Small Home Energy System Analysis using

Conventional Methods vs. SunDrum Solar's HarvestHP System

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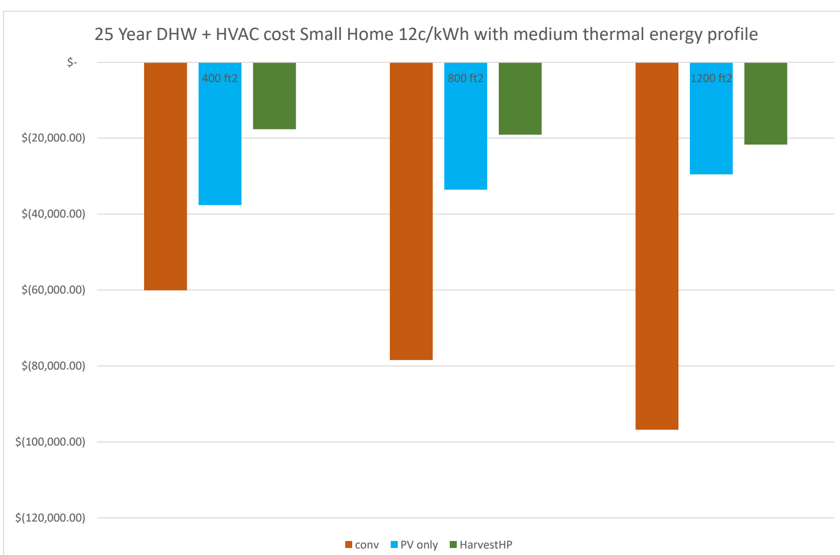
Executive Summary

The following report compares the 25 year cost of ownership to install and operate heating and cooling systems for small homes. State of the art conventional hot water heating and HVAC systems are compared to installing a PV system to power these systems or a PVT solar system to replace these systems and minimize electrical requirements by combining solar electric and thermal advantages. The conventional system is one of the most efficient on the market, using the least amount of electricity to satisfy a home's thermal needs. The option of adding a PV array to power this system is included. Also compared is using a solar PVT system that has the advantage of using the sun's energy to deliver both electricity and thermal energy. SunDrum Solar's HarvestHP™ system is used as the PVT system. On an 800 ft^2 home the PVT system reduced its annual electrical needs from 11.1MWh to 7MWh.

In all cases the HarvestHP system had the lowest cost of ownership. On homes where there was an excess of available roof space where surplus PV panels could be added and there was a low thermal need, the PV only option came close to HarvestHP cost of ownership. As the percentage of thermal needs increased the advantages of using a solar system that can deliver both electrical and thermal energies resulted in greater advantages for the HarvestHP system.



Introduction

In response to the “go green” movement, the demand for more efficient cars, electronics, and overall livelihood has skyrocketed. Consumers have growing interests in products that lead their field in efficiency and renewability. Products such as hybrid/electric cars, smart devices, solar panels, and wind turbines capture the green movement and have been extremely popular. In line with this, many people have a growing interest in minimalistic living, resulting in the popularity of “tiny houses”. However, the structure of a building, although the most important part, is only a small part of what makes a building. The addition of plumbing for running water and DHW, wiring for electricity, and HVAC systems for a comfortable environment is the bulk of a building. The selection of appropriate technology for satisfying these needs is an important factor in determining the cost-effectiveness and energy efficiency of the building.

This report presents the analysis of three different energy solutions for providing DHW heating, space heating, space cooling, and spa heating for small residential homes: Conventional, PV only, and SunDrum Solar’s HarvestHP system. The first method uses a high efficiency conventional approach by using a tankless DHW heater, a ductless mini split heat pump, and a spa. The spa representing a increased thermal load that could substitute for a different area of the country or higher than assumed thermal density. These systems run strictly on electricity and were analyzed using grid power. The “PV only” method adds PV panels to the conventional system to offset the electricity used by the heating and cooling equipment, as well as other electrical needs in the home. The third method replaces the conventional equipment with SunDrum Solar’s HarvestHP system to fully meet the energy needs of the home. This system is able to maximize the energy efficiency of a home by combining standard PV panels with SunDrum Solar’s patented solar thermal collector. The resulting hybrid solar collector is able to achieve efficiencies of up to 86%, compared to a stand-alone PV panel system which only runs at 15-20% efficiency. Each of these three methods was tested against three design scenarios. The first was a 1200 sq.ft home, the next design was a 800 sq.ft home, and the final design was the smallest with a 400 sq.ft home.

