Manufacturing Climate Solutions

Carbon-Reducing Technologies and U.S. Jobs

CHAPTER 6

Electric Heat Pump Water Heaters

by

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Summary

Electric heat pump water heater technology draws in warm ambient air to more efficiently heat water for residential use. Heat pump water heaters are more than twice as efficient as standard water heating technologies and are the most cost-effective electric water heating product, but they currently account for a negligible portion of the U.S. water heater market (ENERGY STAR, 2008). Market adoption of this mature technology has been limited due to high upfront costs, poor public awareness of the product, perception of poor reliability, and insufficient installation and maintenance infrastructure (Douglas, 2008). If the technology were adopted and achieved a 10% market share, it could save almost 1.3 billion kilowatt-hours of energy annually. Furthermore, with estimated annual household savings of $290 (ENERGY STAR, 2009b) and a payback period of less than three years (ENERGY STAR, 2008), consumers would benefit from lower utility bills.

Current residential heat pump water heater products are add-on units used in conjunction with conventional storage tanks and they are produced by a handful of very small U.S. companies with fewer than 20 employees. The products are distributed mainly through utility cooperatives and directly to consumers and are not available at large retailers. The recent introduction of ENERGY STAR water heater criteria appears to be incentivizing some larger appliance manufacturers to develop new heat pump water heater products that will be more widely available. These products are expected to reach the market in late 2009. In addition, the technology would likely benefit from greater publicity of its cost savings and the availability of a federal government tax credit for purchase of ENERGY STAR-labeled products. If consumer interest in heat pump water heaters does increase, the market would need to scale up significantly to meet greater demands. This would likely require large appliance manufacturers to enter the market, and thus result in a very different set of firms than the current producers highlighted in this report. Such a change would likely have a positive impact on U.S. assembly jobs. It may also positively impact component manufacturing if these larger companies access the existing U.S. network of component suppliers for the heating, ventilating, and air conditioning industry rather than sourcing components from abroad as is the case currently.

Introduction

In the United States, water heating is the second largest residential energy-consuming application and it accounts for approximately 15.5% of residential energy use (Energy Efficiency and Renewable Energy, 2006). The most prevalent water heating technologies in the United States are conventional tank storage units, of which approximately half are natural gas and half are electric (ENERGY STAR, 2008). Conventional storage hot water heaters use large tanks (between 20 and 80 gallons) to keep water hot all day so it is available when needed. This constant heating of water, even when not used, leads to what is termed “standby losses.” Alternative residential water heating technologies that could reduce both standby losses and overall energy consumption include gas and electric high performing conventional storage water

heaters, tankless and solar products, and electric heat pump and gas condensing water heaters. Table 1-1 outlines the American Council for an Energy Efficient Economy (ACEEE) estimates of the total cost of varying water heating technologies over a 13-year life span.

Table 1-1. American Council for an Energy Efficient Economy Water Heating Technologies Life-Cycle Costs

Energy Source	Water Heater Type	Efficiency (Energy Factor, EF[1])	Installed Cost	Yearly Energy Cost	Life (years)	Total Cost (Over 13 Years)
Natural gas	Demand gas (tankless)	0.80	$1,600	$262	20	**$5,008**
	Condensing gas storage	0.86	$2,000	$244	13	**$5,170**
	High-efficiency gas storage	0.65	$1,025	$323	13	**$5,220**
	Conventional gas storage	0.60	$850	$350	13	**$5,394**
Electric	Electric heat pump water heater	2.20	$1,660	$190	13	**$4,125**
	High-eff. electric storage	0.95	$820	$439	13	**$6,528**
	Minimum Efficiency electric storage	0.90	$750	$463	13	**$6,769**
	Solar with electric back-up	1.20	$4,800	$175	20	**$7,072**
Oil	Conventional oil-fired storage	0.55	$1,400	$654	8	**$11,299**

Source: (Energy Efficiency and Renewable Energy, 2008)

Electric heat pump water heaters are one of the most promising energy-saving technologies in the residential water heating market because of their energy efficiency and payback potential. According to ACEEE, electric heat pump water heaters have the lowest total 13-year costs at approximately $4,125. Estimates from ENERGY STAR indicate electric heat pump water heaters could save 2,662 kilowatt hours of energy per year, or 55% of water heating costs annually (ENERGY STAR, 2008).

[1] ENERGY STAR defines Energy Factor (EF) as "the ratio of useful energy output from the water heater to the total amount of energy delivered to the water heater" (ENERGY STAR, 2009c).

Existing Federal Standards and New ENERGY STAR Criteria

The National Appliance Energy Conservation Act, which went into effect in 1990 and was revised in 2004, introduced federal efficiency standards for home appliances including hot water heaters (Consortium for Energy Efficiency, 2008). The standards vary by tank size and type of unit. Since the introduction of these standards, the typical electric water heater with a 50-gallon tank has an energy factor of 0.904 and the typical gas water heater with a 50-gallon tank has an energy factor of 0.575 (ENERGY STAR, 2008). These average energy factors are right at the federal standard, thus, the industry has not been incentivized to increase its energy efficiency further.

