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Ductless Heat Pump Market Research and Analysis

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Executive Summary

Market Characterization

The U.S. DHP market differs significantly from overseas markets. Almost all residential HVAC systems in Asia and a vast majority of systems in Europe are ductless, while only a small percentage of homes in the U.S. utilize DHP technology. Slower U.S. adoption rates can be explained partly by cultural differences and partly by differences in home architecture--U.S. homes are generally designed with ducted systems in mind and allow for more livable space. Energy costs are much higher in Asia and systems with increased energy efficiency are more desirable. Lastly, refrigerant handling is not as strictly regulated overseas as it is in the U.S.

Many companies currently manufacture DHPs for the U.S. market including Mitsubishi Electric, Fujitsu, Daikin, Sanyo, LG, Samsung, EMI/Retroaire, Goodman, Heil, and Unionaire. Trane, Carrier, and Lennox do not manufacture DHPs for the U.S. market. Instead, a third party manufacturers the product for them and privately labels the systems for distribution in the U.S. DHP models range from single-zone to multi-zone units with differences in price, SEER, and HSPF ratings.

Two main distribution channels exist for DHPs in the U.S. Many manufacturers use independent distributors, such as wholesale, plumbing, heating, air conditioning, and refrigeration distributors throughout the country. Others manufacturers use company-owned dealer distribution of their DHPs. DHPs are not sold through retail channels because of the restricted refrigerant used in the systems.

Approximately 250,000-300,000 ductless systems were sold in the U.S. last year, with the ductless industry growing steadily each year for the past few years. This growth, despite a slow residential construction market, is likely due to the remodel and retrofit application of DHPs, along with their high level of energy efficiency.

Single zone units are currently more popular than multi-zone units, with Mitsubishi Electric, Fujitsu, and Sanyo dominating the ductless market.

DHP Awareness and Perceptions

DHP awareness is limited among consumers and builders, with more awareness among HVAC contractors. Participants in the qualitative phases of this study perceived these systems to be best used in retrofit and remodel applications, while only a handful believed them to be appropriate for whole-house heating and cooling. Qualitative participants also believed that with more awareness on the part of consumers, builders, installers, engineers, and architects, the DHP industry would grow. As of now, only 5% of the American public knows that DHPs are even an option.

Most participants in the qualitative phases of research perceived the notion of “ductless” to be valuable in situations where ducted systems were impossible or improbable. Brand

was perceived to be important according to HVAC installers, as many were willing to pay more money for a better system.

Characteristics of Decision Makers with High Likelihood of Adoption

Various market experts, manufacturers, and consumers living and not living with DHPs speculated as to the types of homeowners and builders who may have a high likelihood of adopting these systems. Consumer characteristics included homeowners with electric heating systems, those living in moderate or coastal climates, people looking to condition a single room or unconventional space, and homeowners wanting a combination heating and cooling system. Consumers who are energy conscious and concerned about their electric expenses might also adopt minisplit systems. Builders considered likely to adopt these systems included those constructing or remodeling smaller attached apartments, condominiums, and smaller homes.

Compelling Value/Selling Propositions for Decision Makers

Many compelling advantages of DHPs existed for consumers. Participants and experts believed the system's ability to use energy more efficiently, thus translating into lower electric bills, was an important benefit of DHPs. Greater personal control of a home's climate, improved air quality, and noise reduction were also highly regarded characteristics. Corrosion reduction, a DHP's capability to be added onto a ducted system, and perceived safety benefits were also considered valuable. Other consumer advantages included the potential for increased resale value of a home, reduced system maintenance/service when compared to other systems, relatively easy installation of DHP units, reduction of greenhouse gas emission, and increased livable space.

Utilization of DHPs to gain points in green building programs was viewed by builders as a huge benefit of these systems. The ability to differentiate themselves from other builders by offering DHPs, coupled with a relatively easy installation process, was also extremely compelling for builders. Increased customer satisfaction through DHP technology was also suggested as a benefit of the system.

For HVAC contractors, minisplits offer easy installation and limited system maintenance, both of which were consistently perceived as valuable selling propositions. DHPs were regularly regarded as a unique solution to certain installation challenges. DHPs were another option to offer clients, allowed for company differentiation, and were a means of meeting green building criteria—all of which were considered secondary selling propositions to HVAC contractors.

From a distributor point of view, DHPs were considered a more profitable product than unitary systems because of their price premium. Handling of ductless systems is much easier for distributors when compared to traditional units because DHPs are smaller and easier to inventory. Both variables were considered valuable propositions for distributors.