System Design and Assumptions

To start this analysis a few engineering assumptions were made. The first was that the DHW (domestic hot water) consumption for the 1200 sq.ft home, 800 sq.ft home, and 400 sq.ft home were 48GPD, 32GPD, and 16GPD respectively. Then it was assumed that the spa would maintain a temperature of 102˚F with a size of 35 sq.ft/600 gallons. It is also required that the DHW would need to be heated to 120 ˚F in order to follow the residential plumbing code. RETScreen was used with a location of Atlanta, GA in order to calculate the average temperature per month along with the heating and cooling degree-days. This data was used to calculate the number of therms needed annually to heat the DHW, space heating, space cooling, and spa heating. The spa, assumed to be covered 23 hrs/day, remained the same size throughout each design making this load requirement constant at 77 therms. All system types and home sizes were modeled with and without the spa. The annual space heating and cooling loads were assumed to be proportional to the square footage of the home and were estimated using data from the

EIA website for homes in Georgia. The resulting space heating load for the 400 sq.ft home is about 49 therms, and the cooling load is about 98 therms, where the loads for the other two home sizes are scaled proportionally. All PV panels are assumed to be a 340 watt standard PV panel, and all thermal collectors are assumed to be SunDrum Solar's 800 watt collector.

Conventional System

The conventional method was analyzed first and the Model 3 Water Heater by Heat Works was chosen to heat the DHW in all three home sizes. This is a top of the line water heater and is much different than the traditional tankless water heater. The 'traditional' tankless water heater uses a resistant heating element in order to heat the water. This requires that the metal heating element has to get extremely hot, which in return uses a lot of electricity and puts extreme wear on the unit. Another fault with this type of water heater is that there is a delay from when the water is turned on to when it actually gets hot. Heat Works utilizes Ohmic Array Technology in order to create a hot water heater that eliminates all of these negatives and results in a much more efficient product.

The Model 3 Water Heater has a price of $800 and is advertised at an energy efficiency of 99%. It is capable of 41˚F temperature rise at a flow of 4 GPM and an 82 ˚F temperature rise at a flow of 2 GPM. This equates to spending approximately $627.24 annually for the 1200 sq.ft home, $418.41 and $208.83 annually for the 800 sq.ft and 400 sq.ft homes, respectively. This is calculated using the DHW load requirement of 85 therms, 57 therms, and 28 therms, all at an electrical cost of $0.25/kWh. With a price of electricity at $0.12/kWh the cost annually would drop by 52%. Heat Works recommends a licensed plumber for installation.

The next system chosen for the conventional method analysis was the ductless mini-split heat pumps that would be used. Three different mini-split systems had to be chosen since each home size requires a different heating and cooling load. The Gree Sapphire 1.5 ton mini split air conditioner and heat pump were chosen for the 1200 sq.ft home. This mini split has a rating of 18K Btu cooling and heating with a 24.5 SEER rating. It costs $2,299 to purchase and has an annual electricity cost of $809.38. The annual electricity cost was calculated in order to satisfy the space heating and cooling load demand of 441.6 therms. On the 800 sq.ft design the 1 ton Mitsubishi M-Series mini split air conditioner and heat pump was chosen. This system has a 12K Btu cooling capacity, a 13.6K Btu heating capacity, and a SEER rating of 26.1. This mini-split costs $1,914 to purchase. The 800 sq.ft design has a smaller load requirement than the 1200 sq.ft design and a more efficient mini split system, resulting in a cost of $539.59 annually for electricity. This would completely satisfy the load of 294.4 therms. The 400 sq.ft design has the lowest space cooling and heating demand of only 147.2 therms, which required the ¾ ton Mitsubishi M-Series mini split. This system has a 9K Btu cooling capacity, a 10.9K heating capacity, and the highest efficiency with a SEER rating of 30.5. It costs $1,712 to purchase and costs $269.79 annually for electricity. A licensed technician is also required to install these systems.

The final system chosen for the conventional method analysis is a heater for an outdoor spa. The Smart Spa 5.5 was chosen. This EcoSmart spa heater uses flow sensor technology instead of the traditional pressure switch activation in order to reduce burned out elements. This system has a cost of $450. Based on the 77 therms demand annually for spa heat and an efficiency of 99.8%, this would cost $565.65 annually in electricity. A cost of $500 was added for a professional installation of the spa.

