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Residential Inverter-Driven Heat Pump International Market Characterization

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Executive Summary

In an effort to transform the residential space heating market in the Northwest, the Northwest Energy Efficiency Alliance (NEEA) has focused on promoting inverter-driven ductless heat pumps (DHPs) as a promising technology for displacing electric resistance heat. Ductless split system air conditioners and heat pumps are used extensively in Europe and Asia. In North America, ductless air conditioners and heat pumps were a small niche market until the early 2000s but have been gaining in market share since that time. This study assessed international DHP markets to determine how international experience can be leveraged to enhance market uptake of this technology in the Northwestern U.S.

ES.1 Key Findings

This section presents an abbreviated version of the key findings of this study. The main report contains a full version of the findings.

Market Drivers

Globally, the adoption of ductless split systems has been driven primarily by the desire to add cooling to homes that did not already have it and/or to replace noisy and inefficient window air conditioners. However, ductless solutions are not nearly as successful in markets where they must displace ducted products. In those markets, the high efficiency and multi-zone control of ductless solutions can be key selling points, and the products are frequently used as add-on solutions when additional cooling is needed due to home renovations or other changes to the building load profile.

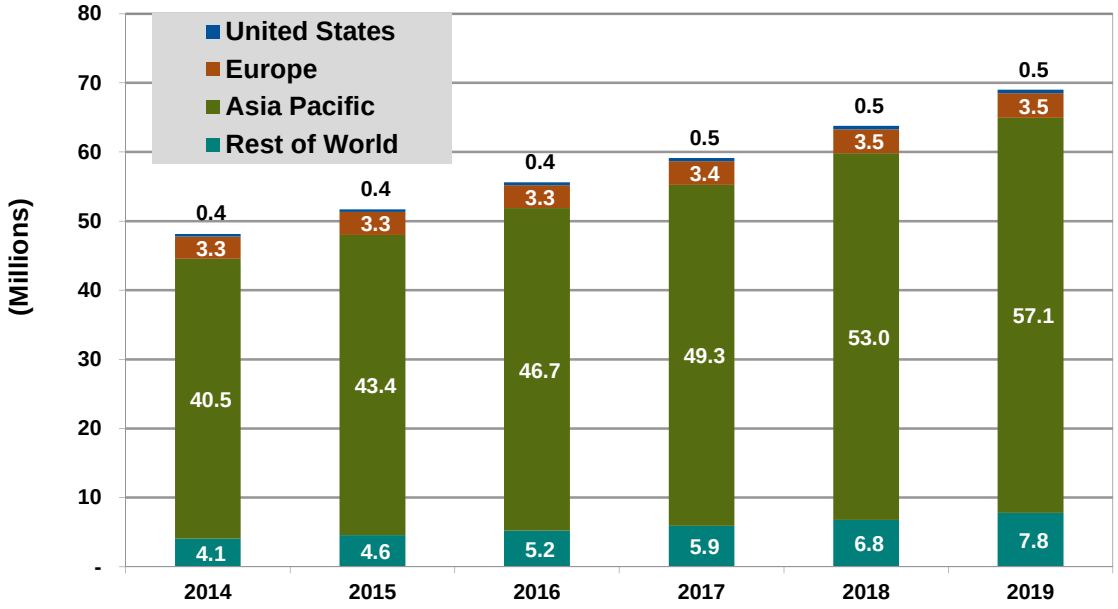
In the United States, the key factors inhibiting further adoption of ductless split systems stem from the fact that ducted systems are the standard solution in the market. On the supply-side, sales channels and contractors have historically focused on ducted solutions, which has led to a lack of familiarity with ductless products. As a result, installation costs of ductless systems in the United States are higher than other countries, and contractors often lack the training to install ductless products. In addition, U.S. consumers generally are not aware of ductless systems. Moreover, most existing homes were designed for ducted solutions, and the majority of the heating, ventilation, and air conditioning (HVAC) market is for replacement products. For replacement of existing HVAC systems, nearly all of which are ducted, it is typically far more expensive and complex to use a ductless solution.

There are two use cases for DHPs in U.S. homes: new home construction and replacement of existing systems. However, in new construction, homebuilders can easily install ductwork and the higher expense of ductless systems make them unattractive. For the replacement of electric baseboard heat or hydronic heating, ductless split systems face fewer barriers and are a viable solution. However, when ducted units must be replaced, the cost and disruption associated with installation of ductless systems usually precludes it from being a realistic option.

Market Size

The global market size for residential DHPs is estimated to be 48.2 million units in 2014. As shown in Figure 1, moderate to strong growth is expected, driven by a recovering global economy and the increased importance of energy efficiency for end users. China represents the largest residential market for DHPs, with an estimated 30.3 million shipments in 2014. DHP shipments to the U.S. market size were approximately 370,000 units in 2014. Heat pumps comprise over 70% of the overall ductless market. In warm climates, cooling-only units are more common. In areas that require both cooling and heating, the share of DHPs is increasing.

Figure 1. Residential Ductless Heat Pump Shipments by Region, World Markets: 2014-2019



Source: Navigant Research

Regional Comparison

The ductless split system market varies substantially by region. As indicated in Table 1, DHPs cost more to install in the United States than in other regions. According to manufacturers interviewed, the installed cost of a ductless split system is $800-$2,000 in Asia Pacific and Latin America and $1,400 - $2,000 in Europe. This is partly due to higher labor costs in certain regions, but labor costs do not explain the substantial differences relative to Europe or Japan. Low volumes, two-step distribution, and a higher prevalence of premium product also impact installed costs.

Table 1. Summary of Regional Differences for Ductless Split Systems

Metric	Asia Pacific	Europe	Latin America	United States
Typical Unit Nom. Cooling Capacity	Single head, 9,000-12,000 Btuh	Single head 9,000-12,000 Btuh	Single head 9,000-12,000 Btuh	Single head 12,000-18,000 Btuh

Installed Cost ($)	$800-$2,000	$1,400-$2,000	$800-$2,000	$3,000-$4,500
Labor Cost as % of Total	25%-35%	35%-40%	40%-50%	50%-65%
Typical Displaced Equipment	Window AC, portable heater	Hydronic heating	Window AC, portable heaters	Ducted systems, hydronic heating, baseboard electric resistance
Sales Channel	Retail direct	Retail two-step	Retail two-step	Two-step
Major Manufacturers	Midea Gree Daikin Mitsubishi Electric Panasonic	Daikin Mitsubishi Electric Fujitsu General LG Panasonic	Hitachi Midea LG Mitsubishi Electric Daikin	Mitsubishi Electric Fujitsu General Daikin LG Panasonic

Source: Navigant Research

ES.2 Recommendations

Market forces are already driving increased sales of DHPs in the United States. Manufacturers are investing in sales, marketing, and product development, and NEEA can take additional steps to accelerate adoption. Navigant's key recommendations are:

- ***Partner with manufacturers to help reduce costs, improve contractor awareness, and training.*** Compared to other regions, low U.S. sales volumes lead to higher sales, marketing, and distribution costs for manufacturers, higher installation costs for contractors, and higher installed costs for consumers. Because leading global manufacturers are already producing tens of millions of ductless systems annually for Asian markets, an increase in the U.S. market size will have limited impact on global manufacturing volumes and factory costs. However, training contractors how to sell, size, and install ductless products, combined with increasing installation volumes, can help reduce contractor costs and lower risks.

- ***Facilitate establishment of retail sales channels to help reduce cost and build consumer awareness.*** In the United States, consumers currently purchase HVAC equipment through a contractor. As a result, their options are limited to what contractors offer. Establishing retail sales channels for DHPs will enhance consumer choice and price competition, enabling consumers to learn more about the products and compare a wide array of solutions. Additionally, retail distribution may help reduce distribution channel markups.

- ***Help facilitate market entry of lower-cost products, including those from major Chinese manufacturers.*** While major global manufacturers of DHPs are currently active in the U.S. market, low-cost solutions produced by Chinese manufacturers are not widely available. Introducing these solutions to the U.S. market could increase price competition and reduce the overall installed cost of DHPs.

- ***Implement tiered system for rebates of highly efficient equipment.*** Current utility rebate programs are structured to be simple, often with only one efficiency threshold level or efficiency tier. However, ductless solutions are available at many different efficiency levels and become more competitive with ducted solutions at the highest efficiency levels. Implementing higher efficiency tiers that provide higher incentives but require a higher Seasonal Energy Efficiency Ratio (SEER) and/or Heat Seasonal Performance Factor (HSPF) ratings would likely enhance the adoption of ductless systems.

1 Product Overview

This section presents an overview of ductless heat pump (DHP) products.

1.1 Introduction

Ductless split systems, including DHPs, are composed of an outdoor unit coupled to one or more indoor cooling units. A compressor circulates refrigerant from the outdoor unit to the indoor unit(s). Once inside, fans within the indoor unit(s) force air past a refrigerant/air heat exchanger, thereby conditioning air within the indoor space. DHPs can operate either as an air conditioning unit or in reverse as a heating unit. Essentially, a DHP can act in one of two ways:

- Draw heat from internal building air through a heat exchanger and release that heat into the environment, thereby cooling the building
- Draw heat from the external environment and release it to building air through a heat exchanger, thereby warming the building

In the United States, ducted split systems are far more common than ductless systems. Functionally, both types of systems serve the same purpose. Where they fundamentally differ is that ducted systems condition air at a central location and then circulate the conditioned air throughout the house, whereas ductless systems circulate refrigerant to each room or living space and then condition the air locally. As shown in Figure 2, a ducted system and its associated ductwork requires more space than a ductless one. However, ductless installations require the installation of indoor units in each room or set of adjacent rooms to be conditioned. Ductless systems may be easier to install in older homes, especially in homes without existing ductwork.