Barriers to DHP Adoption

Barriers to widespread DHP adoption were discovered during multiple phases of this research project. Higher system cost and unattractive indoor and outdoor aesthetics were

substantial drawbacks of these systems from a consumer point of view. A general lack of consumer awareness and low temperature heating concerns were also considered substantial barriers to adoption. In addition, preferences related to fuel type, and questions about overall system operation and product terminology were viewed as slightly less significant impediments to consumer adoption, though barriers nonetheless.

Substantial barriers to builder adoption included trouble finding a qualified DHP installer, general wariness towards any new technology not commonly found in the building industry, and a DHP's unsightly appearance. Less significant barriers included issues with humidity, the necessity of another heat source during home construction, fuel preferences, and overall confusion about system operation.

Significant barriers to contractor adoption included concerns about installation and a pervasive mindset that DHPs were solely application specific. Other considerable barriers included a perceived lack of awareness on the part of contractors and the need for supplemental heating. Less significant hindrances to contractor adoption included possible refrigerant leakage, unpleasant aesthetics, higher cost, and problems with condensate pumps.

Since traditional, ducted systems are typical practice in the U.S., distributors might not be as likely to offer DHPs. Additionally, certain geographic areas, such as the Pacific coast, may be more receptive to the idea of DHPs. In other areas where energy efficiency is not top of mind, distributors might not be as likely to offer DHP technology.

DHPs represent only a fraction of the U.S. HVAC market. For widespread adoption, the first obstacle that must be overcome is lack of awareness and practical knowledge of DHPs. Once some familiarity is established, DHPs may be well received based on their energy efficiency, compatibility with green building programs, and ease of installation.

Introduction

The Northwest Energy Efficiency Alliance (NEEA) sought to better understand the potential for ductless heat pump (DHP) market adoption within the United States. NEEA identified seven core objectives for the scope of this project. The objectives are summarized as follows:

1. Deliver a comprehensive characterization of DHP market structure
2. Identify characteristics of decision-makers (builders and homeowners) with high likelihood of adoption
3. Estimate potential market size—US and Northwest
4. Identify awareness, perceptions, and barriers to adoption of DHPs among key market stakeholders
5. Identify most compelling value/selling propositions for decision makers
6. Understand how to speak to decision makers about HVAC in their own language
7. Understand initial experiences of early participants in both supply and demand side markets

Project Methodology

The research design for this project included a secondary literature review, in-depth interviews, telephone dyads/triads, and in-person focus groups. Information gathered in each research phase addressed the stated objectives of the project.

Secondary Literature Review

In the secondary literature review, the Research Center uncovered and synthesized information already available about the DHP market including advantages and disadvantages of DHPs, manufacturers of DHPs and their current product offerings, as well as notions of pricing. This data came from searches of previously published information available on the internet, in journals, and in periodicals. This secondary literature review also identified experts in the field for the purposes of conducting in-depth interviews in the next phase of research.

In-Depth Interviews

The first type of qualitative data collection the Research Center conducted involved in-depth interviews with thought leaders earlier identified in secondary research. These in-depth interviews allowed for greater insight into DHP market characterization and structure. A total of 13 market actors were interviewed during February and March 2008. Interviewees included experts in the field of DHPs, distributors of DHPs, representatives from active U.S. DHP manufacturers, and representatives from third party DHP manufacturers. Interviewer guides differed among each group.

Expert and trade ally in-depth interviews. A total of five expert and trade ally in-depth interviews were conducted. Participants included those from the following companies or organizations:

1. Heating, Air Conditioning and Refrigeration Distributors International (2)

2. Air Conditioning and Refrigeration Institute
3. Air Conditioning Contractors of America
4. Home Energy Sciences

DHP distributor in-depth interviews. Three active U.S. DHP distributors interviews were conducted. Participants were from the following companies:

1. CFM Distributors
2. Thrifty Supply
3. Thermal Supply

Active DHP manufacturer in-depth interviews. Three active DHP manufacturer interviews were conducted by the Research Center. Representatives from the following companies were interviewed:

1. Fujitsu
2. Daikin AC
3. Mitsubishi Electric

Third party DHP manufacturer in-depth interviews. Two third party DHP manufacturer interviews were conducted for this project. Representatives from the following companies were interviewed:

1. Carrier Corporation
2. Trane

Telephone Dyads/Triads or Telephone Focus Groups of DHP Users

The second type of qualitative data collection involved telephone focus groups of two to three participants, also known as dyads and triads. The purpose of these dyads and triads was to collect in-depth information regarding barriers and facilitators to adoption, levels of awareness, influences, and motivators in the decision to use DHPs, and characteristics of decision makers with a high likelihood of DHP adoption. The Research Center conducted a total of six telephone dyads and triads involving two groups of builders who built or remodeled homes with DHPs, two groups of HVAC contractors who installed DHPs, and two groups of consumers who lived with DHPs in their homes. Topics covered in moderator guides differed among each of the three groups.