The federal standards leave significant potential to improve efficiency and reduce energy consumption for residential water heaters. Furthermore, until they were added this year, residential water heaters were the only major home energy-consuming appliance not labeled by ENERGY STAR, the federal program developed and overseen by the U.S. Department of Energy and the Environmental Protection Agency to promote energy-efficient products. Therefore, on April 1, 2008 ENERGY STAR introduced new criteria for residential water heaters which went into effect January 1, 2009. The U.S. Department of Energy hopes these new criteria will push efficiency development in the water heating market and expand consumer awareness and purchasing of more energy-efficient products (ENERGY STAR, 2008). The final ENERGY STAR criteria for residential water heaters are outlined in Table 1-2. Furthermore, consumers who purchase ENERGY STAR qualified electric heat pump water heaters during 2009 are eligible for a $300 federal tax credit (ENERGY STAR, 2009a).

Table 1-2. ENERGY STAR Residential Water Heater Qualifying Product Criteria

Water Heater Type	**Energy Factor (EF)**	**First –Hour Rating** (where applicable)	**Warranty**
Heat pump	2.0 or greater	≥ 50 gallons/hour	≥ 6 years sealed system
High-efficiency gas storage	≥ 0.62 (until 8/31/2010); ≥ 0.67 (thereafter)	≥ 67 gallons/hour	≥ 6 years sealed system
Gas condensing	≥ 0.8	≥ 67 gallons/hour	≥ 8 years sealed system
Whole-home gas tankless	≥ 0.82	2.5 gallons/minute over a 77°F rise	≥ 10 years on heat exchanger ≥ 5 years on parts
Solar water heater	Solar fraction ≥ 0.5	NA	≥ 10 years solar collector, 6 years storage tank, 2 years controls, 1 year piping & parts

Source: (ENERGY STAR, 2009c)

Electric Heat Pump Water Heaters

Electric heat pump water heaters are more efficient than conventional storage hot water heaters because rather than generating all of their own heat, heat pump water heaters use the ambient air surrounding it to heat the water (Energy Efficiency and Renewable Energy, 2005). The process is like a reverse refrigeration system. A low pressure, low temperature refrigerant passes through an evaporator, absorbing heat from the ambient air and vaporizing the refrigerant. It then moves through a compressor that raises its temperature and pressure. Then the heated refrigerant travels through the condenser, thereby transferring the heat to the water and returning to a liquid state (Ashdown et al., 2004; Sinha & Dysarkar, 2008). Heat pump water heaters have an efficiency rating of approximately 2.20, meaning that the useful energy produced for water heating is more than twice that used to operate the water heater. By comparison, high efficiency electric storage heaters are 0.95 and have limited potential to improve. Heat pump water heaters also offer the added benefits of dehumidification and space cooling because they pull warm vapors from the air (Baxter et al., 2005).

Electric heat pump water heaters are engineered as both add-on units, which connect to conventional electric hot water heaters, and integrated, or drop-in, units that replace the entire conventional unit and include a storage tank. Traditionally, the major difference between add-on and drop-in units is that add-on units draw water out of the tank and through the heat exchanger, whereas drop-in units incorporate the heat exchanger in the tank (Butzbaugh, 2009). Efficiency of the heat pump water heater varies by product design, rather than by product configuration, so in some cases an add-on product may be more efficient than a drop-in model and vice versa. As of February 2009, only add-on products are available, although at least two companies plan to introduce drop-in units to the market by the end of the year.

Figure 1-1. Residential Electric Heat Pump Types

Drop-In (Integrated)

Source: (General Electric, 2008)

Add-On With Storage Tank

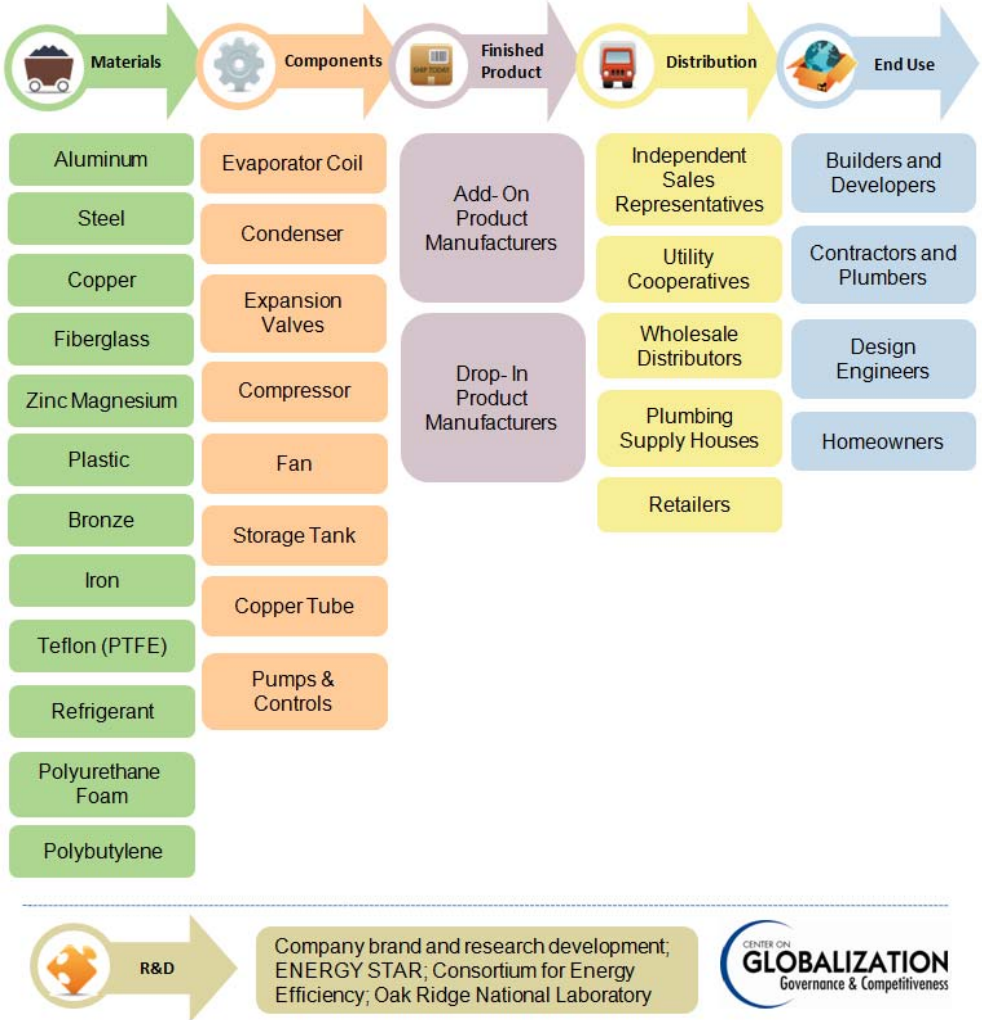
Source: (Applied Energy Recovery Systems, 2008)