Figure 2. Typical Residential Installation of Ducted and Ductless Split Systems

Source: Fine Homebuilding

Typical ducted systems range in nominal cooling capacity between 24,000 Btuh and 60,000 Btuh and their cooling efficiency, as measured by Seasonal Energy Efficiency Ratio (SEER), is between 13 and 21. Ductless systems are smaller, typically 9,000 Btuh to 18,000 Btuh, though units can be as large as 36,000 Btuh. Ductless split systems are often, though not always, more efficient than ducted ones, typically ranging from 13 SEER to 25 SEER compared to a maximum of about 21 SEER with ducted systems. Ductless systems with much higher SEER ratings are also available. In January 2015, Fujitsu General announced that one of its Halcyon models achieved an efficiency rating of 33 SEER.

Importantly, ductless split systems often have better part-load performance because many ductless systems are inverter-driven. As a result, they are able to modulate their capacity based on the heating or cooling load. Ducted systems typically operate entirely on or entirely off, leading to significant cycling losses and poor comfort relative to modulating systems. However, at least a two major manufacturers offer inverter-driven ducted heat pumps that provide similar part-load performance benefits. Additionally, in ducted systems, further inefficiencies can occur due to leakage from ducts into unconditioned spaces, as well as heat transfer through duct walls. Duct losses can be significant, in some cases accounting for up to a 30% loss in efficiency. Ductless systems avoid the use of ducts for the circulation of air, thereby avoiding duct-related losses.

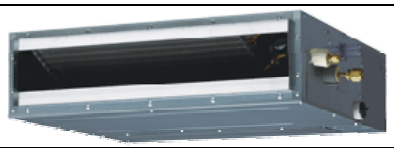
1.2 Equipment Type

Within the ductless split system product category, the number and type of indoor units can vary considerably. While the most common installation is a system with a single outdoor unit and a single indoor unit (often referred to as a single split or mini-split), multiple indoor units can be paired with a single outdoor unit (often referred to as a multi-split). Using multiple indoor units allows for zone control, where the temperature of different areas of a house can be regulated independently.

Figure 3 shows a variety of indoor unit types. Indoor units may be mounted on a wall, ceiling, or floorboard. However, indoor units can also be installed such that only the register remains visible. This is accomplished either by installing a recessed cassette unit in a ceiling or by installing a slim duct unit in a ceiling and using several feet of duct to distribute air to a space or to multiple rooms. Exposed units are cheaper to install and more common than recessed units, which are often practical in new construction or major renovations. Many consumers, especially in the U.S. prefer recessed units for aesthetic reasons.

Figure 3. Ductless Indoor Unit Types

Wall	
Cassette	

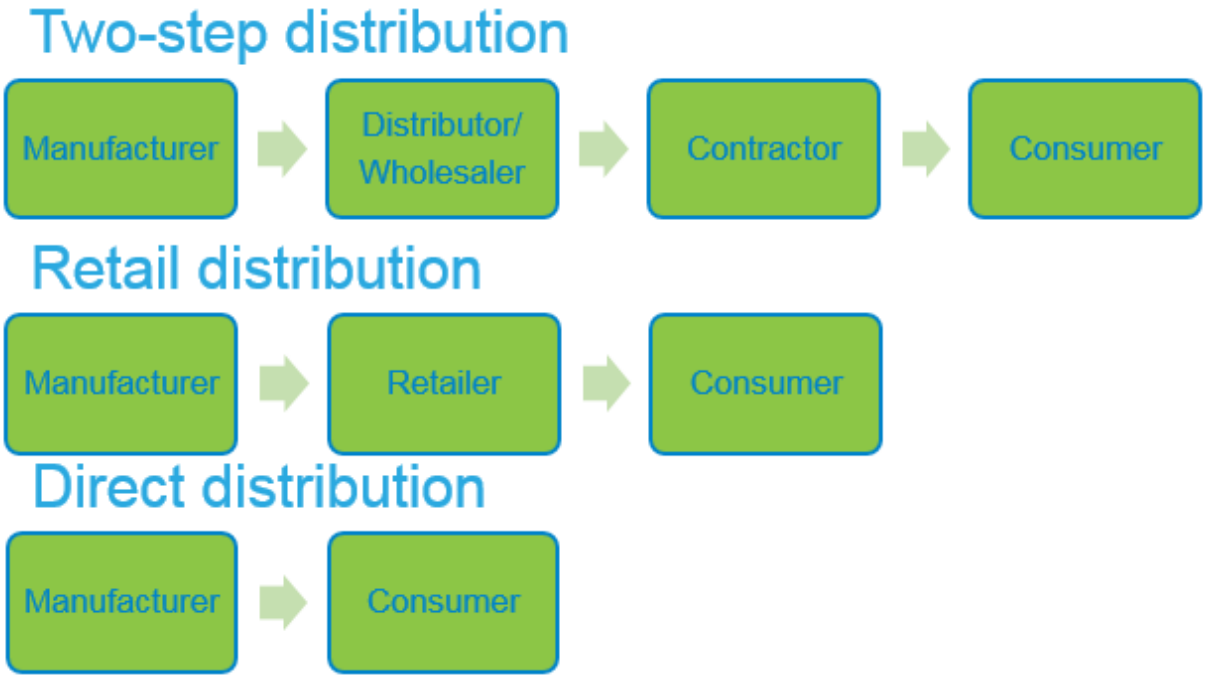
Floor/Ceiling	
Slim Duct/Short-Run Duct	

Source: Fujitsu General

1.3 Typical Sales Channels

Distribution channels for ductless split systems vary globally, and some countries have more than one distribution channel. Figure 4 outlines the typical channels, which include two-step distribution, retail distribution, and direct distribution. However, regardless of channel, contractors typically install the equipment—not the consumers. Installation of ductless systems requires handling refrigerant, joining pipes, and electrical work. Self-installation by consumers is rare and is prohibited by regulation in most regions, primarily because governments require licensing for refrigerant handling to minimize discharge of refrigerant to the atmosphere and the associated global warming impacts.

Figure 4. Overview of Typical Sales Channels



Source: Navigant Research

1.3.1 Two-Step Distribution

Two-step distribution involves a manufacturer providing equipment to a distributor or wholesaler. Contractors purchase equipment from the wholesaler or distributor and resell it to a consumer along with the installation. This is the predominant sales channel in the United States.

1.3.2 Retail Distribution

With distribution through a retail channel, manufacturers sell ductless split systems to retailers and retailers sell them to consumers. The retail outlets that sell ductless split systems are often appliance or home improvement stores. Typically, these stores are aligned with contractors to provide installation services. However, contractors in some countries have retail storefronts where consumers can purchase equipment and arrange for installation. In countries that have retail distribution of ductless split systems, retailers typically require manufacturers to set up service centers to facilitate installation and provide after-purchase support. Consumers that purchase through retail channels often purchase ductless split systems to address an immediate need, particularly in countries with more than one sales channel. For planned purchases, they often buy equipment through a contractor channel.

1.3.3 Direct Distribution

In direct distribution, a manufacturer sells equipment directly to a consumer. However, the consumer typically secures a contractor to install the equipment. Such distribution is typically limited to small, less developed markets.

1.4 Technology Trends

DHP manufacturers are continually improving their products to improve efficiency and better meet the requirements of their consumers. The following section outlines some recent technological trends in the global DHP market.

1.4.1 Combination Heat Pumps

Houses require heating both to maintain a comfortable environment and to provide domestic hot water. Heat pumps are being used in both applications to efficiently provide heat. Coupling both functions in a single air-to-water heat pump eliminates the total amount of equipment in a house and can provide additional energy savings to its occupants. Air-to-water heat pumps are becoming more common in Europe, where hydronic heating is well-established.

1.4.2 Improved Cold Climate Performance

In the past, the capacity and efficiency of heat pumps dropped dramatically at low temperatures, below about 35 to 40 degrees Fahrenheit. However, technological improvements in the design of the systems now allow for operation in temperatures of 5 degrees Fahrenheit with far less loss of capacity, and even produce heat in temperatures as low as -10 degrees Fahrenheit. In many regions, current heat pump technology provides adequate heating without a supplemental heating system. However, colder climates generally require a supplemental heating system, which is often electric resistance heat, but can be a fuel-fired furnace or boiler (especially in retrofit installations where a furnace or boiler is already present).

1.4.3 Integrated Natural Gas Heating

The availability, low cost, and high performance of natural gas heating (furnace or boiler) has made it a common choice among homeowners in the United States. Typically, a single indoor unit is employed, thus requiring the running of a single gas line. Manufacturers are exploring the addition of natural gas heating to DHPs to provide low-cost, energy efficient supplemental heating for cold climates.

1.4.4 Aluminum Microchannel Heat Exchangers

Aluminum microchannel heat exchangers employ flat tubes connected between two headers rather than the traditional approach of round tubes with attached fins. Microchannel heat exchangers can reduce the size and cost of ductless split systems.