Builder telephone dyads/triads. Five builders participated in two dyads/triads. Participants in these groups were aged 18-55, characterized themselves as a builder, contractor, or remodeler, were involved primarily in residential construction for a minimum of three years, and used at least one DHP in home construction. Current HVAC systems used

HVAC contractor telephone dyads/triads. Seven HVAC contractors participated in two telephone dyads/triads. Participants in these groups were aged 18-55, characterized themselves as an HVAC installer or one who performs HVAC system maintenance, were involved primarily in residential construction for a minimum of three years, worked primarily in the Pacific Northwest, and installed at least one DHP system.

Consumer telephone dyads/triads. Five consumers living with DHPs participated in two telephone dyads/triads. Participants in these groups were aged 18-55 and had at least one DHP in their home.

In-Person Focus Groups of Non-Users

The final qualitative research phase consisted of eight in-person focus groups.

Audience not familiar with DHPs	Location	Total number of groups
Homeowners	Portland, Eugene, Spokane	4
HVAC Contractors	Portland, Spokane	2
Builders	Portland	1
Hybrid of HVAC/Builders	Spokane	1

Four groups consisted of consumers unfamiliar with DHPs while two groups consisted of HVAC contractors who did not install DHPs. One group consisted of builders who did not use DHPs. The final group was a blend of HVAC installers, builders, and architects who did not implement DHP technology. The purpose of these focus groups was to gauge initial participant reaction to DHPs, identify compelling value/selling propositions, key messages to emphasize, and potential barriers to overcome, as well as to identify levels of awareness and motivators in the decision to install or use DHPs. Moderator guides differed among groups and covered a variety of topics. The groups were exploratory in nature and were intended to provide input for future quantitative research.

Builder focus groups. Participants in builder and blended builder-contractor focus groups did not use DHPs.

HVAC contractor focus groups. Participants in HVAC contractor and blended builder-contractor focus groups were those who did not use DHPs.

Consumer focus groups. Participants in consumer focus groups were unfamiliar with DHPs.

Detailed Findings

Introduction to DHPs

Ductless heat pumps (DHPs), or minisplits, are heating and cooling systems that combine the climate control advantages of window air conditioners with the entire house cooling and heating capabilities of central, ducted systems. Minisplit systems include a single outdoor unit comprised of a compressor and condenser and one or more indoor, wall-mounted units containing individual coils within air handlers. In DHP systems, refrigerant is piped from the outdoor unit, through small diameter insulated refrigerant lines directly to indoor wall units. Cooled or heated air is then blown into the room by a fan located in the evaporator unit. One outdoor unit can be linked to one or more indoor units.

DHP Market Characterization

Through an existing literature review and multiple in-depth interviews with market actors, the Research Center determined various characteristics of the DHP market.

Overseas DHP market. Minisplit technology dominates Asian and European HVAC markets but has yet to significantly penetrate the U.S. market. While ducted systems are the norm in the U.S., minisplits and other types of ductless systems account for 98% of all air conditioning in Asia. In Europe, ductless systems, in general, account for 50-70% of air conditioning systems (Fujitsu, unpublished interview). Though U.S. DHP sales have increased over the past few years, Asia and Europe remain the leaders in ductless system sales (IEA Heat Pump Centre Newsletter 2003). In 2003, China had the largest minisplit market and production center in the world, while East Asia and Southern Europe were the fastest growing regions for DHP sales (IEA Heat Pump Centre Newsletter 2003). Slower U.S. adoption rates can be explained partly by the evolution of heating and cooling in Asia and in the U.S., differences in system architecture, energy consciousness, space constraints, and refrigerant handling.