It is notable that only integrated, or drop-in, products are included in ENERGY STAR's final qualifying product criteria for heat pump water heaters. Add-on products, which are the only items available on the market as of February 2009, were not included due to utility partner input based on their experiences promoting add-on units. Utilities found that drawing water out of the tank and into the add-on unit can lead to issues with product reliability (Butzbaugh, 2009).

Electric Heat Pump Water Heater Value Chain

For this report we analyzed the heat pump water heater value chain, focusing on add-on products but noting future drop-in manufacturers, and divided it into five segments: materials, components, finished product, distribution, and end use (see Figure 1-2). A more complete value chain with illustrative company information appears at the end of this chapter.

Figure 1-2. Electric Heat Pump Water Heater Simplified Value Chain



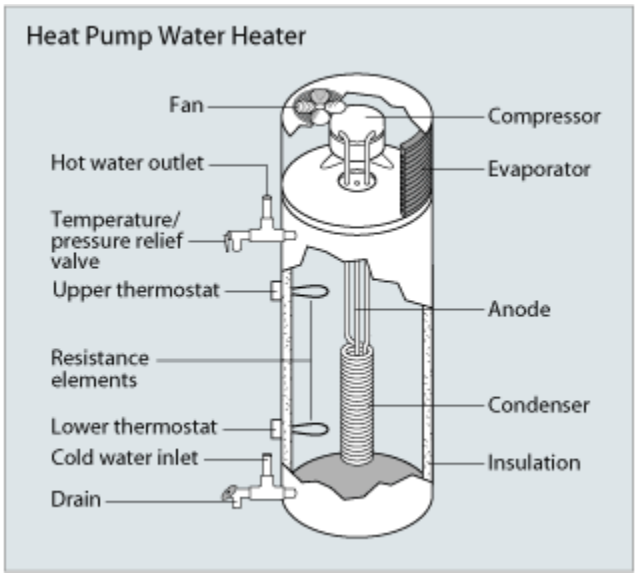
Source: CGGC, based on company websites, interviews, and industry sources.

Materials & Components

The major components in an electric heat pump water heater vary slightly depending on whether the product is an add-on or integrated unit. The major materials used in electric heat pump water heaters are steel, copper, aluminum, and plastics. A broader range of materials used in the components is listed in Figure 1-4.

Although interviews indicate the vast majority of component manufacturing is done abroad, the United States is one of the leading producers of most of the major materials used for production. This may create an opportunity to expand jobs within the value chain as the market for heat pump water heaters increases.