1.4.5 Refrigerants

A refrigerant (i.e., the working fluid in an air conditioner or heat pump) must be selected to meet product capacity, efficiency, physical size, safety, and cost requirements. Additionally, many potential refrigerants are precluded from use based on their flammability, toxicity, and impact on the ozone layer. Currently, hydrofluorocarbons (HFCs) are employed in air conditioning and heat pump applications because they meet the engineering requirements of systems and do not deplete the ozone layer. However, the most common refrigerants employed today produce a greenhouse effect when discharged to the atmosphere, thus contributing to global climate change.

The R-32 refrigerant has a lower global warming potential compared to conventional refrigerants. However, it is mildly flammable. R-32 was first commercialized in Japan in November 2012; in March 2013, India began sale of air conditioners using R-32. Some manufacturers are exploring carbon dioxide (CO_2) as a refrigerant. CO_2 is currently widely used as a refrigerant in Japaneses heat pump water heaters, but the cost and performance has not been shown to be attractive in comfort conditioning applications like DHPs.

1.4.6 Remote Monitoring

In addition to the performance of equipment, many manufacturers are investigating improvements in how consumers interact with the equipment. This includes providing Wi-Fi connectivity to ductless split system controllers, enabling users to view and change setpoints. Better control over ductless split systems can lead more efficient operation by making it easier for users to reset their thermostat when asleep or away from home. Many manufacturers are working on providing better control integration with smart phones.

1.4.7 Demand Response

The ability of inverter-driven ductless split systems to modulate capacity makes them good candidates for demand response (DR) programs. During demand events, when the demand for electricity threatens the capabilities of sufficient supply and distribution, DR programs allow utilities to request reductions in electricity consumption. During these events, ductless split systems can reduce capacity while still providing cooling. Many ductless products now have DR capabilities.

2 Market Size

2.1 Market Summary

Ductless split systems have historically been utilized most widely in Europe and Asia. Currently, the largest market is China. In the United States, ductless cooling systems were a small niche market until the early 2000s but have been gaining in market share since that time. However, the North American market is dominated by ducted unitary systems, which are more readily applicable to typical U.S. architecture.

2.2 Methodology

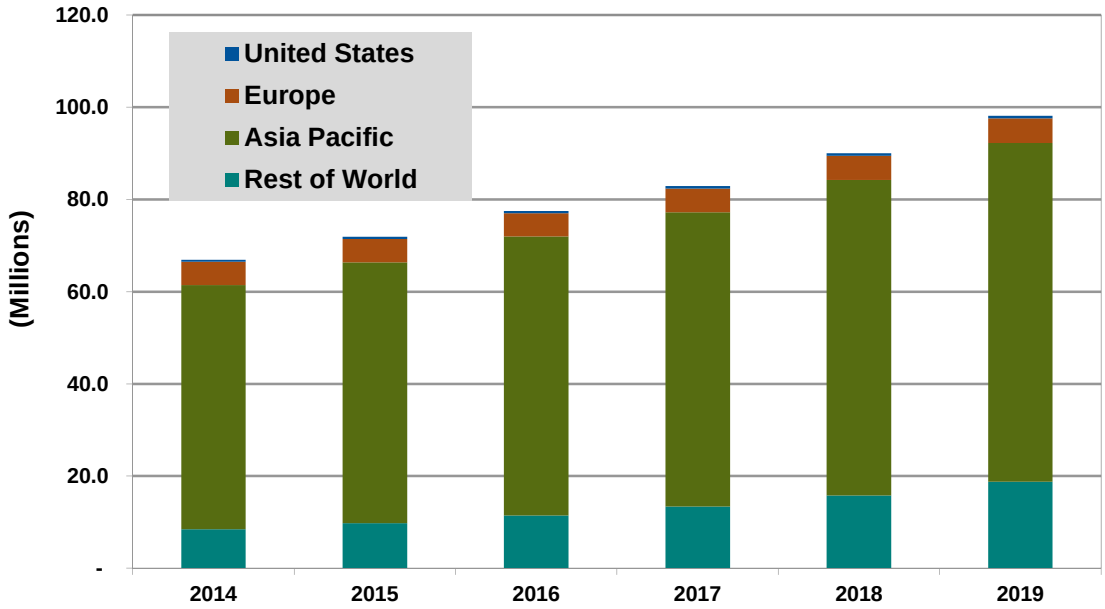
We developed forecasts from a combination of primary and secondary research, Navigant Research's library of syndicated market research reports including *Energy Efficient HVAC Systems* and *Energy Efficient Buildings: Global Outlook* , and modeling of the existing global building stock. Primary research included interviews with ductless split system manufacturers and other players active in the industry. Secondary research included industry reports, trade industry association publications, government statistics and reports, vendor information and literature, and other relevant literature.

To generate the model of the DHP market, Navigant developed assumptions about air conditioning penetration, ductless split system penetration, equipment replacement cycles, and heat pump penetration based on primary and secondary sources. Navigant then applied these assumptions to its database of the global building stock. Global and regional economic forecasts (gross domestic product and population growth) provided in the World Economic Outlook Database October 2014 by the International Monetary Fund were utilized as a baseline for economic judgments. Public revenue and shipment data from key suppliers was used to provide a top-down correlation with the bottom-up modeling of DHP adoption and growth rates.

2.3 Ductless Split Systems

Globally, ductless split systems are expected to show moderate to strong growth, driven by a recovering global economy and the increased importance of energy efficiency for end users. Navigant expects shipments to grow from 66.9 million units in 2014 to 98.1 million units in 2019, a compound annual growth rate (CAGR) of 8%. Asia Pacific is the largest market for ductless split systems, representing nearly 80% of the market, and is expected to continue to experience strong growth.

Figure 5. Ductless Split System Shipments by Region, World Markets: 2014-2019



Source: Navigant Research

Ductless split systems remain a small, though rapidly growing, segment of the U.S. HVAC market. Shipments of ductless split systems in the United States are expected to grow from 0.4 million units in 2014 to 0.6 million units in 2019. In Europe, continued advancement toward net zero energy buildings will drive growth in ductless cooling systems. However, Navigant expects the strongest growth over the forecast period to be outside of Europe, particularly in Latin America. Ductless manufacturers are increasing their focus on Latin America and making advances in ductless system deployment.

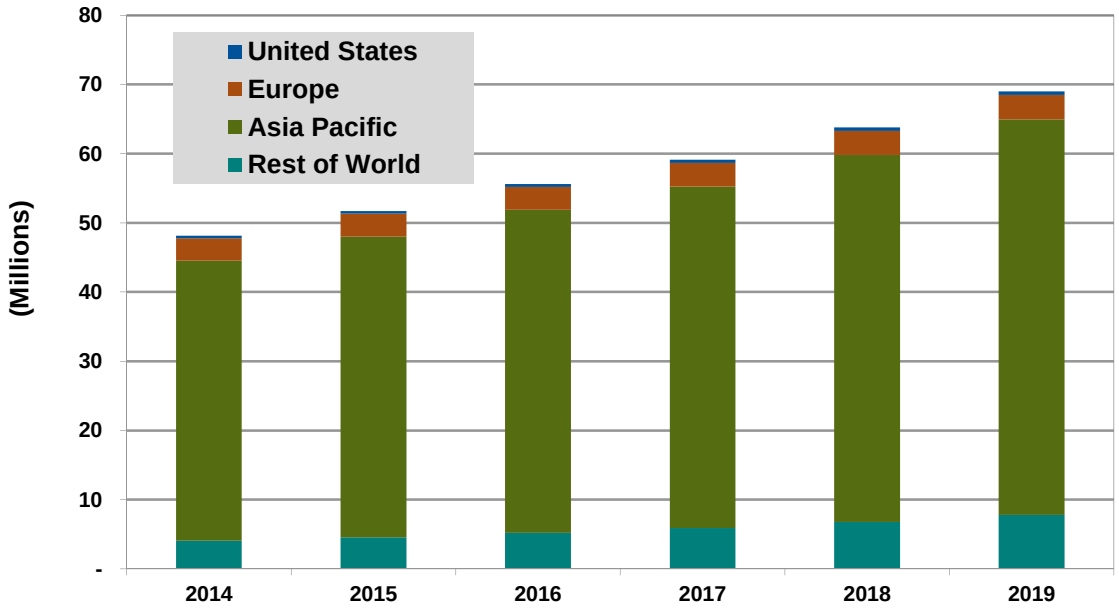
2.4 DHPs

Heat pumps comprise over 70% of the overall ductless market with the remainder of the market consisting of cooling-only units. However, climate often dictates the applicability of heat pumps. In areas where heating loads are minimal, such as Southeast Asia and parts of Latin America, cooling-only units are often employed. However, in areas that require both cooling and heating, the share of DHPs is increasing. Manufacturers can simplify distribution logistics by eliminating cooling-only units. Operational savings through reducing the number of models distributed can offset the higher component costs of heat pumps (which require 4-way valves and additional controls). Fujitsu General, for instance, announced in 2015 that it will discontinue sales of cooling-only ductless split systems in the United States.