Ductless systems are a direct evolution from the hibachi (CFM Distributors, unpublished interview), a traditional Japanese heating device consisting of a heat-proof open container designed to hold hot charcoal. Hibachis were carried from room to room to heat only rooms that were occupied. This mindset remains as the Japanese continue to only heat, and now cool, rooms in use with minisplits. This mindset has not transferred to the U.S.

Conversely, in the U.S., the warm air heating market emerged from coal-fired, solid-fuel, and gravity-flow furnaces with large gravity set ductwork (CFM Distributors, unpublished interview). DHPs were not introduced into mass production in Japan until the 1940s or 1950s, and by that time, the U.S. had already committed to ducted systems (Air Conditioning Contractors of America, unpublished interview). According to Daikin AC, the market in the U.S. for ductless systems was first established in the mid-1980s (Daikin AC, unpublished interview). Around that same time, there was backlash against putting Japanese technology in homes, so Japanese manufacturers were forced to build

their air conditioning framework around US manufacturers (Fujitsu, unpublished interview).

Central ducted systems are rarely installed overseas due to limited residential space and close proximity to other buildings (Mitsubishi Electric, unpublished interview). U.S. builders generally do not have such tight space constraints, making it easier to install ductwork and conventional central systems. Therefore, DHP popularity overseas is a direct result of residential architecture and design (Roth, Westphalen, and Brodrick 2006). If ducts are not present, minisplits provide an alternative for effective heating and cooling. Also, many residences in Europe are older and built before the concept of central heating and cooling. Instead of installing invasive ductwork, it is often easier to use minisplits to preserve the original structure of the home (Wardlaw Fuels).

Increased energy costs is another factor for Asia's widespread adoption of DHPs. Energy costs are reportedly five times higher than those in the U.S. (Mitsubishi Electric, unpublished interview). Minisplits provide a way in which to combat high energy prices by leveraging their strong energy efficiency ratings. Rising U.S. energy costs and increased energy conservation awareness among consumers may encourage DHP adoption in the U.S.

Also, Asia does not regulate refrigerant handling. Installing DHPs in Asia does not require training or certification. In fact, manufacturer's installation instructions are intended for the non-technical person to install DHPs (CFM Distributors, unpublished interview). According to CFM Distributors, only the U.S. and Western Europe are concerned with refrigerant usage (CFM Distributors, unpublished interview). The ease of installation by non-certified installers is another reason for the large DHP market overseas.

U.S. DHP Market Structure

Market size. It is difficult to discern actual DHP sales because DHPs represent a small percentage of overall HVAC equipment sales as noted in Table 1. Additionally, many manufacturers do not wish to disclose annual sales figures. However, in 2005, Sanyo estimated that Americans only purchased about 125,000 ductless systems annually (Wardell 2005) and according to manufacturers interviewed, data provided to them by the Air Conditioning and Refrigeration Institute (ARI) showed that approximately 250,000-300,000 ductless units were sold last year. Currently, the U.S. commercial and residential market amounts to approximately $15 billion, yet ductless system purchases account for less than 1% (Daikin AC, unpublished interview). Mitsubishi, Fujitsu, and Sanyo account for approximately 80% of the market share of ductless systems (Daikin AC, unpublished interview).

Table 1. U.S. Sales/Shipments of DHPs

	2005
Total U.S. manufacturer shipments of unitary air conditioners and air-source heat pumps[a]	9,246,559
Estimated number of ductless systems sold in the U.S.	125,000

a Source: Air Conditioning, Heating, and Refrigeration Institute http://www.ahrinet.org/ARI/util/showdoc.aspx?doc=630

b Source: (Wardell 2005)

Leading industry experts believed sales and implementation of residential DHPs were on the rise in the U.S. (Mitsubishi Electric, unpublished interview and Home Energy Sciences, unpublished interview). However, a Mitsubishi Electric representative cautioned that only 5% of the U.S. population knows that DHPs are even an option, which may also explain low sales numbers when compared to Europe and Asia (Mitsubishi Electric, unpublished interview).

Selected models. Mitsubishi, Fujitsu, Daikin, and Sanyo are considered the leaders in DHP technology (Home Energy Sciences, unpublished interview) but exact sales numbers for each DHP manufacturer are not publicly disclosed. Table 1 offers a glimpse at select minisplit models from larger U.S. manufacturers. Included in the table are each model's cooling and heating capacity, zone capability, seasonal energy efficiency ratio (SEER) and HSPF ratings, and price (if available). Models found in this table include single units for small rooms, single units for larger rooms, and multiple units for more than one room.