Figure 1-3. Integrated or Drop-In Electric Heat Pump Water Heater Components

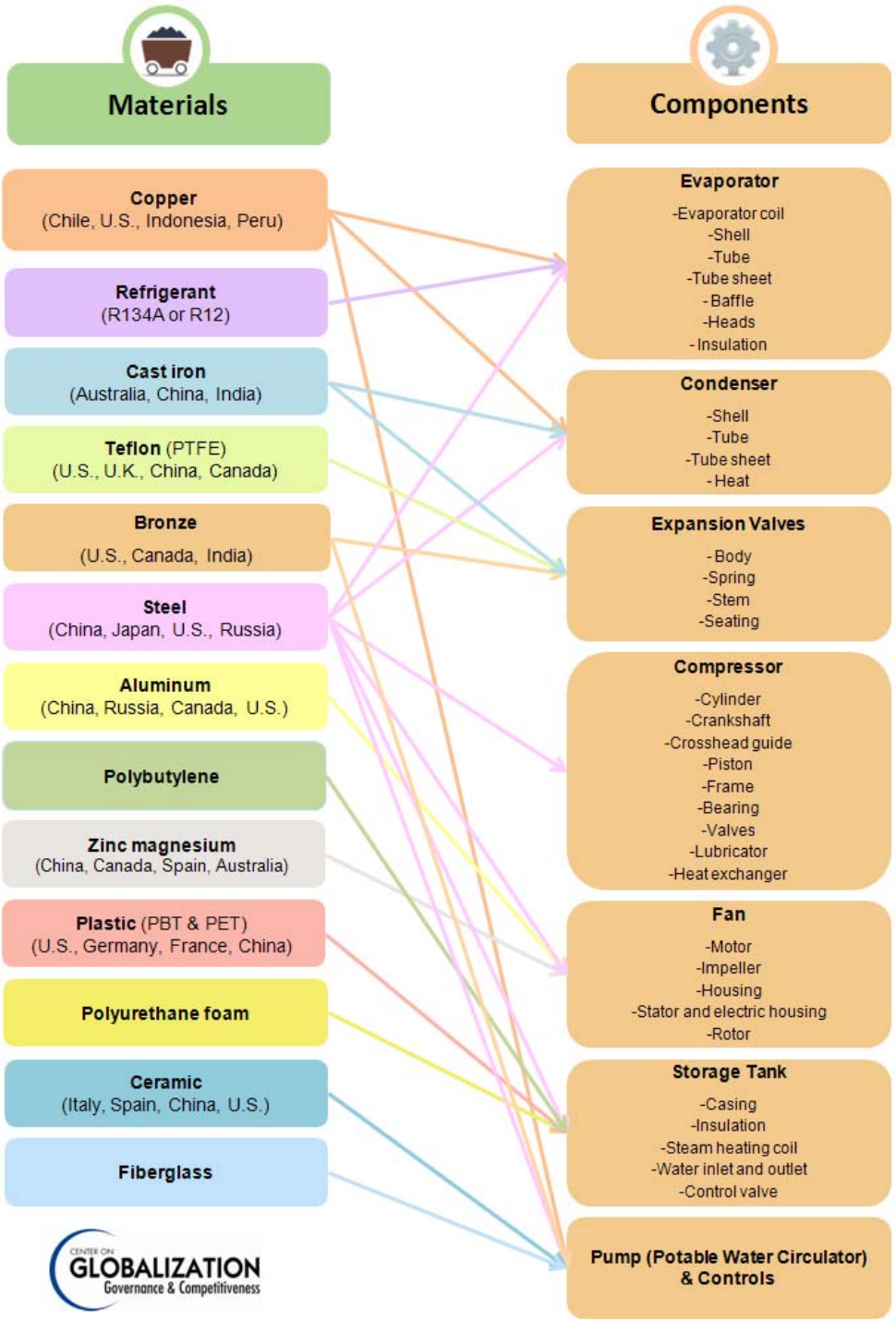


Source: (Energy Efficiency and Renewable Energy, 2005)

The process by which electric heat pump water heaters function is relatively similar across products. However, there are a number of differences between add-on and integrated units. As mentioned previously, traditional add-on electric heat pumps are connected to standard storage tank water heaters and they pull water from the tank into the add-on where it is heated in the heat exchanger. The add-on units generally include a compressor, evaporator, controls, condenser, and a small pump (Baxter et al., 2005). By contrast, integrated heat pump water heaters incorporate the heat exchanger in the tank and all components are in one unit. Integrated designs were originally developed through a collaboration between Arthur D. Little, Inc., EnviroMaster International (a subsidiary of ECR International, a former heat pump water heater manufacturer), and Oak Ridge National Laboratory (Baxter et al., 2005) with funding from a number of state and federal agencies. The newest heat pump water heater on the market, the AirTap™ by

AirGenerate, is a hybrid of the two system types. It places the heat exchanger and the controls in the tank, rather than moving the water from the tank to the add-on unit (Borzoni, 2009; Sinha, 2008).

Figure 1-4. Heat Pump Water Heater Materials and Components



Source: CGGC, based on company websites, interviews, and industry sources.

Illustrative Component Suppliers

The types of companies manufacturing components for heat pump water heaters are those making products such as compressors, evaporators, water-cooled condensers, expansion valves, evaporator coils, and fans as used in the heating, ventilation, and air-conditioning (HVAC) industry. Company interviews indicate existing heat pump water heater producers source the majority of their components from abroad. Many of these components are likely manufactured as subassemblies in China and Mexico. Therefore, current U.S. production presence is limited to general assembly jobs. However, there is a strong U.S. manufacturing presence for similar types of subcomponents used in the HVAC industry and Table 1-3 illustrates some of these U.S. companies. They are included here as illustrative U.S. manufacturers who may have potential to supply the electric heat pump water heater market. It is possible that if heat pump water heaters become more popular and larger appliance manufacturers begin producing such products, they may access components from the existing U.S. HVAC supply chain, thus potentially increasing U.S. manufacturing job opportunities.

Table 1-3. Illustrative Component Manufacturers for the U.S. HVAC Industry*

Company	Headquarters	Component
Atlas Copco Compressors Inc.	Westfield, MA	**Compressor Manufacturer**
Copeland Corp. (Emerson Climate Technologies)	Rushville, IN	
Danfoss Compressors	Lawrenceville, GA	
Dresser-Rand	Houston, TX	
Ingersoll Rand Air Compressors	Edison, NJ	
Quincy Compressor	Bay Minette, AL	
Armstrong Engineering Associates	West Chester, PA	**Evaporator Manufacturer**
Blissfield Manufacturing Co.	Blissfield, MI	
Packless Industries	Waco, TX	
Perry Products Corp.	Hainesport, NJ	
Tranter Inc.	Wichita, TX	
Airdyne Refrigeration & Air Conditioning	Fullerton, CA	**Water Cooled Condenser Manufacturer**
Doucette Industries	York, PA	
FES Systems Inc.	York, Pa	
GEA Rainey Corp.	Catoosa, OK	
Packless Industries	Waco, TX	
Tranter Inc.	Wichita, TX	
Turbotec Products Inc. (Thermodynamics)	Windsor, CT	
MSC Industrial Supply Co.	New Castle, DE	**Expansion Valve Manufacturer**
Onyx Valve Co.	Cinnaminson, NJ	
Watts Regulator Co.	North Andover, MA	
SPX Corp.	Charlotte, NC	
Watsco Inc.	Coconut Grove, FL	