Growth in DHPs is expected to outpace the overall growth of ductless split systems in the United States, Asia Pacific, and Europe between 2014 and 2019. As shown in Figure 6, Navigant estimates that global DHP shipments will grow from 48.2 million units in 2014 to 69.0 million in 2019. Figure 7 highlights the countries that have the largest number of DHP shipments. China

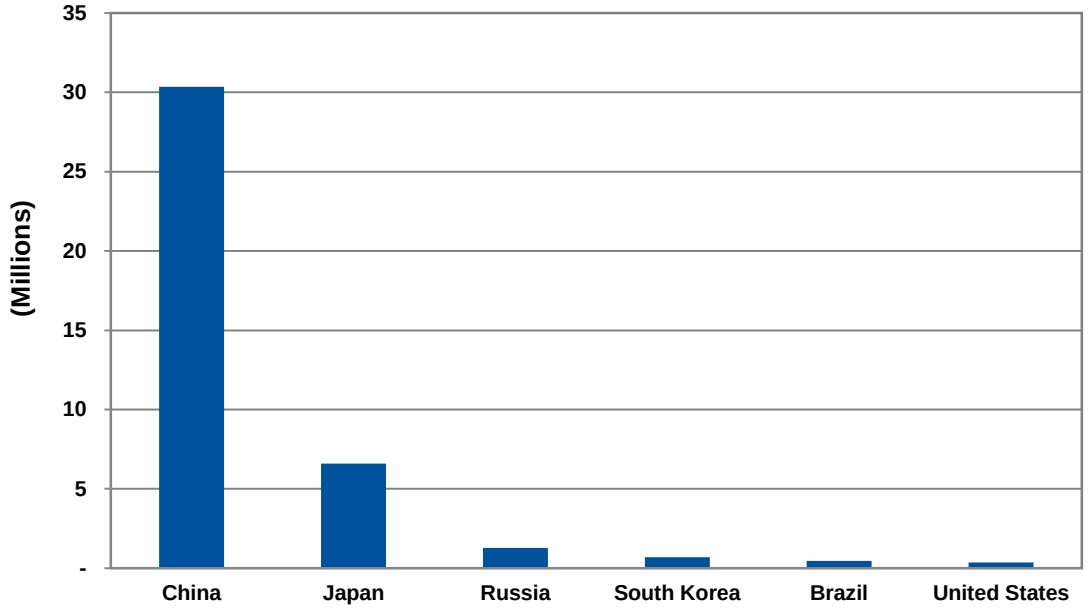
represents the largest market for DHPs, with an estimated 30.3 million shipments in 2014. The market for the United States is estimated at approximately 370,000 in 2014.

Figure 6. Ductless Heat Pump Shipments by Region, World Markets: 2014-2019



Source: Navigant Research

Figure 7. Ductless Heat Pump Shipments by Top Market: 2014



Source: Navigant Research

3 Competitive Environment

3.1 Overview

Asia Pacific is not only the largest market—it also hosts the major manufacturers of the technology. As shown in Table 2, the leading manufacturers are based in Japan, South Korea, and China. Though the United States is one of the largest HVAC markets, the slow adoption of DHPs has led to a lag in their manufacture. As such, few manufacturing facilities are currently in the United States. Daikin operates a 525,000 SF manufacturing plant in Houston, Texas that produces residential cooling products and commercial variable refrigerant flow (VRF) systems. However, most U.S. HVAC manufacturing companies, such as Trane and Lennox, do not manufacture ductless systems. Rather they have agreements with Asian manufacturers to rebrand equipment produced there.

Table 2. Size and Location of Major Ductless Split System Manufacturers

Company	Headquarters	Estimated HVAC Revenue
Daikin	Osaka, Japan	$15.9
LG Electronics	Seoul, South Korea	$10.1
Gree	Zhuhai, China	$9.2
Mitsubishi Electric	Tokyo, Japan	$5.5
Midea	Shunde, China	$5.5
Fujitsu General	Kawasaki, Japan	$4.6
Panasonic	Osaka, Japan	$4.4
Samsung	Seoul, South Korea	$3.9
Toshiba Carrier	Tokyo, Japan	$2.1

Source: Navigant Research

Within Asia Pacific, the country of a company's headquarters generally indicates the company's strategy and products. The leading premium brands, such as Daikin, Fujitsu General, and Mitsubishi Electric, are headquartered in Japan, where ductless technology originated. Korean manufacturers, notably LG and Samsung, have established themselves through competitive prices and quality. Chinese manufacturers typically provide lower cost products.

U.S. manufacturers have been slow to adopt ductless split systems. Though all major manufacturers sell ductless systems, they are often sourced from original equipment manufacturers (OEMs) in China. However, the U.S. Big Three (Carrier, Trane, and York) are collaborating with Asian manufacturers to improve their portfolios of ductless products. In 1999, Carrier Corporation, a subsidiary of United Technologies Corporation, and Toshiba Corporation formed a joint venture, Toshiba Carrier. The partnership added Toshiba-branded residential and light commercial HVAC equipment to Carrier's product portfolio and allowed Carrier to

leverage Toshiba's manufacturing quality and field reliability. Additionally, Carrier was able to combine Toshiba's sales network in Singapore, Hong Kong, France, and Germany with its own operations. In 2010, the Toshiba-branded residential air conditioning business in Japan was transferred from Toshiba Carrier to Toshiba Home Appliances to allow Toshiba Carrier in Japan to focus on high-efficiency, engineered commercial air conditioning solutions. In 2014, Toshiba and Carrier strengthened their partnership through the announcement of expanded collaboration of engineering and sales resources outside of Japan.

Similarly, in 2013, Johnson Controls announced a joint venture with Hitachi, in which Johnson Controls assumed 60% ownership in Hitachi Appliances' global air conditioning business, excluding sales and service operations in Japan. The partnership will leverage Johnson Controls' global sales network with Hitachi's portfolio of VRF (generally used in commercial buildings) and ductless products. Johnson Controls expects to generate $2.6 billion in 2016 sales from the joint venture. In 2013, Trane and Samsung Electronics entered into a collaborative agreement to sell VRF systems in the United States. Trane will use its existing nationwide sales network to sell Samsung's DVM line of equipment.

Though manufacturers in Asia Pacific supply a majority of the ductless split system market, there are several small regional manufacturers. Israel is home to two manufacturers: Tadiran Air Conditioners and Electra. Similarly, Blue Star is India's largest central air conditioning company and has a portfolio of products that include residential ductless split systems.

4 Regulatory Factors

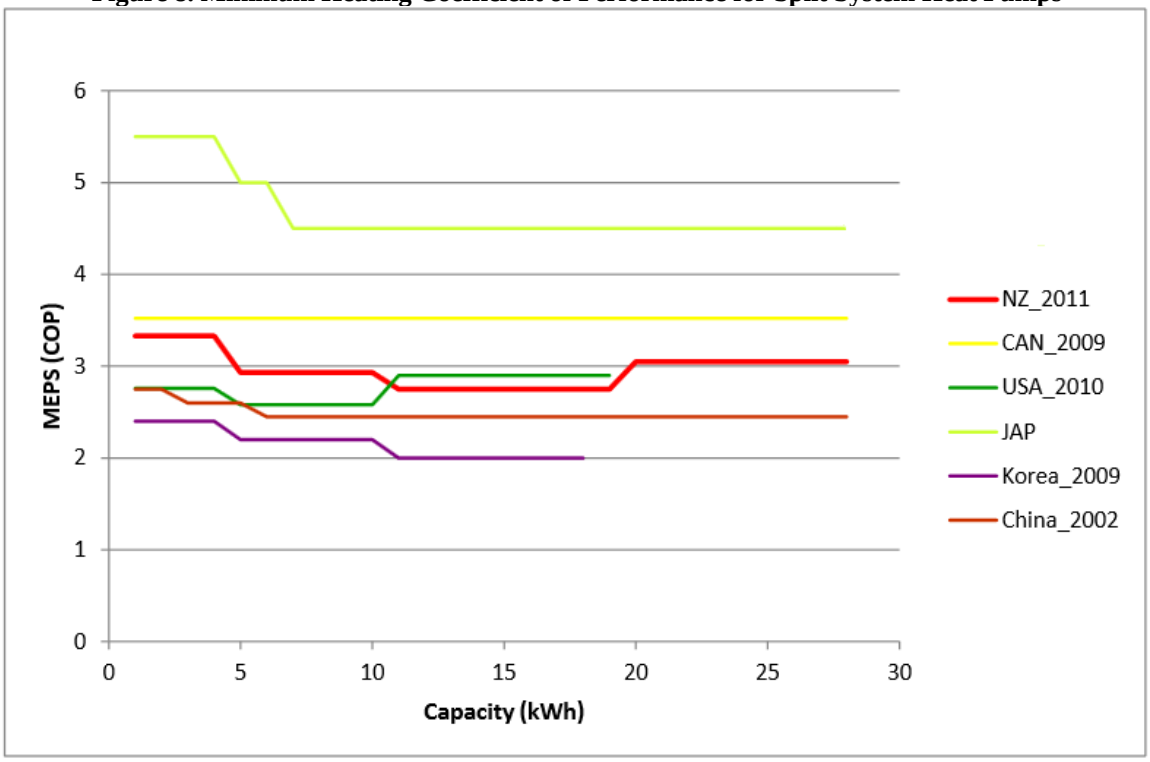
4.1 Introduction

Building codes, government regulations, and other initiatives are important drivers of growth for DHPs. Most major global regions have enacted measures aimed at reducing energy consumption and reducing carbon dioxide (CO_2) emissions, including Minimum Energy Performance Standards (MEPS), labeling programs, building energy efficiency codes, and DR programs. Such moves are shaping both the adoption and design of DHPs.

