pathways in the ceiling plane and pressure differences caused by duct leakage or balancing problems. To reduce energy use in the summer, it is imperative to keep this heat out of the living space of the home. Otherwise, the air conditioning system is in a never-ending battle trying to overcome the influx of hot air.

2.4 Duct Sealing

In homes with forced-air heating and cooling systems, ducts are used to distribute conditioned air throughout the home. In the Southwest and California, many homes have ducts running through the attic where the hottest air in the home exists during the summer. If these ducts have leaks or are improperly insulated, up to 30% of the cold air from the air conditioner is being lost before it gets to the living space. Furthermore, efficiency is lost through improperly insulated ducts that are constantly being heated by the hot attic air, which magnifies the inherent problem. Properly sealing (Fig. 4) or installing insulated ducts can reduce space conditioning energy consumption by more than 20%.

Fig. 4 Duct work being properly sealed with mastic

2.5 Air Conditioning

The SEER rating describes the efficiency of an air conditioning system. The higher the SEER number, the higher the efficiency, which equates to less energy use. The size of the air conditioner also impacts energy consumption. By sealing all air infiltration points in a home, super insulating the attic, and sealing all ducts, a much smaller air conditioning unit can be installed. A smaller air conditioning unit not only uses less electricity but will typically provide better comfort [2].

Table 1 illustrates the electricity use and operating costs for a 5-ton SEER 8 unit versus a 5-ton SEER 14 unit; assuming 85% efficient ducts and 1,200 cooling hours per year. [3]

Table 1. SEER 8 vs. SEER 14

	5-ton, SEER 8	5-ton, SEER 14
Annual Energy Used (kWh)	10,588	6,051
Cost per kWh	$0.15	$0.15
Annual Operating Costs	$1,588	$908

Not only is 40% less electricity being consumed, but the operating costs are reduced by more than $600 per year.

Table 2 illustrates the electricity use and operating costs for a 5-ton SEER 14 unit versus a 3.5-ton SEER 14 unit; assuming 85% efficient ducts and 1,200 cooling hours per year.

Table 2. 3.5-ton vs. 5-ton

	3.5-ton, SEER 14	5-ton, SEER 14
Annual Energy Used (kWh)	4,235	6,051
Cost per kWh	$0.15	$0.15
Annual Operating Costs	$635	$908

As shown in table 2, there is a significant difference in electricity use between a 3.5-ton and 5-ton unit. Without sacrificing comfort, the only way to reduce the compressor size of the air conditioning unit is to install Home Performance improvements first.

2.6 Air Handlers

In a forced-air cooling system, the air handler delivers cold air throughout the home. Single-stage motors operate at one speed. Variable-speed or electrically commutated motors (ECMs) adjust their speeds to deliver optimal airflow at all times. Implementing Home Performance solutions allow variable-speed blowers and ECMs to consistently operate at their lowest speeds, and lower energy use [2].

2.7 Lighting

Lighting is one of the biggest sources of electricity use in the home. The Environmental Protection Agency (EPA) has gained national recognition through its "Change a Light" campaign and for good reason. Replacing incandescent light bulbs and fixtures with Compact Fluorescent Lights (CFLs) or LEDs can reduce electricity use for lighting by 70% or more. Installing more energy efficient lighting should be part of any Home Performance improvement project.

3 PRE-CURSOR TO RENEWABLES

Before a renewable energy source such as Solar PV is installed on a home, it is imperative for the home to be optimized for energy efficiency. Performing comprehensive air sealing, super insulating the attic, sealing ducts, replacing incandescent light bulbs with CFLs, installing an ECM air handler, and replacing the old air conditioner with a smaller SEER 14 or higher unit will reduce the electricity load of the home by at least 25%. These energy efficiency improvements will enable the home to generate sufficient electricity with significantly less solar panels.

4 DEEP EFFICIENCY & RENEWABLES

As an example, Table 3 illustrates the cost of installing a 5 kW solar PV system in California. Table 4 illustrates the cost of a solar system after Home Performance improvements. Due to the electricity demand reduction of 30% from the energy efficiency improvements, the home only requires a 3.5 kW solar PV system. The $10,500 saved from installing a smaller solar PV system can be used to fund a majority of the Home Performance upgrades.

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solutions such as solar PV, combined heat and power (CHP) furnaces, and geothermal will have a lower initial and long-term cost since the size of the equipment required is significantly smaller.

Table 3. Solar PV System Only

Photovoltaic System Size	5.0	kW
Install Cost/ watt	$9.50	
Gross PV System Price	$47,500	
CA State Rebate	<$12,500>	
Federal Tax Credit	<$2,000>	
Final PV System Price	**$33,000**	

Table 4. Solar PV System after Efficiency Upgrades

Photovoltaic System Size	3.5	kW
Install Cost/ watt	$9.50	
Gross PV System Price	$33,250	
CA State Rebate	<$8,750>	
Federal Tax Credit	<$2,000>	
Final PV System Price	**$22,500**	
Deep Efficiency Upgrades	**$12,000**	
Total Project Price	**$34,500**	

Table 5 below demonstrates the electricity use before and after the Home Performance (HP) improvements. Not only is the electricity use reduced but the electricity required from the grid post-PV is less. In fact, a 4.3 kW solar PV system in conjunction with the Home Performance improvements would enable the home to be virtually grid-free [4].

Table 5. Electricity Use Analysis

	HP + PV	PV Only
Annual electricity use (Baseline)	8,600 kWh	8,600 kWh
Annual electricity use (After HP)	6,020 kWh	8,600 kWh
Solar PV electricity generation [4]	<4,900 kWh>	<7,000 kWh>
Electricity required from grid	1,120 kWh	1,600 kWh

5 ANCILLARY BENEFITS

Another large benefit of implementing Home Performance is the homeowner will also reduce their heating fuel demand in the winter (natural gas, propane or oil). Table 6 demonstrates the natural gas use before and after Home Performance upgrades. A well sealed and insulated home will use far less heating fuel than a non-improved home. The combination of lower electricity and heating fuel use also significantly reduces the home's overall carbon footprint and year-round utility bills when compared to a Solar PV only installation.

Table 6. Natural Gas Use Analysis

Annual natural gas use (Before)	1,400 ccf
Annual natural gas use (After)	980 ccf
Natural gas use reduction	**<420> ccf**

In addition to reducing the home's energy consumption, there are numerous ancillary benefits resulting from a Home Performance improvement project:

- Draft-free rooms
- Cleaner indoor air quality
- Rooms are cooler in the summer/warmer in the winter
- Considerably less dust, noise and insects in the home
- A more sustainable and lower cost home
- Increased home resale value
- The home is closer to being "zero net energy"
- Less solar panels installed—which may help with HOA issues

Under the scenario presented, the gas savings and the other benefits come at no additional cost beyond that shown in Table 4.

6 CONCLUSION

Prior to installing renewable energy sources, a home should be made as energy efficient as possible. By investing essentially the same amount as planned for the Solar PV-only project, the homeowner receives a more comfortable, healthy, and safe home that uses less energy, and the world benefits due to a smaller carbon footprint.

7 REFERENCES

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