Conventional System Cost Assumptions Summary

	With Spa			Without Spa		
	400 sq. ft.	800 sq. ft.	1200 sq. ft.	400 sq. ft.	800 sq. ft.	1200 sq. ft.
DHW (tankless water heater)	$ 799.00	$ 799.00	$ 799.00	$ 799.00	$ 799.00	$ 799.00
Mini-Split Heat Pump	$ 1,712.00	$ 1,914.00	$ 2,299.00	$ 1,712.00	$ 1,914.00	$ 2,299.00
Spa	$ 2,500.00	$ 2,500.00	$ 2,500.00	$ -	$ -	$ -
Labor Price (32 hrs@ $130/hr)	$ 4,160.00	$ 4,160.00	$ 4,160.00	$ 4,160.00	$ 4,160.00	$ 4,160.00
Misc. (pipes, valves, etc.)	$ 3,000.00	$ 4,000.00	$ 5,000.00	$ 2,500.00	$ 3,500.00	$ 4,500.00
Total Cost	**$ 12,171.00**	**$ 13,373.00**	**$ 14,758.00**	**$ 9,171.00**	**$ 10,373.00**	**$ 11,758.00**

PV Only System

The PV Only system is identical to the Conventional system described above, except with a PV array installed to offset the electricity used by the home for heating, cooling, and standard household appliances. On the systems with the spa, a larger PV array had to be installed to make up for the energy needed to heat the spa. On the 1200 sq.ft design, 30 solar panels were added which gave it a total PV system size of 10.2kW. Installing these solar panels adds an additional cost of $20,400, but allows for the opportunity to save on the monthly electric bill which increases the value of the design. On the 800 sq.ft design, 20 solar panels were added for a total PV system size of 6.8kW. This costs an additional $13,600. Finally, on the 400 sq.ft design, 10 solar panels were added for a total PV system size of 3.4kW at a cost of $6,800. These PV prices are based on an assumed cost of $2.00/W. Due to the limited roof size our PV system is undersized for the 800 and 400 sq.ft design.

The PV Only system without the spa required a smaller array which decreased the overall system price. On the 1200 sq.ft design, 24 solar panels are required for a PV size of 8.16kW and a price of $16,320. The 800 sq.ft design has 18 solar panels. This has a 6.12kW PV size at a cost of $12,240. Finally on the 400 sq.ft design 10 solar panels were added at a system size of 3.4kW and a price of $6,800. All of the PV systems installed without the spa, except for the 400 sq.ft design, satisfy the electrical demand.