4.2 Energy Performance Standards

Individual countries implement energy performance standards to reduce energy consumption. MEPS a) establish procedures to test the energy consumption of appliances, and b) set performance thresholds based on those test procedures that all products must meet. As shown in Figure 8, MEPS can vary widely from country to country. Different countries often prescribe different test procedures and performance thresholds. Additionally, the types and sizes that these requirements apply to vary by country. .

Figure 8. Minimum Heating Coefficient of Performance for Split System Heat Pumps



Source: Centre for the Study of Agriculture, Food and Environment (CSAFE)

MEPS are accelerating the adoption of DHPs. Inverter-driven ductless systems can reach much higher efficiencies than competing products, such as window room air conditioners (WRACs). Furthermore, HVAC manufacturers are reluctant to invest in developing new WRAC products

because of their shrinking market and low profit margins. Indeed, to accommodate increased MEPS, fixed-speed equipment manufacturers have already had to increase condenser surface area and improve compressors. Further increases in MEPS may drive a shift to inverter-driven systems as further increases to the efficiency of fixed-speed units may become impractical. Most DHP systems are inverter-driven and most ducted systems are not. However, some manufacturers have introduced inverter-driven ducted heat pump systems.

4.3 Labeling Programs

Most major economies have adopted energy labeling to lower household energy consumption by helping to inform consumer purchase decisions. As shown in Table 3, program specifics vary by country.

Table 3. Overview of Labelling Programs

Country	Status	Year	Country	Description
Australia	Mandatory	1987	Comparative	Categorical: Six-star base label and ten-star superefficient label. The more stars the more energy efficient.
China	Mandatory	2005	Comparative	Categorical: Five-class label with the 1st class being the most efficient and the 5th class being the least efficient.
European Union	Mandatory	2002	Comparative	Categorical: Seven-letter (from A to G) base label with A being the most efficient and G the least efficient.
India	Mandatory	2010	Comparative	Categorical: Five-star base label. The more stars, the more savings.
Japan	Mandatory	2006	Comparative	Categorical: Five-star label. The more stars an AC has the more efficient it is.
Korea	Mandatory	1992	Comparative	Categorical: Five-grade labeling with the first grade the most efficient and the 5th grade the least efficient.
United States	Mandatory (EnergyGuide)	2007	Comparative	Continuous: Range of energy use for similar appliances. The further the arrow to the right, the lower the operating cost of the appliance.
	Voluntary (ENERGY STAR)	1986	Endorsement	Identifies products using substantially less energy than required by standards.

Source: The Collaborative Labeling and Appliance Standards Program (CLASP). June 2011. Cooling Benchmarking Study Report

4.3.1 Labeling Information

The information provided through labelling programs varies. Table 4 summarizes the content of various countries' labeling programs. The most common requirements for labeling programs are the efficiency rating, energy consumption, and make and model.

Table 4. Information Reported on Labels by Country

Country	Efficiency Rating	Energy Consumption	Comparison with Similar Modals	Operating Cost	CO_2 Emissions	Make and Model	Assessment Standard	Capacity	Features	Year of Manufacture	Appliance Specific
Australia	■					■	■				
China	■					■					
European Union	■	■						■			■
India	■	■				■		■		■	
Japan		■				■					
Korea	■	■			■	■		■			
United States		■	■	■		■		■	■		

Source: The Collaborative Labeling and Appliance Standards Program (CLASP)

4.4 Regional Efficiency and Greenhouse Gas Reduction Initiatives

Most major global regions have adopted targets for reduction of energy consumption, reduction of CO_2 emissions, and/or increases in energy efficiency. As indicated in Table 5, with the exception of the United States, the largest developed and developing economies have set targets for reducing energy consumption. To achieve these targets, building energy codes establish minimum requirements for the energy efficient design and construction of buildings. In many countries around the world, these codes have an impact on the HVAC equipment installed.

Table 5. Energy Efficiency Targets by Select Country or Region

Country	Nature of Target	Base Year	Target Date
European Union	Reduce primary energy consumption by 20%	BAU 2020	2020
United States	No target	N/A	N/A
Japan	Reduce energy intensity by 30%	2003	2030
Brazil	Reduce projected power consumption by 10%	2011	2030
China	Reduce energy intensity by 16%	2011	2015
India	Improve energy efficiency by 20%	2007	2012

Source: National Bureau of Asian Research

United States

The U.S. Environmental Protection Agency (EPA) has a number of initiatives to help reduce greenhouse gas (GHG) emissions. On June 2, 2014, the EPA released a proposal to cut emissions using state-by-state targets. As states begin to explore different compliance options, regional cap-and-trade programs, such as the Northeast's Regional Greenhouse Gas Initiative (RGGI), have gained traction.

Europe

Since 2009, it has been the European Union's objective to reduce carbon emissions by 80% below 1990 levels by 2050. To achieve this, the buildings sector is seeking a projected GHG reduction of 88% to 91%. Most current buildings will still be in place in 2050. Fortunately, the standard replacement and refurbishment cycles of major building components and systems suggest buildings will undergo one to two renovations between 2015 and 2050.

This long-term policy framework with interim milestones at 2020, 2030, and 2040 will provide signals to the market that efficiency gains will be needed through both products/technologies and service innovations. Research by the Buildings Performance Institute Europe (BPIE) shows, however, that major changes in both the rate and depth of building renovations (coupled with efforts focused on reducing the carbon emissions of energy generation) will be needed to meet the 2050 target.

Japan

Japan has announced a goal to reduce GHG emissions 30% by 2020 against 2005 levels. This policy lists a variety of segments for targeted reduction, including air conditioning equipment.

China

In the lead-up to the Copenhagen climate negotiations in the fall of 2009, the Chinese government pledged a 40% to 45% reduction in national carbon intensity from 2005 levels by 2020. To achieve this 2020 target, the 12th Five-Year Plan sets an interim target of reducing carbon intensity 17% from 2010 levels by 2015. The plan also has the goal of gradually establishing a carbon trade market but does not elaborate.

4.5 Demand Response

Inverter-driven heat pumps are a natural candidate for DR programs, as they can modulate capacity without shutting off completely. Many countries, including the United States, Canada, United Kingdom, France, and Ireland, either have established or piloted a DR program or are working on establishing the framework to enable DR programs. In Asia Pacific, the governments of China and Japan are working on developing DR programs. Though no DR program specifically uses DHPs, their ability to modulate their capacity makes them good candidates for such programs.

5 Regional Comparisons

5.1 Overview

The ductless split system market varies substantially by geography. The United States is one of the few world regions where ductless systems are not the standard product type for residential cooling. Table 6 outlines the differences in regional markets. Several factors explain the disparity in adoption between the United States and other regions. Notably, installed cost in the United States is higher than other regions. Part of this difference results from a higher labor cost in the United States relative to some parts of Asia, but differences in labor costs between the US and Japan or Northern Europe are modest. Many U.S. contractors are unfamiliar with ductless systems and require more time and technicians to install a DHP than is common in markets like Japan where installations volumes are very high. Further, low sales volumes (leading to higher overhead costs for manufacturers), two-step distribution, and a higher prevalence of premium products contribute to higher installed costs in the United States. The prevalence of cooling-only versus heat pump products do not have a substantial impact on the differences in equipment cost.

Table 6. Summary of Regional Differences for Ductless Split Systems

Metric	Asia Pacific	Europe	Latin America	United States
Typical Unit	Single head, 9,000-12,000 Btuh	Single head 9,000-12,000 Btuh	Single head 9,000-12,000 Btuh	Single head 12,000 - 18,000 Btuh
Installed Cost ($)	$800-$2,000	$1,400-$2,000	$800-$2,000	$3,000-$4,500
Labor Cost as % of Total	25%-35%	35%-40%	40%-50%	50%-65%
Other Typical Equipment	Window AC, portable heater	Hydronic heating	Window AC, portable heaters	Ducted systems
Sales Channel	Retail Direct	Retail two-step	Retail two-step	Two-step
Major Manufacturers	Midea Gree Daikin Mitsubishi Electric Panasonic	Daikin Mitsubishi Electric Fujitsu General LG Panasonic	Hitachi Midea LG Mitsubishi Electric Daikin	Mitsubishi Electric Fujitsu General Daikin LG Panasonic

Source: Navigant Research

One key difference between distribution channels in the United States and other countries is that retail distribution through electronics retailers and home improvement stores is common in non-U.S. regions. Although retail distribution reduces costs somewhat, the products are still nearly always installed by a skilled contractor, as required by law in almost all countries.

5.2 Japan

Ductless split systems were developed in Japan specifically to address the needs of the Japanese market. As a result, the country has strongly adopted DHPs. When ductless systems were

introduced, they replaced portable room units for heating and cooling, enhancing comfort and efficiency.
Consumers purchase the equipment through appliance or home improvement stores. Often, installers align with these stores. Japanese DHP manufacturers account for nearly all of the domestic market. Daikin and Mitsubishi are the leading manufacturers in Japan.

5.3 China

China is both the largest market for DHPs and the largest manufacturer of DHPs. The adoption of ductless split systems has been driven by a desire to add cooling where none was available before and to replace window units. In 1990, China had one air conditioner for every 300 urban households. By 2009, there were 106 units for every 100 households (Auffhammer and Wolfram 2014).

Consumers purchase equipment through retail channels or through contractors or manufacturers. In cities, installers have their own storefronts where consumers can purchase equipment. Chinese manufacturers have the largest market share in their home market.