Table 2. U.S. DHP Manufacturers and Select Models

Model[a]	Heating/cooling capacity (BTU/h)	Zones (or number of rooms)	Price (in dollars[b])	SEER	HSPF
AmcorAire					
UCHW-H09AF2	9,000/9,000	Single	699.00	13.0	UNK[c]
UCHW-H24AF2	24,000/24,000	Single	1449.00	13.0	UNK
Carrier					
40QNQ009-3	9,000	UNK	UNK	13.0	7.7
40QNQ036-3	36,000	UNK	UNK	13.0	7.7
Comfort-aire					
DMH09SB-0	9,800/9,800	Single	955.00	13.0	7.8
SMH24SA-1	24,000/24,000	Single	1466.99	13.0	7.7
DMH24DB-1	11,800/11,800	Dual	2084.00	14.1	7.8
DMH36TB-1	11,730/11,730	Tri	3581.00	16.4	7.8
Daikin					
FTXS09DVJU/RX09DVJU	9,000	Single	1111.50	13.0	UNK
FTXS24DVJU/RXS24DVJU	24,000	Single	2341.01	16.0	UNK

Model[a]	Heating/cooling capacity (BTU/h)	Zones (or number of rooms)	Price (in dollars[b])	SEER	HSPF
Fedders Corp.					
HFE1009NDF	9,000/8,800	UNK	UNK	10.0	UNK
HFE4018NDF	18,500/17,500	UNK	UNK	10.0	UNK
Friedrich					
M09YF	9,600/9,700	Single	1199.95	14.3	8.2
M24YF	27,600/24,200	Single	2049.95	18.0	10.0
M24DYF	28,000/24,000	Dual	2899.95	16.5	9.0
M36TYF2	38,100/35,100	Tri	4049.95	15.0	9.0
M36QYF	38,000/35,200	Quad	4399.95	15.0	9.0
Fujitsu					
9RLQ	9,000	Single	1972	21.0	UNK
24RLQ	24,000	Single	3005	18.0	UNK
LG					
LA091HNP	9,000/9,000	Single	1245.00	13.0	UNK
LA121HNM	12,000/12,000	Single	1375.00	13.0	UNK
MSLG12IHP/MSLG12IHP	24,000/24,000	Dual	2565.00	13.0	UNK
MSLG012IHP/MSLG012IHP/ MSLG012IHP	36,000/36,000	Tri	3825.00	13.0	UNK
Mitsubishi					
MSZ-A09NA	10,900/9,000	Single	1252.00	17.0	8.2
MSZ-A24NA	23,200/22,000	Single	1989.00	16.0	8.2
MXZ-3A30NA (17+17)	28,000/26,900	Dual	4664.00	13.0	7.7
MXZ-3A30NA (09+09+17)	28,600/28,400	Tri	4828.00	13.0	7.7
Pace Air					
09HPEWHEC	9,500/9,000	Single	809.00	13.0	9.2
24HPXWHEC	25,000/24,000	Single	1379.00	13.0	9.2
Quietside					
QSH09	9,000/9,000	Single	1199.00	13.0	7.7
QSH24	24,000/24,000	Single	1999.00	13.0	7.7
Samsung					
AQV09	11,950/9,000	Single	1243.00	20.0	10.0
AQV24	27,000/24,000	Single	2145.00	15.5	7.8
Sanyo					
09KHS71	12,000/9,000	Single	1409.57	16.0	7.7
26KHHS72R	23,000/27,600	Single	3749.00	15.9	10.3
KMHS1872-2	36,000	Dual	6161.42	13.0	UNK
KMHS1272-3	36,000	Tri	6383.69	13.0	UNK
KMHS0972-4	36,000	Quad	6712.90	13.0	UNK
Soleus-Hitachi					
KFIHP-09	9,500/9,000	Single	690.00	16.0	UNK
KFHHP-22	24,200/22,000	Single	1248.00	14.0	UNK

a All non-price information taken from manufacturer websites.

b Price information taken from distributor websites including ductlessdepot.com, http://www.ajmadison.com/, http://www.amroyal.com/, http://www.smarterwayinc.com, www.ductlessdepot.net, www.qualitymatters.com.

c Unknown value

Active manufacturers. Mitsubishi, Fujitsu, Daikin, Sanyo, LG, Samsung, EMI/Retroaire, Goodman, Heil, and Unionaire are currently manufacturing DHPs in the United States.