SunDrum Solar's HarvestHP System

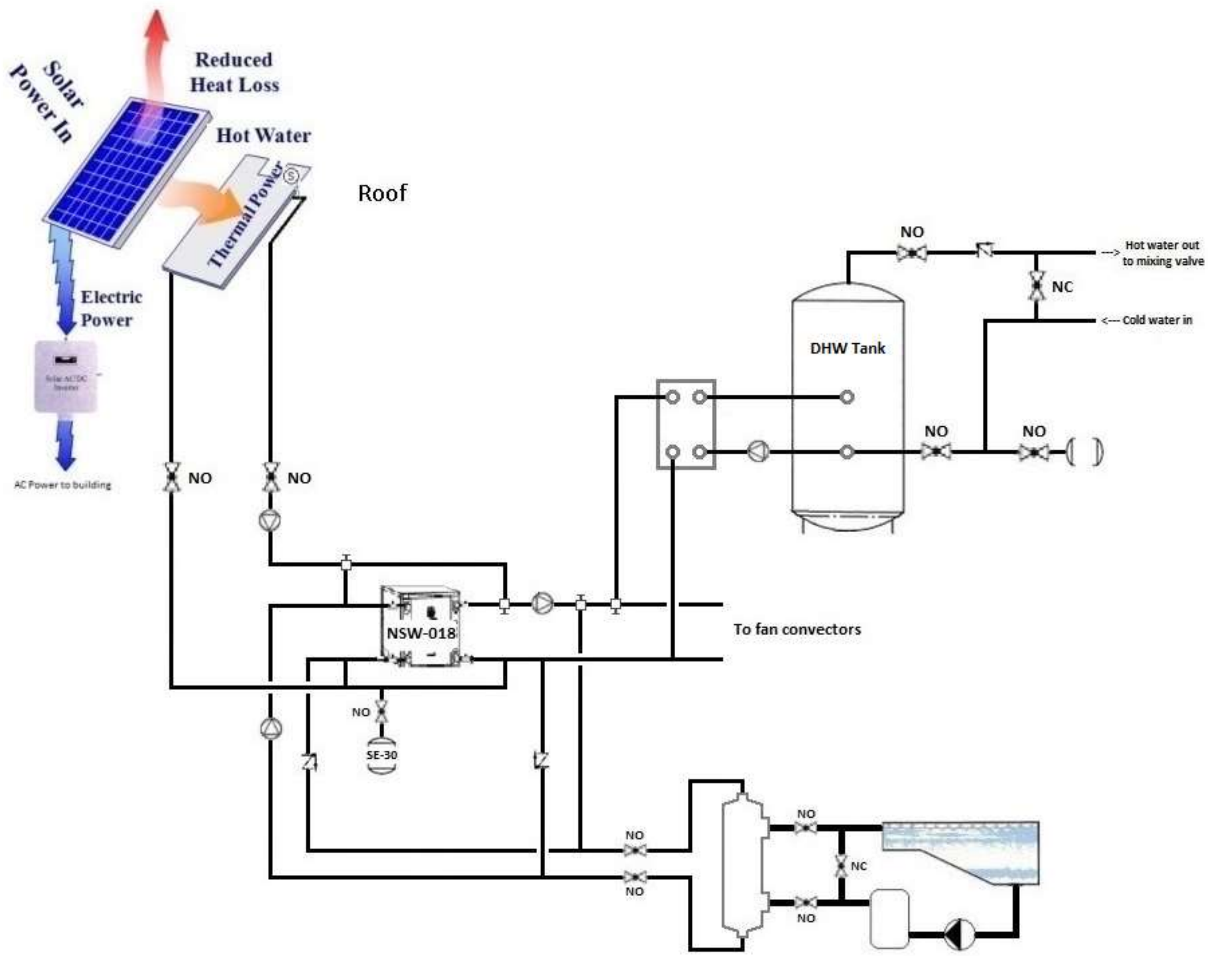
SunDrum Solar's HarvestHP™ system combines the most efficient hybrid solar collectors in the world, developed and patented by SunDrum Solar®, with water to water heat pump technology to provide unprecedented performance. When the sun is shining, the system is in "Active Mode" and captures thermal and electrical energy from the sun, as any traditional solar system. When the sun's direct rays are weak or not available, "Harvest Mode" uses the collectors to absorb thermal energy from the air, and utilizes the heat pump to boost the useable thermal temperature of the fluid, making the system capable of running 24 hours a day. The energy produced in either mode can be applied to provide DHW heating, space heating, and spa heating for all three home sizes. In addition, by reversing the energy flow, space cooling can be provided. This all-in-one energy solution is capable of satisfying 100% of the loads in warmer climates, where colder climates may require backup space heating and DHW heating equipment in colder climates. The current analysis was performed for Atlanta, GA, where backup heat is not required.

The basic system design is the same for all three home sizes, where the differences lie in the sizing of the components. The solar array consists of 10, 14, and 18 PV panels, respectively, where in all cases ten are converted to hybrid panels using SunDrum Solar's thermal collectors. Also included is a 1.5-ton water to water heat pump and an 80-gallon DHW storage tank with external heat exchanger to isolate the potable water from the solar glycol loop. For the 400 sq.ft home, a 40-gallon DHW tank is used. Space heating and cooling are provided through the use of hydronic fan convectors, where the whole home is treated as a single zone to eliminate the need for a buffer tank.

For the homes in which a spa is included, the spa doubles as a thermal battery for the HarvestHP system. During the winter, the spa serves as a heat source for space heating at night. The heat removed from the spa can be recharged with solar heat from the collectors during the day. During the summer, the spa provides a heat dump for the air conditioning load when the solar collectors are too hot to be used for cooling. This has a dual effect of simultaneously heating the spa and cooling the home using the same energy input, and can be viewed as free air conditioning or free spa heating. Since the spa is a relatively small battery, the cover should be left off during the cooling season to allow the extra heat to escape. In the heating season the cover should be kept on when the spa is not in use.