5.4 Europe

Adoption of DHPs in Europe is also strong. In most countries, DHPs are the primary technology used for cooling. Spain and Italy have the strongest adoption, followed by France. In Northern Europe, residential air conditioning is less common, leading to the use of heating-only systems. Distribution varies from country to country. In Spain and Italy, retail channels are used. The United Kingdom and Germany use individual contractors for distribution, similar to the United States.

Heating is often more of a concern than cooling in the European climate. As a result, DHPs replaced hydronic heating and electric baseboard heating. However, the desire to add cooling to homes has driven adoption in some countries of Europe, particularly in the south. The leading manufacturers in Europe are Daikin, Mitsubishi, Fujitsu General, and LG. However, Panasonic, Samsung, and Toshiba are also present. Chinese manufacturers like Gree and Midea have limited market share.

5.5 Latin America

The ductless split market in Latin America has also grown rapidly in recent years, displacing window room air conditioners in countries like Brazil and Mexico. Heat pump adoption varies according to climate. Growth in sales of ductless split systems in Latin America has been largely driven by a desire to replace window room air conditioners and to add cooling as incomes rise. The retail channel is present and growing in Latin America. Retailers typically require manufacturer service centers to assist with installation and after-sales support.

Brazil and Mexico are the largest markets. Hitachi has the largest market share in Brazil, while the market in the rest of Latin America consists of a mix between South Korean, Japanese, and Chinese manufacturers.

5.6 Australia

Daikin and Hitachi were the first entrants in the Australian ductless market in the early 1980s, and offered ductless systems as a replacement to window units and packaged terminal units. Ducted units, however, are still common in Australia. Historically, manufacturers sold directly to consumers, but retail is also prevalent. Distributors are beginning to appear as well. Daikin and Fujitsu have large market shares.

5.7 Key Differences with the U.S. Market

The United States differs from other markets in several important ways. Most importantly, ducted split systems are common in the United States. In countries with strong adoption of ductless split systems, the prevalence of ducted systems was never established. As a result, many of the underlying needs that have driven adoption of ductless split systems internationally have largely been met in the United States by ducted systems.

Importantly, the volume of ductless split systems sold in the U.S. market is low. The U.S. market accounts for approximately 400,000 units per year, compared to 6.6 million units in Japan and 30 million units in China. Because the number of ducted systems is much larger than the number of ductless systems, both in terms of annual sales and total installed base, few stakeholders are eager to adopt ductless systems.

Additionally, the way consumers purchase air conditioning equipment in the United States differs from many countries with stronger ductless adoption. Two-step distribution is standard in the United States, as retail distribution is an insignificant channel in the market. Consumers typically purchase equipment and labor through a contractor.

Architecturally, the United States is different from many other regions. In the United States, houses are primarily wood-framed and designed to include ductwork. Internationally, concrete, stone, and brick are more common. In existing houses in the United States, ductwork is standard. Ductwork is far less likely to have already been installed in existing houses overseas.

Consumer expectations are also an important difference. In many countries, heating and cooling are performed room-by-room and consumers expect that approach. In the United States, however, consumers expect heating and cooling to be performed centrally and expect all rooms to be conditioned continuously. Moreover, in new construction, U.S. consumers expect air conditioning and heating equipment to be delivered with the house. In some countries, homeowners expect to purchase the equipment and have it installed independently of the construction of the house. Furthermore, the aesthetics of wall hung, ceiling suspended or even floor mounted indoor units of ductless systems are a barrier for many U.S. consumers, who do not want heating and cooling equipment to be visible in the living space. While ceiling recessed

terminal units are available, they are expensive and are particularly difficult and disruptive to install in existing homes.

6 Market Forces

6.1 Introduction

A diverse set of factors have supported and hindered the global adoption of ductless split systems. Ductless split systems originated in a market where ducted systems were not an option. They were designed to satisfy the needs of the Asian market. Ductless solutions were then marketed globally and adopted in most regions of the world. The United States is one of the few areas where ducted split systems have remained the leading solution.

6.2 Market Drivers

Ductless systems have several advantages over other solutions, including efficiency (both due to their design and the elimination of duct losses), multi-zone control, and low noise. These factors, coupled with the architectural style of homes, have driven the adoption of ductless split systems.

6.2.1 Efficiency

Efficiency has been a major driver of ductless split systems, particularly when consumers are switching from widow room air conditioners. As many countries continue to increase efficiency requirements of HVAC equipment, replacement of window units with ductless ones may become more feasible. In fact, in some markets, window units cannot meet minimum efficiency requirements. In space-constrained locations like major Asian cities, ductless split systems are also able to meet the requirements without the large increases in cost and size associated with high efficiency ducted units. Independent of efficiency requirements, high energy costs motivate consumers to select the equipment that provides low-cost operation.

6.2.2 Architecture

In areas where ductless split systems have experienced the strongest adoption, the architecture and design of homes were never intended to accommodate ductwork the way U.S. homes do. Homes constructed of concrete, stone, and brick are more common, which limits the ability to install ducts. As the refrigerant lines of ductless split systems require a much smaller hole than the ducts of ducted systems, they are much easier to install. In most regions, ducted products (or window units) were the only ones available before ductless systems emerged. However, those products were really designed for the North American market and were not adopted elsewhere. As a result, architecture never evolved to accommodate ducts in much of the world.

6.2.3 Multi-Zone Control

Many consumers expect to have the ability to only heat or cool rooms that they are occupying. Central ducted systems typically do not accommodate this need. Ducted systems are either on, conditioning all spaces served by the system (or at least a large zone consisting of multiple rooms), or off, conditioning none. However, ductless units can maintain different setpoints for different zones. This functionality provides additional energy savings as well as comfort.

6.2.4 Low Noise

Ductless split systems operate with lower noise than many alternatives, particularly window air conditioners. Additionally, when people are exposed to constant, low noises, the noises are difficult to perceive—they blend into the background. However, when there is a sharp change in the level of noise, the noise becomes more apparent. As a result, ducted split systems that are either on or off will be perceived as creating more noise than ductless ones whose fan operates constantly but whose capacity is modulated by an inverter. Low noise is of greater importance in regions like Asia, where residences and rooms are typically smaller than in the U.S.

6.3 Market Barriers

In the United States, ductless split systems have two different use cases: installation in new home construction and replacement of existing systems. Despite having some advantages over ducted systems, ductless split systems face many barriers in each of these use cases in the United States. Indeed, ductless systems face the same barriers in many countries. However, the lack of an established ducted market when ductless systems were introduced seems to be the best predictor of the successful adoption of ducted units. Nowhere in the world have ductless split systems replaced substantial numbers of ducted systems. Globally, the adoption of ductless systems has generally been driven by the desire to add cooling or to replace inefficient, noisy, and inconvenient window or portable units.

For both new home construction and the replacement of existing systems, ducted systems are the status quo. As a result, consumers expect ducted solutions, and the residential building stock has been designed for ducted solutions. In new construction, homebuilders can easily install ductwork, but the higher expense of ductless systems makes them unattractive. For the replacement of electric baseboard heat or hydronic heating, ductless split systems could face fewer barriers. However, when replacing ducted units, the cost and disruption associated with installing ductless systems often precludes it from being a realistic option. On the supply-side, sales channels and contractors remain focused on ducted solutions. Additionally, better ducted products are being developed, which may eliminate some of the ductless systems' advantages.

6.3.1 Expectations

Because ducted systems are standard in homes in the United States, consumers are comfortable with the technology and expect a ducted solution in their homes. Specifically, consumers expect a solution that can condition their entire house. According to manufacturers interviewed, they are skeptical of room by room solutions. In Europe and Asia, consumers are satisfied with only conditioning occupied rooms. As a result, they accept a delay while the temperature of a room transitions from an unoccupied to an occupied state. However, consumers in the United States expect all parts of their house to be conditioned when the house is occupied.

Moreover, because consumers expect nothing more than a register to be in an occupied space, the aesthetics of ductless systems becomes a problem. Many models of ductless systems require the placement of an indoor unit on a wall or a ceiling, which many U.S. consumers find unattractive.

6.3.2 Lack of Awareness

Many consumers are unfamiliar with ductless split system technology. Even consumers that are familiar with the technology may not realize that DHPs are an appropriate solution for their home. While many advances have been made in the cold climate capabilities of DHPs, many consumers are still unaware that they are viable in cold climates.

6.3.3 Residential Building Stock

In 2009, 87% of U.S. households were equipped with air conditioning (U.S. Energy Information Administration 2011). For a majority of these households, the air conditioning they are equipped with is a ducted solution. As a result, U.S. homes typically have ducts already installed. Replacing an existing ducted unit with a ductless system is almost never as economical as simply installing a new ducted system.

Additionally, many homes in the United States are large and require multiple indoor units. Installation of ductless systems is expensive and complicated in larger homes, requiring multiple outdoor units, each with several indoor units. When installed in an existing home, ductless split systems in interior rooms can be particularly problematic. Refrigerant piping needs to be run through other rooms, which is costly and disruptive.

6.3.4 Sales Channel

Ducted unitary systems are the primary revenue source for contractors and distributors, and for most of them, little incentive exists to substitute a primary revenue source with another technology. Dedicating warehouse space to ductless systems likely means taking some away from ducted systems and undermining the driver of the majority of the revenue. Additionally, contractors greatly influence a consumer's decision on what unit to purchase. They are more likely to recommend the systems with which they are familiar and comfortable and that they can install quickly and reliably, thus avoiding expensive callbacks.