Table 1-3. Illustrative Component Manufacturers for the U.S. HVAC Industry*

Company	Headquarters	Component
Acme Refrigeration of Baton Rouge	Baton Rouge, LA	**Evaporator Coil Manufacturer**
Blissfield Manufacturing Co. Inc.	Blissfield, MI	
Goodman Global Inc.	Houston, TX	
Packless Industries	Waco, TX	
Turbotec Products Plc	Windsor, CT	
York International Corp. (Johnson Controls)	York, PA	
Dunham-Bush Inc.	Pawtucket, RI	**Fan Manufacturer**
International Environmental Corp.	Oklahoma City, OK	
McQuay International	Owatonna, MN	
SPX Corp.	Charlotte, NC	
Trane (Ingersoll Rand)	La Crosse, WI	
Advanced Conservation Technologies	Costa Mesa, CA	**Pump (Potable Water Circulator) & Controls Manufacturer**
Armstrong Pumps	N. Tonawanda, NY	
Bell and Gossett Pumps	Morton Grove, IL	
Enovative	Costa Mesa, CA	
Grundfos Pumps Corp.	Fresno, CA	
Laing Thermotec Inc.	Chula Vista, CA	
RedyTemp (Temtrol Delta T Inc.)	Oceanside, CA	
TACO Inc.	Cranston, RI	
Wilo EMU USA	Thomasville, GA	

Source: CGGC, based on individual interviews, company websites, Marketline, OneSource, ThomasNet

*The companies in this table are U.S. suppliers for the heating, ventilating and air conditioning industry. They are not actual suppliers for heat pump water heaters. Research indicates components are mostly supplied from outside the U.S.

Residential Water Heater Market

Approximately 9.8 million residential water heaters were sold in the United States in 2006 (ENERGY STAR, 2008). Electric heat pump water heaters are a negligible segment of that market because only approximately 2,000 residential electric heat pump water heater units are sold annually. The majority of units installed in the latter 1990s were part of utility incentive programs and federal and state test programs (Baxter et al., 2005). Furthermore, in 2008 there were four small U.S. heat pump water heater manufacturers – AirGenerate, Applied Energy Recovery Systems (E-Tech brand), Nyle Special Products, and Trevor-Martin Corporation[2] – with less than 20 employees each. These companies currently produce add-on units and, thus, none qualify as of yet for ENERGY STAR labeling. ECR International, which manufactured a drop-in unit called the Watter$aver, discontinued sales a few years ago due to poor consumer

[2] Trevor-Martin Corporation pulled the Hot Water Generator off production in mid-2008 to do some redesign and will resume production in 2009 (Borzoni, 2009).

response to the product (Hoyt, 2008). AirGenerate is a new entry to the water heater market and its product, the AirTap, sold approximately 1,000 residential units after it was introduced in mid-2008 (Sinha, 2008), making it the market leader. Much of its success is a result of its comparative price advantage. It costs $699 which is 20%-40% less than conventional add-on products.

The majority of the existing heat pump water heater products are sold through utility cooperatives, independent sales representatives to rehab projects, and directly to homeowners. Add-on heat pump water heaters are not currently available at big box retailers, like Home Depot or Lowe's, although some can be purchased at plumbing supply houses or from wholesale distributors.

Table 1-4. Residential Electric Heat Pump Water Heater Manufacturers, 2008

Company Name	Model Name(s)	2008 Units Sold	Headquarters	Employees	Manufacturing Location
AirGenerate	AirTap	1,200	Houston, TX	7	China
Applied Energy Recovery Systems, Inc	E-Tech R060 "Hot Water Cube"; R-106	100	Norcross, GA	15	Norcross, GA
Nyle Special Products	Nyletherm-1	150	Bangor, ME	15	Bangor, ME
Trevor-Martin Corporation	Hot Water Generator	NA	Mooresville, NC	NA	Mooresville, NC

Sources: (Borzoni, 2009; Lewis, 2008; Sinha, 2008; Wilson, 2008).

General Electric (GE) plans to release a drop-in unit in 2009. The General Electric Hybrid Electric Water Heater contains the same components as a standard tank water heater so that it can continue to provide large quantities of water when needed, in addition to having all the components of a heat pump system to make it more energy efficient (Schiller, 2008). This product may be made available at big box retailers, like Lowe's. General Electric has expressed plans to submit the new system for ENERGY STAR qualification. AirGenerate is also in the process of designing a drop-in unit that they expect to meet ENERGY STAR criteria and plan to release at the end of 2009 (Sinha, 2009). If these products are successful, it is possible other large appliance manufacturers may develop products of their own.

U.S. job implications for the products currently on the market are limited to assembly because the main components and subassemblies are manufactured abroad. However, if consumer interest in the drop-in units entering the market in 2009 is high, other large U.S. appliance manufacturers may develop products as well and this could dramatically change the current

market structure. The impact of such a change on U.S. jobs is unclear. At a minimum, heightened popularity for heat pump water heaters would increase the demand for U.S. assembly workers. If large U.S. appliance manufacturers were to develop their own products, then the job impact could be significantly greater because it may be more efficient for certain components to be made in U.S.-based supply chains such as those identified in Table 1-3.