In the homes where the spa is not included, alternative thermal storage is included in the design. The extra thermal storage is assumed to add \$500, \$1,000, and \$1,500 to the system cost, respectively for the three home sizes.

The mechanical design of the HarvestHP system is illustrated below.



Financial Analysis

The tables below break down the costs and savings of all system types and all home sizes. The first table is for systems where the spa is included, and the second table is for systems with no spa. For the systems with spa, the cost of the spa heating equipment is included, including the cost of the spa itself. A dealer profit margin is not included in the system costs. System costs for the PV Only and HarvestHP systems are based on an assumed cost of \$2.00/W for the PV portion of the system and \$1.50/W for the thermal portion of the system. All data is presented for electricity rates of \$0.12/kWh and \$0.25/kWh.

The Annual Energy Usage includes the energy required for the various heating and cooling loads, as well as the basic household electrical load (refrigerator, lights, etc.). The basic electrical loads for the three home sizes are assumed to be 4 MWh, 5 MWh, and 6 MWh, respectively.

The tables include the 10- and 25-year cost of ownership for all systems, as well as the expected number of payback years. These are simple cash flow and payback numbers, which do not account for tax credits, depreciation, or other government incentives. A 5% annual inflation rate is included for the cost of energy. Note that the payback for the Conventional system is infinity, as this type of system does not generate renewable energy and thus will continue costing the customer money through its entire lifecycle.

With Spa

		400 ft^2 Home		800 ft^2 Home		1200 ft^2 Home	
		$0.25/kWh	$0.12/kWh	$0.25/kWh	$0.12/kWh	$0.25/kWh	$0.12/kWh
Conventional System	Annual Electrical Energy Usage (MWh)	8.19		11.12		14.03	
	Annual Electrical Energy Savings (MWh)	0.00		0.00		0.00	
	Annual Energy Cost	-$2,047.00	-$982.56	-$2,781.18	-$1,334.97	-$3,507.96	-$1,683.82
	System Retail Cost	$12,171.00		$13,373.00		$14,758.00	
	10 Year Cost of Ownership	$ (39,964.93)	$ (25,512.08)	$ (51,135.62)	$ (31,499.06)	$ (62,388.77)	$ (37,620.77)
	25 Year Cost of Ownership	$ (111,915.30)	$ (60,048.26)	$ (148,892.04)	$ (78,422.14)	$ (185,690.93)	$ (96,805.81)
	Simple Payback (Years)	—	—	—	—	—	—
PV Only System	Annual Electrical Energy Usage (MWh)	8.19		11.12		14.03	
	Annual Electrical Energy Savings (MWh)	5.00		10.00		15.00	
	Annual Energy Cost	-$797.00	-$382.56	-$281.18	-$134.97	$242.04	$116.18
	System Retail Cost	$18,971.00		$26,973.00		$35,158.00	
	10 Year Cost of Ownership	$ (29,792.56)	$ (24,165.35)	$ (30,790.89)	$ (28,805.59)	$ (31,871.67)	$ (33,580.56)
	25 Year Cost of Ownership	$ (57,806.43)	$ (37,612.01)	$ (40,674.29)	$ (33,549.62)	$ (23,364.31)	$ (29,497.03)
	Simple Payback (Years)	5.4	11.3	5.4	11.3	5.4	11.3
HarvestHP System	Annual Thermal Energy Generated (MWh)	7.6		12.9		18.2	
	Annual Electrical Energy Usage (MWh)	5.10		7.00		9.10	
	Annual Electrical Energy Savings (MWh)	5.30		7.42		9.54	
	Annual Energy Cost	$50.00	$24.00	$105.00	$50.40	$110.00	$52.80
	System Retail Cost	$18,800.00		$21,520.00		$24,240.00	
	10 Year Cost of Ownership	$ (18,121.11)	$ (18,474.13)	$ (20,094.32)	$ (20,835.67)	$ (22,746.43)	$ (23,523.09)
	25 Year Cost of Ownership	$ (16,363.65)	$ (17,630.55)	$ (16,403.65)	$ (19,064.15)	$ (18,880.02)	$ (21,667.21)
	Simple Payback (Years)	3.2	6.6	2.8	5.9	2.6	5.5