6.3.5 Contractor Training

The installation of ductless systems is fundamentally different from the installation of ducted systems. Many contractors lack experience with ductless systems and are still unfamiliar with ductless installation. As a result, contactors must learn new methods of installation and cost estimation. However, no new training is required to continue installing ducted systems.

7 Conclusions and Recommendations

7.1 Conclusion

In almost every country outside of the United States, ductless split systems are an attractive solution for heating and cooling homes largely because they can provide cooling to houses that do not already have it. Outside of the United States, ductless split systems substantially compete

with other ductless solutions, such as boilers and baseboard electric for heating and fans/blowers for cooling. However, ductless split systems do not compete well with ducted solutions.

Globally, DHP use is growing because ducted solutions face many barriers in most counties. Ducts take up usable space and lower system efficiency. Additionally, outside of the United States, concrete, stone, and brick house construction is more common, which also makes it harder to install ductwork. Ductless systems compete well when the building stock and consumer expectation has not been established around ducted solutions. Conversely, ductless split systems do not perform well in markets where ducted solutions are established. In Australia, for instance, the ducted market continues to experience growth, even as the ductless market also grows.

In the United States, the major factors holding back adoption of ductless systems are architecture, aesthetics, awareness, and distribution. Most U.S. houses are designed for and supplied with ducted systems, making it harder for ductless solutions to compete. Additionally, consumers in the United States are not accustomed to having indoor units mounted on walls or ceilings in occupied spaces. They prefer the aesthetics of the registers associated with ducted solutions. Furthermore, many consumers are not aware of the benefits ductless split systems provide. Moreover, relying on contractors to proactively switch the equipment they offer will not change the market. They are more familiar with ducted systems and thus are better at estimating, installing, and selling ducted systems. Switching to ductless split systems introduces a high level of uncertainty for them and requires abandoning a proven business model.

Ductless split systems are rarely viable as replacements for existing ducted systems in the United States. As a replacement for non-ducted solutions such as electric baseboard heat, ductless split systems offer many advantages but still face barriers associated with cost, aesthetics, and awareness. The installation of ductless split systems during the construction of new homes may be viable. However, in order for large scale adoption to occur, both consumer and contractor expectations need to change.

7.2 Recommendations

Despite the barriers facing the adoption of ductless split systems in the United States, their sales continue to grow. Market forces are driving DHP adoption, and manufacturers are encouraging growth by investing in sales, marketing, and product development. NEEA can help accelerate this trend through the following approaches:

- ***Partner with manufacturers to help reduce costs, improve contractor awareness, and training.*** Compared to other regions, low U.S. sales volumes lead to higher sales, marketing, and distribution costs for manufacturers, higher installation costs for contractors, and higher installed costs for consumers. Because leading global manufacturers are already producing tens of millions of ductless systems annually for Asian markets, an increase in the U.S. market size will have limited impact on global manufacturing volumes and factory costs. However, supporting the training of contractors to enable them to effectively market, size, and install ductless products, combined with increasing installation volumes, can help reduce contractor costs and lower risks.

- ***Facilitate establishment of retail sales channels to help reduce cost and build consumer awareness.*** In the United States, consumers currently purchase HVAC equipment through a contractor. As a result, their options are limited to what contractors offer. Establishing retail sales channels for DHPs will enhance consumer choice and price competition, enabling consumers to learn more about the products and compare a wide array of solutions. Additionally, retail distribution may help reduce distribution channel markups.

- ***Help facilitate market entry of lower-cost products, including those from major Chinese manufacturers.*** While all major global manufacturers of DHPs are currently active in the U.S. market, low-cost solutions produced by Chinese manufacturers are not widely available. Introducing these solutions to the U.S. market could increase price competition and reduce the overall installed cost of DHPs, as long as quality and reliability are not compromised. Not all consumers want a premium product. Lower cost DHPs that are available in other countries could provide a solution to those willing to accept performance and efficiency that is slightly lower than the premium products available in the US market. Additionally, the impact of the adoption of these units could still provide efficiency benefits over existing equipment.

- ***Implement tiered system for rebates of highly efficient equipment.*** Current utility rebate programs are structured to be simple, often with only one efficiency threshold level or efficiency tier. However, ductless solutions are available at many different efficiency levels and become more competitive with ducted solutions at the highest efficiency levels. Implementing higher efficiency tiers that provide higher incentives but require a higher Seasonal Energy Efficiency Ratio (SEER) and/or Heating Seasonal Performance Factor (HSPF) ratings would likely enhance the adoption of ductless systems. Consumers who install ducted systems as part of a rebate program could be motivated to instead install ductless systems if the higher efficiency of ductless systems is rewarded with a larger rebate.

8 References

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Appendix A Manufacturer Profiles

This section provides profiles of selected ductless split system manufacturers that maintain significant HVAC market share.

A.1 Daikin

Daikin Industries, Ltd. manufactures and sells air conditioning systems and chemical products. Founded in 1924, it employs 56,240 people. The company is headquartered in Osaka, Japan and generated $15 billion in sales in 2013. Daikin's Air Conditioning & Refrigeration division makes a variety of HVAC products, including split/multi-split air conditioning systems, heating systems, and air-to-water heat pumps.

Japan represents the largest single market for Daikin's air conditioning systems, though 61% of its revenue comes from international countries. Daikin's Altherma Flex Type air-to-water heat pump is a novel product because it enables multiple sectors (apartments or tenants) to customize heating and cooling needs. In 2012, Daikin acquired Houston-based Goodman, which has a significant presence in the ducted-style residential unitary HVAC segment in North America.

A.2 Mitsubishi Electric

Established 1921 in Tokyo, Japan, Mitsubishi Electric is a multinational electronics and electrical equipment manufacturing company. It is one of the core companies of the Mitsubishi Group and generated $34.4 billion in revenue in 2013. The company's Cooling & Heating division manufactures air conditioning applications and products, including air curtains, compressors, dehumidifiers, heat pumps, package air conditioners, room air conditioners, ventilators, and HVAC systems for commercial buildings.

Mitsubishi Electric has focused on research and development of its products. Mitsubishi Electric's H2i MXZ Multi-zone Heat Pump System won the 2015 AHR Expo Innovation Award for heating. Additionally, Mitsubishi Electric Air Conditioning Systems Europe Ltd. has established house-type HVAC evaluation facilities in Scotland to test HVAC systems with the aim of developing HVAC products best tailored to cold climate zones in Europe.

A.3 Fujitsu General

Fujitsu General is one of the many companies making up Fujitsu Ltd. Fujitsu General manufactures and sells air conditioners, cameras, and transmitters worldwide. Founded in 1936, the company has 5,766 employees and generated sales of $2 billion in 2013. Fujitsu General is headquartered in Kawasaki, Japan. In 2013, the company expanded its Shanghai technical center to promote the localization of product design for the Chinese market.

A.4 LG Electronics

A multinational electronics company, LG Electronics is the flagship subsidiary of the LG Group. Headquartered in Seoul, South Korea, LG Electronics' sales in 2013 amounted to $53 billion. The company's Air Conditioning & Energy Solution business division makes a variety of HVAC products, including residential and system air conditioners. LG offers HVAC systems for commercial buildings and residences by emphasizing VRF technology. The company's VRF system is engineered to minimize the use of ductwork (or use no ductwork), which results in savings on the cost of large distribution fans, multiple water pumps, and water piping. Recently, LG has strengthened its HVAC business operations to enter the Association of Southeast Asian Nations (ASEAN) commercial buildings markets.

A.5 Panasonic

Panasonic Corp. consists of various business domain companies, and manufactures products ranging from home appliances and consumer electronics to industrial solutions. Founded in 1918, the company employs 271,789 people worldwide and is headquartered in Osaka, Japan. In 2013, Panasonic generated $65.8 billion in revenue. Panasonic's Appliances business segment manufactures HVAC-related products, including heat pumps.

In 2009, Panasonic acquired a 50.2% stake in Sanyo, a major Japanese electronics company, making Sanyo a subsidiary of Panasonic. In 2011, Sanyo HVAC USA was integrated into Panasonic Corporation of North America. Sanyo manufactures residential, commercial, and industrial air conditioning systems and heat pumps.

A.6 Samsung

Samsung Electronics, the South Korean multinational headquartered in Seoul, has several subsidiaries that are active in the buildings energy efficiency sector. Founded in 1938, and with 96,945 employees, the company reported revenue of $207 billion in 2013. In August 2014, it purchased Quietside LLC, a U.S. air conditioning firm, to help bolster its smart home business. Samsung recently signed a collaborative agreement with Trane to supply commercial VRFs to the U.S. market.

A.7 Toshiba

Established in 1939, Toshiba is a multinational engineering and electronics conglomerate corporation whose products and services include IT and communications equipment and systems, electronic components and materials, power systems, industrial and social infrastructure systems, household appliances, medical equipment, office equipment, lighting, and logistics. The company has 200,260 employees. Headquartered in Tokyo, Japan, Toshiba generated $54 billion in revenue.

In 1999, Toshiba Corporation and Carrier Corporation, a subsidiary of United Technologies Corporation, formed a joint venture based on Toshiba's Air Conditioning Equipment division.

The strategic alliance, Toshiba Carrier Corporation, combined Toshiba's technology with Carrier's sales network. In 2010, Toshiba Consumer Electronics Holdings Corporation transferred the Toshiba-branded residential air conditioning business in Japan from Toshiba Carrier Corp. to Toshiba Home Appliances Corp.