AirGenerate Case Study

AirGenerate, a company dedicated to developing and manufacturing renewable energy products, introduced a heat pump water heater, the AirTap™, in mid-2008. The AirTap™ is a modular system that is a cross between the traditional "add-on" and "drop-in" units. The modular unit attaches to any conventional storage tank water heater to create an integrated system. The AirTap™ places a heat exchanger in the water tank and the added unit uses a compressor to extract heat from the surrounding air and sends this heat through long copper tubes that disperse it throughout the water.

AirTap™ is the most energy efficient water heater in the United States, as certified by GAMA, an association of appliance and equipment manufacturers, under the Department of Energy guidelines. This product can be used in conjunction with any 30-80 gallon water tank, and the technology results in 300% improved efficiency and up to 80% in energy savings. The AirTap™ can operate under extremely cold conditions; however, if the ambient temperature is below 35° F, the efficiency of the unit will drop by approximately 50%.

During the first six months of sales, AirGenerate sold approximately 1200 heat pump water heaters, making AirTap™ the U.S. heat pump water heater market leader. AirGenerate estimates it will sell 10,000 units in 2009. AirGenerate currently markets its product to home owners, builders, business operators, utility companies and government agencies. As part of an efficient water heater pilot program with Atlanta-based Southern Company AirGenerate was invited to install water heaters in several Southern Company customer homes. The success of the pilot program resulted in an increased market response to the AirTap™.

The major difference between the AirGenerate product and similar products on the market is the patented technology (described above), lower cost and ease of installation. The AirGenerate product costs $699, but with an estimated annual savings after the first year between $200 and $300, the payback period is estimated to be less than 3 years (AirGenerate, 2008). The AirTap™ is not currently certified by ENERGY STAR because only drop-in models are eligible. However, the company is hopeful ENERGY STAR will consider reviewing the product because of its technical differences from traditional add-on technology. AirGenerate also plans to release a drop-in model in summer 2009, which it expects to meet ENERGY STAR criteria.

The AirGenerate headquarters are located in Houston, TX, but all manufacturing is done in China, and all the components suppliers are international companies. The company began to source its product from an offshore supplier in order to meet increasing demand in the United States. AirGenerate has 7 employees and 12 contractors in the United States, and the China facility employs engineers and technicians. Products are manufactured on a mass scale and 600 heat pump water heaters are produced in one batch.

With an upfront cost that is relatively low in comparison to other heat pump water heater products currently on the market, AirGenerate expects a marked increase in sales as more people see value in purchasing products that are more energy efficient. If the market for heat pump water heater manufacturing continues to grow in the U.S., AirGenerate may consider using more domestic component manufacturers and assembly processes (Sinha, 2009).

Market Barriers

There are a number of reasons heat pump water heaters have not yet penetrated the U.S. residential water heating market. The primary reason is cost. A conventional heat pump water heater is estimated to cost between $900 and $1200 plus installation compared to conventional storage water heaters that cost approximately $200 (Baxter et al., 2005). However, the return on the premium paid for a heat pump water heater is approximately three years so that investment can quickly become cost savings (ENERGY STAR, 2008). Another barrier is that heat pump water heaters are frequently replaced on an emergency basis when the existing unit breaks. Thus, homeowners may be less likely to do extensive research to determine the cost effectiveness of different water heating options prior to purchase of a replacement (Murtishaw & Sathaye, 2006). Another barrier to market penetration is that the water heating appliance is often chosen by someone other than the primary occupant. For example, a home builder will purchase the unit for new homes but the energy cost savings would accrue to the homeowner. Similarly, a rental unit owner may not see the financial savings of an energy efficient unit if the utilities are paid by the renter (Murtishaw & Sathaye, 2006).

The efficiency of heat pump water heaters also varies; they are most efficient in warm climates because the warm ambient air surrounding the units supplies much of their energy. Thus, units kept in locations where the ambient air drops below 40 degrees Fahrenheit will experience reduced efficiency (Energy Efficiency and Renewable Energy, 2005). For example, as mentioned previously, the AirGenerate AirTap loses half of its efficiency savings when the ambient temperature is below 35° F. Nonetheless, it is still more efficient than standard storage tank products. Furthermore, when the weather is warm, the technology's process of capturing warm air can be a benefit because it can help cool and dehumidify the air around it. The Trevor-Martin Hot Water Generator, which is currently being redesigned and will return to the market in 2009, was developed to accommodate ducting that allows consumers to draw air from the warmest areas of their homes, such as attics. Consequently, benefits of the unit include a) capability to

access more warm ambient air from locations in the house other than immediately surrounding the unit, like an attic, and b) preventing the area around the unit from becoming too cool (Borzoni, 2009). Heat pump water heaters could offer even greater efficiency if used in combination with heating and air conditioning systems. These systems working together would transfer cool air produced by the heat pump water heater to the air conditioning unit to increase the efficiency of the cooling system and draw in warm air released from the air conditioning unit for use with the heat pump (Energy Efficiency and Renewable Energy, 2005) (Borzoni, 2009).

Market penetration of heat pump water heaters also has been limited due to a perception of inadequate product reliability (Douglas, 2008). Technical problems with heat pump water heaters experienced during early utility and federal pilot programs resulted in this perception. Although many of these problems have been fixed, the perception remains. The lack of availability of heat pump water heater products from larger retailers also may limit public awareness and interest in the product. Furthermore, if demand were to increase rapidly, it is unclear that the existing small manufacturers will be able to supply large purchase requests. Therefore, until General Electric or other large appliance manufacturers enter the market, it may be very difficult to meet high demand for electric heat pump water heaters.