Without Spa

		400 ft^2 Home		800 ft^2 Home		1200 ft^2 Home	
		$0.25/kWh	$0.12/kWh	$0.25/kWh	$0.12/kWh	$0.25/kWh	$0.12/kWh
Conventional System	Annual Electrical Energy Usage (MWh)	5.91		8.84		11.75	
	Annual Electrical Energy Savings (MWh)	0.00		0.00		0.00	
	Annual Energy Cost	-$1,476.78	-$708.85	-$2,210.97	-$1,061.26	-$2,937.75	-$1,410.12
	System Retail Cost	$9,171.00		$10,373.00		$11,758.00	
	10 Year Cost of Ownership	$ (29,222.56)	$ (18,795.75)	$ (40,393.26)	$ (24,782.72)	$ (51,646.40)	$ (30,904.43)
	25 Year Cost of Ownership	$ (81,130.22)	$ (43,711.42)	$ (118,106.96)	$ (62,085.30)	$ (154,905.85)	$ (80,468.97)
	Simple Payback (Years)	—	—	—	—	—	—
PV Only System	Annual Electrical Energy Usage (MWh)	5.91		8.84		11.75	
	Annual Electrical Energy Savings (MWh)	5.00		9.00		12.00	
	Annual Energy Cost	-$226.78	-$108.85	$39.03	$18.74	$62.25	$29.88
	System Retail Cost	$15,971.00		$22,613.00		$28,078.00	
	10 Year Cost of Ownership	$ (19,050.20)	$ (17,449.02)	$ (22,083.00)	$ (22,358.60)	$ (27,232.73)	$ (27,672.27)
	25 Year Cost of Ownership	$ (27,021.34)	$ (21,275.17)	$ (20,710.98)	$ (21,700.03)	$ (25,044.55)	$ (26,621.95)
	Simple Payback (Years)	5.4	11.3	5.4	11.3	5.4	11.3
HarvestHP System	Annual Thermal Energy Generated (MWh)	5.2		10.5		15.9	
	Annual Electrical Energy Usage (MWh)	4.80		6.90		8.80	
	Annual Electrical Energy Savings (MWh)	5.30		7.42		9.54	
	Annual Energy Cost	$125.00	$60.00	$130.00	$62.40	$185.00	$88.80
	System Retail Cost	$19,300.00		$22,520.00		$25,740.00	
	10 Year Cost of Ownership	$ (17,602.76)	$ (18,485.33)	$ (20,754.87)	$ (21,672.74)	$ (23,228.09)	$ (24,534.28)
	25 Year Cost of Ownership	$ (13,209.11)	$ (16,376.37)	$ (16,185.48)	$ (19,479.43)	$ (16,725.49)	$ (21,413.03)
	Simple Payback (Years)	6.3	13.2	5.2	10.8	4.5	9.3

The tables clearly show that it is a wise decision to opt for a solar energy system vs a conventional heat pump system, especially at higher electricity prices. Keep in mind that there are three important factors which, when taken into account, will actually make the solar options even more attractive. The first is the availability of government incentives such as SREC's and the 30% income tax credit for systems installed in the U.S. These types of credits serve to reduce the effective cost of the system, and thus improve the cost of ownership and payback numbers for both solar system options. The second factor is the expectation that energy costs associated with conventional fossil fuels are expected to increase in the future. Installing a solar system on your home is a way to protect against rising energy costs. The numbers in the tables above do not account for rising energy costs. The third factor is the impact of mass production, which can significantly lower both material and installation costs. This has the potential to be quite substantial for the HarvestHP system, as SunDrum Solar is currently a fairly low-volume supplier, and thus has a lot to gain in terms of lowering costs at higher volume.

Conclusion

Advances in solar technology have brought its costs down to where they are highly competitive with conventional heating and cooling equipment. In particular, SunDrum Solar's HarvestHP system combines standard PV technology with its unique heat pump assisted solar thermal technology to produce an all-in-one energy solution capable of providing customers with tremendous savings on their energy bills. In this report, the HarvestHP system was determined to provide the best payback and 25-year cost of ownership values to customers when compared to a conventional mini-split heat pump system and a conventional system with a standard PV array. On homes with low thermal requirements and ample roof space, the cost of ownership of the PV only system is on par with (but still higher than) the HarvestHP system. Accounting for government incentives and tax credits for solar technology and the potential cost savings associated with high volume production will increase the value of the HarvestHP system even further. Finally, no financial numbers can account for the value that the HarvestHP system brings to the fight against climate change.

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