A.8 Gree

Gree Electric Appliances Inc. is the world's largest residential air conditioner manufacturer. Founded in 1989, the company has manufacturing facilities in China, Brazil, and Pakistan that can produce 10 million air conditioning units per year. Gree has 72,150 employees and is headquartered in Zhuhai, China. In 2013, the company reported sales of $19.2 billion.

A.9 Midea

Established in 1968, Midea Group is a comprehensive business conglomeration engaged mainly in household appliances as well as real estate and logistics. The group is also one of the largest manufacturers of HVAC and air conditioners for the residential segment in China. Midea has over 126,000 employees worldwide and generated $18.7 in revenue in 2013. The company has 10 major production bases across China and one in Vietnam, with 7 million square meters (75 million SF) of total factory space. Its marketing network covers the United States, Germany, Japan, Hong Kong, South Korea, Canada, and Russia.

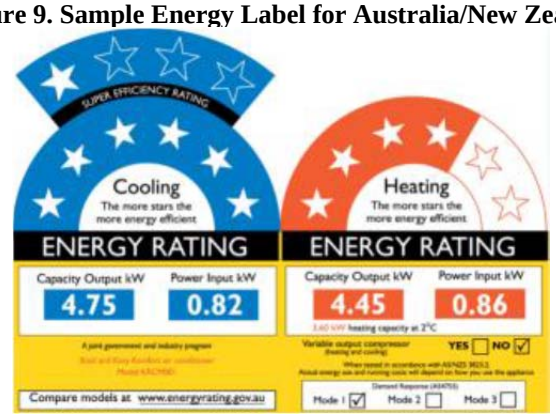
In 2004, Midea and Toshiba Carrier formed a joint venture to sell air conditioning products to the Chinese market. The deal strengthened Midea's research and production capabilities. In 2008, Carrier entered into a joint venture with Midea to produce residential and light commercial ductless split systems exclusively for Carrier for the global market.

Appendix B International Energy Labelling Programs

B.1 Australia/New Zealand

Australia and New Zealand share a common energy labelling program. They use a six-star rating to indicate the energy efficiency of the appliance, and indicate the energy consumption in kilowatt hours per year, the make and model of the appliance, the standard against which the energy efficiency of the appliance is tested, and a link to the Energy Rating website where the energy consumption of various models can be compared. An example of the Australia and New Zealand energy label can be seen in Figure 9.

Figure 9. Sample Energy Label for Australia/New Zealand



Source: CSAFE

B.2 China

The Chinese energy label only provides an energy efficiency rating, and the make and model number of the appliance. It is required on motors, air conditioners, refrigerators, washing machines, gas kettles, photocopiers, air compressors and flat-screen televisions. The energy efficiency rating is on a five-point scale that ranges from red to dark green. Air conditioner performance is based on comprehensive cooling performance factor. For heat pumps, the energy rating only considers the cooling performance, not heating. An example of the China energy label can be seen in Figure 10.

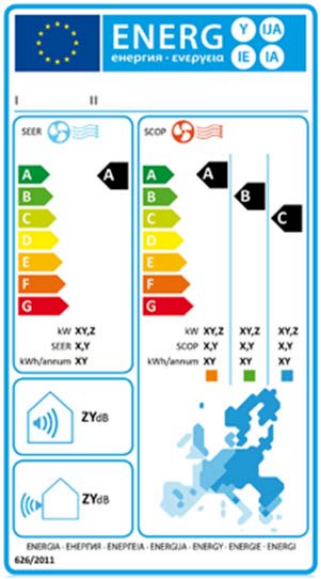
Figure 10. Sample Energy Label for China

Source: CSAFE

B.3 European Union

EU energy labels are required in all EU member countries for products such as refrigerators, freezers, clothes washers, clothes dryers, combination washer-dryers, dishwashers and lamps. The label currently rates appliances on a scale that consists of 7 classes, A to G. However, there are plans to modify the ratings to accommodate more efficient products in the future. In 2015, it will range from A+ to F and in 2017, it will range from A+++ to D. DHPs are rated on seasonal energy efficiency ratio (SEER), seasonal coefficient of performance (SCOP), and noise. An example of the EU energy label can be seen in Figure 11.

Figure 11. Sample Energy Label for the European Union



Source: CSAFE

B.4 Japan

Japan's label includes a 5-star energy rating, an energy saving mark, the energy-saving standard achievement ratio, and the annual energy consumption in kWh/year. The energy saving mark is either green, indicating that it meets the saving target, or orange, indicating that it does not. An example of the Japan energy label can be seen in Figure 12.

Figure 12. Sample Energy Label for Japan

Source: CSAFE

B.5 Korea

The Korean energy label is required on many consumer products, including: refrigerators, freezers, washing machines, dish washers, hot and cold water dispensers, rice cookers, vacuum cleaners, electric fans, air cleaners, lamps and ballasts, electric motors, domestic gas boilers, external power supplies, electric cooling and heating equipment, TVs, electric stoves, and automobiles. The label provides information on energy rating, energy consumption, CO_2 emissions, and capacity. It uses an absolute five-point scale to enable consumers to make direct comparisons among products. An example of the Korea energy label can be seen in Figure 13.

Figure 13. Sample Energy Label for Korea

Source: CSAFE

Appendix C Demand Response Programs

C.1 United States

In early 2011, the Federal Energy Regulatory Commission (FERC) issued Order 745, which requires wholesale energy markets to pay consumers the same rates for DR as for electricity generation. Grid operators will have to match the full market price, known as the locational marginal price, for DR resources in real-time and day-ahead energy markets – as long as the dispatch of DR is cost-effective. According to the FERC, without such compensation, demand-side resources cannot compete fairly with generation sources. All regional transmission organizations (RTOs) and independent system operators (ISOs) made compliance filings that have been ruled on by the FERC.

In 2008, the North American Electric Reliability Corporation (NERC) established its Demand Response Data Task Force to help the industry develop a more systematic and uniform approach to collecting and quantifying DR performance on an ongoing basis. This task force specified statistics to quantify DR performance and its contribution to improved grid reliability as well as the data collection requirements that address DR enrollment and event information.

C.2 Canada

Some provinces in Canada have adopted DR programs following to the plethora of U.S. activity. The Alberta Electric System Operator has a contract with EnerNOC to deliver 150 MW of fully automated DR to enable sub-second dispatch speed. The program, known as the Load Shed Service for Interruptibles, is intended to allow Alberta to import more hydroelectricity from British Columbia.

Ontario has been the site of DR programs since 2008. The Ontario Power Authority (OPA) has managed these programs for the province, ranging from residential load control to large commercial and industrial load shedding. The programs will transition from OPA to the Independent Electricity System Operator (IESO) by the end of 2014 to consolidate all grid operations under IESO. The province currently has about 2% to 3% of peak load under DR, but the goal is to be at 10% by 2025.

C.3 Europe

Growing peak demand, higher electricity prices in many countries and regions, and the declining reliance of traditional generation resources are forcing many European governments and utilities to pay attention to electricity supply. The EU's 20-20-20 energy vision centered on GHG emissions reduction, share of renewables, and energy use savings is expected to serve as the cornerstone of DR programs.

Only the United Kingdom, France, and Ireland are currently developing capacity markets with regulations to support full DR participation. The capacity markets in Germany, Italy, and Spain

only offer programs for the largest industrial customers. Greece and Poland also have capacity markets, but they are not available for DR participation. Thus, in most member states, capacity markets are either nonexistent or inaccessible to DR resources.

C.4 Asia Pacific

Australia and New Zealand have the longest track records of DR in Asia Pacific. Over the last decade, Australia has undertaken major energy reforms, including the development of the National Electricity Market (NEM) in 1998. NEM is a wholesale exchange for electricity for states and territories that are electrically connected, including Queensland, New South Wales, Australian Capital Territory, Victoria, South Australia, and Tasmania. The Australian Energy Market Operator was established in 2009 to implement, administer, and operate the wholesale exchange and manage the security of the power system.

China
China is in the early stages of developing DR programs, but pilot activity has been increasing. The China Electric Power Research Institute (CEPRI) is working on DR policies and regulations, DR technologies and system modeling, and standards development. Organizationally, CEPRI is research organization under the State Grid Corp. of China, the largest electric utility in the world. Meanwhile, the Natural Resources Defense Council is managing the largest pilot DR activity in China, consisting of 500 MW of DR in four pilot cities. The support activities will be conducted in the framework of U.S.-China EcoPartnerships that were established under the 10-Year Framework for Cooperation on Energy and Environment, a bilateral U.S.-China governmental agreement.

Japan
In Japan, the government's goal is to first understand the basics of how DR works and lay the regulatory and operational framework conditions before deployment. In addition to helping to resolve the reliability situation caused by the Fukushima Daiichi disaster, DR is also seen as an economic tool that can improve Japan's industrial competitiveness. It can generate additional revenue for existing facilities and help to mitigate rising electricity prices due to the rising costs of fossil fuels. In addition, DR is viewed as a cheaper and quicker alternative to traditional generation and transmission and distribution investments.

C.5 Rest of World

Not many initiatives are currently in place in the rest of the world. Eskom's program in South Africa is one of the few DR projects in Latin America, the Middle East, and Africa in 2014. In 2015, piloting DR programs in these regions is expected, with a ramp up in full DR programs a few years later.