International Market Perspective: Japan

In Japan water heating accounts for more than 30% of energy consumption and, thus, is the largest source of energy use in Japanese households (Maruyama, 2008). In an effort to increase efficiency the Japanese government has supported the heat pump water heater market over the past decade, leading to exponential growth in sales and use of heat pump water heaters. Market growth was achieved through government partnership with private industry to improve the performance of available heat pumps. This led to development of a heat pump that relies on carbon dioxide refrigerant rather than conventional refrigerants and which is more than 300% energy efficient[3] (Hashimoto, 2006; Maruyama, 2008).

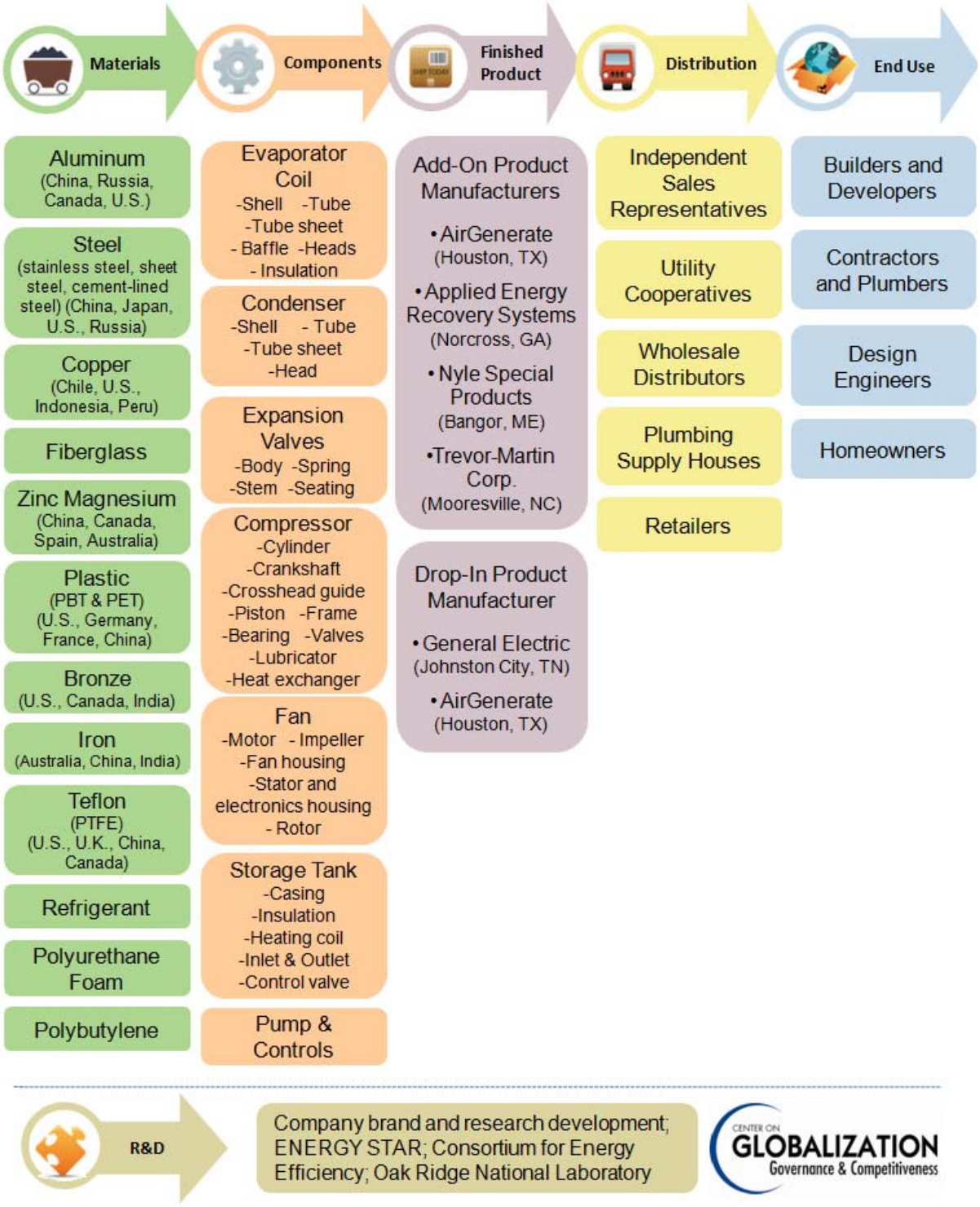
Government subsidies of approximately $420 are available for purchase of the product which costs between $6,000 and $9,500 (Maruyama, 2008). In addition, the heat pump water heater was strongly marketed under a new name, ECO-CUTE. Since introduction of the government subsidy in 2002, other large manufacturers have entered the market (Hashimoto, 2006) and between 2002 and 2007 the annual number of ECO-CUTE shipments increased from 37,000 to more than 400,000, accounting for 9% of the water heating market (Hashimoto, 2006; Maruyama, 2008).

[3] 300% energy efficiency means the unit can produce three times more useful energy than it consumes.

Conclusion

Heat pump water heaters are a mature technology that can save between 30% and 50% of the energy used to heat water in U.S. homes. Nonetheless, high upfront costs, limited public awareness of the product and its cost-saving benefits, and the lack of products from large appliance manufacturers have thus far impeded its growth within the U.S. residential water heating market. The recent introduction of ENERGY STAR criteria for water heating technologies has the potential to increase awareness of the products and may increase demand. It may also draw larger appliance manufacturers to the market leading to a dramatic change in the market structure. Learning from market penetration of heat pump water heaters in Japan, strong government promotion of the U.S. products, which are cheaper than those sold in Japan, could lead to significant increases in sales, greater interest by larger appliance manufacturers, and an increased need for U.S. assembly jobs.

Figure 1-5. Electric Heat Pump Water Heater Value Chain, with Illustrative Companies



Source: CGGC, based on company websites, interviews, and industry sources.

References

AirGenerate. (2008). AirTap™. Retrieved October 2, 2008, from http://www.airgenerate.com/products/airtap.html

Applied Energy Recovery Systems. (2008). E-Tech Residential Water Heating. Retrieved December 8, 2008, from http://www.aers.com/etech_residential_water_heating.html

Ashdown, Barbara G., Bjornstad, David J., Boudreau, Gabrielle, Lapsa, Melissa V., Schexnayder, Susan, Shumpert, Barry, and Southworth, Frank. (2004). *Heat Pump Water Heater Technology: Experiences of Residential Consumers and Utilities*. Oak Ridge, TN: Oak Ridge National Laboratory.

Baxter, Van D., Tomlinson, John J., Murphy, Richard W., Ashdown, Barbara G., and Lapsa, Melissa V. (2005). *Residential Heat Pump Water Heater Development Status - USA*. Oak Ridge, TN: Oak Ridge National Laboratory.

Borzoni, John. (2009). CEO, Trevor-Martin Corporation. Personal communication with CGGC staff. January 23.

Butzbaugh, Josh. (2009). Project Manager, ENERGY STAR Water Heater Program. Personal communication with CGGC staff. January 12.

Consortium for Energy Efficiency. (2008). *High-Efficiency Residential Gas Water Heating Initiative*. Boston, MA.

Douglas, John. (2008). Demonstrations Encourage Wider Use of Efficient Technologies. *EPRI Journal*(4), 15-17.

Energy Efficiency and Renewable Energy. (2005, September 25). Your Home: Heat Pump Water Heaters. Retrieved November 10, 2008, from http://apps1.eere.energy.gov/consumer/your_home/water_heating/index.cfm/mytopic=12840

---. (2006). Buildings Energy Data Book. Retrieved February 2, 2009, from U.S. Department of Energy Building Technologies Program: http://buildingsdatabook.eren.doe.gov/TableView.aspx?table=2.1.5

---. (2008). Water Heating. Retrieved November 3, 2008, from http://apps1.eere.energy.gov/consumer/your_home/water_heating/index.cfm/mytopic=12760

ENERGY STAR. (2008). *ENERGY STAR Residential Water Heaters: Final Criteria Analysis*. Washington, DC: U.S. Department of Energy.

---. (2009a, February 18). Federal Tax Credits for Energy Efficiency. Retrieved February 18, 2009, from http://www.energystar.gov/index.cfm?c=products.pr_tax_credits#c4

---. (2009b). Residential Water Heaters. Retrieved January 29, 2009, from http://www.energystar.gov/index.cfm?c=water_heat.pr_water_heaters

---. (2009c). Residential Water Heaters Key Product Criteria. Retrieved January 12, 2009, from http://www.energystar.gov/index.cfm?c=water_heat.pr_crit_water_heaters

General Electric. (2008, April 1). GE First to Announce Water Heaters That Will Meet New DOE ENERGY STAR Standards. Retrieved November 4, 2008, from http://www.geconsumerproducts.com/pressroom/press_releases/appliances/energy_efficient_products/doetanklesshybrid.htm

Hashimoto, Katsumi. (2006). *Technology and Market Development of Heat Pump Water Heaters in Japan*: Central Research Institute of Electric Power Industry.

Hoyt, John. (2008). Senior Project Engineer, ECR International. Personal communication with CGGC Staff. November 5, 2008.

Lewis, Tripp. (2008). Nyle Special Products, Operations Manager. Personal communication with CGGC staff. December 15, 2008.

Maruyama, Takehiro. (2008, June 2). *ECO-CUTE-CO2 Heat Pump Water Heater in Japan.* Paper presented at the ACEEE Water Heating Forum.

Murtishaw, Scott and Sathaye, Jayant. (2006). *Quantifying the Effect of the Principal-Agent Problem on US Residential Energy Use*. Berkeley, CA: Lawrence Berkeley National Laboratory.

Schiller, Doug. (2008). Interview with GE on Energy Efficient Water Heaters - Education Needed. Retrieved December 2, 2008, from http://www.alternativeenergy.com/profiles/blog/show?id=1066929%3ABlogPost%3A43045

Sinha, Sunil. (2008). AirGenerate Chief Scientist/Co-Founder. Personal communication with CGGC staff. December 16, 2008.

---. (2009). AirGenerate Chief Scientist/Co-Founder. Personal communication with CGGC staff. January 23, 2009.

Sinha, Sunil Kumar and Dysarkar, Asoke. (2008). *United States Patent Application: Heat Pump Liquid Heater*. Retrieved. from http://appft1.uspto.gov/netacgi/nph-Parser?Sect1=PTO2&Sect2=HITOFF&p=1&u=%2Fnetahtml%2FPTO%2Fsearch-bool.html&r=1&f=G&l=50&co1=AND&d=PG01&s1=%22HEAT+PUMP+LIQUID+HEATER%22.TTL.&OS=TTL/%22HEAT+PUMP+LIQUID+HEATER%22&RS=TTL/%22HEAT+PUMP+LIQUID+HEATER%22.

Wilson, Greg. (2008). Vice President, Applied Energy Recovery Systems. Personal communication with CGGC staff. November 20, 2008.