Third party manufacturing. Trane, Carrier, and Lennox do not manufacture DHPs in the U.S. Instead, a third party manufacturers the product under contract and privately labels the systems for distribution in the U.S. (Fujitsu, unpublished interview). Companies like Trane and Carrier participate in this fashion because, as a major OEM, they want to be able to supply a full line of HVAC products (Air Conditioning Contractors of America, unpublished interview).

DHP Distribution and Retail Channels

Distribution channels. In the U.S., two primary distribution methods exist for ductless systems. Companies such as Fujitsu and Daikin mainly use independent distributors, such as wholesale, plumbing, heating, air conditioning, and refrigeration distributors throughout the country. One company, for example, has 2,500 points of sale throughout US and Canada.

The second distribution method involves company-owned dealer distribution. For instance, one-half of Trane's business in the U.S. comes from such company-owned dealer distribution channels (Trane, unpublished interview).

It is also possible to purchase ductless systems directly off the internet. However, the systems must still be installed by a licensed professional or the manufacturer warranty could be in jeopardy (Air Conditioning Contractors of America, unpublished interview).

Retail channels. DHP retail channels do not exist in the U.S. due to the refrigeration-charged system imbedded in the product. These systems require installation by licensed contractors according to the Environmental Protection Agency's (EPA) refrigerant handling regulations (Fujitsu, unpublished interview). Conversely, big-box retail stores such as The Home Depot and Lowe's sell central systems at kiosks (Air Conditioning Contractors of America). Associates schedule appointments for a contractor to visit a home and provide an estimate. According to the Air Conditioning Contractors of America (ACCA), manufacturers use the store as another sales venue. ACCA believes that something similar could be done with ductless systems, but DHPs would never be sold directly off the shelves (Air Conditioning Contractors of America, unpublished interview). Overseas, ductless systems can be purchased from retail channels. One can visit an electronics store in Asia and see a section of ductless minisplits available for purchase (Daikin AC, unpublished interview).

Typical mark-up. Various distributors report the average mark-up for DHPs is similar to other HVAC systems. One distributor explained that the wholesaler needs to make about 26%-27% gross margin, which equates roughly to a 34-36% markup, figuring in the costs of shipping, damage in shipping, technical support, and marketing. Another distributor interviewed indicated their DHP mark-up ranged from 18-20%.

DHP Standards and Test Procedures

Currently, equipment testing for ductless systems occurs under the Air Conditioning and Refrigeration Technology Institute's (ARTI) Standard 210.240, which includes a broad range of unitary, small equipment (Air Conditioning and Refrigeration Institute, unpublished interview). For the past year, ARTI has been working with various DHP manufacturers to create equipment standards and test procedures solely applicable to DHPs. ARTI speculates that once ductless equipment has its own standards and test procedures, the systems will have increased visibility and recognition in the industry, as well as heightened consumer and contractor awareness (Air Conditioning and Refrigeration Institute, unpublished interview). Under these test procedures, manufacturers can voluntarily have their equipment evaluated in order to determine the accuracy of the product's efficiency claims. These tests will enable a ductless manufacturer to promote the system as a certified product that meets its stated efficiency claims. Additionally, consumers will have the advantage of knowing that a third party verifier has tested the efficiency ratings of the product without having to rely solely on the manufacturer's claims (Air Conditioning and Refrigeration Institute, unpublished interview). When this standard is approved, it can easily be incorporated into a green building program which may add to its visibility in the marketplace (Air Conditioning and Refrigeration Institute, unpublished interview).

History of selected DHP manufacturers

Qualitative research conducted by the Research Center involved in-depth interviews with representatives of select DHP manufacturers. These interviews provided insight into the history of DHPs within these companies, popular products, and product costs.

Daikin. Daikin began designing minisplit systems in the 1950s and was the first manufacturer to introduce a multisplit system (Daikin AC, unpublished interview). In 1996, Daikin was the first ductless manufacturer in the world to switch to non-R22 products. According to Daikin, they are the current top HVAC company in the world, both commercially and residentially, but are relatively new to the U.S. marketplace. Daikin established a sales company in the U.S in 2005.

Currently, the one to two-ton capacity single-zone, wall mounted systems are the biggest selling products for Daikin (Daikin AC, unpublished interview). One manufacturer representative we spoke to reports that equipment cost remains relatively constant across the country. The cost of a unit is approximately $1300 to $1500 per ton, with installation running $1500 or more. These installation prices, however, can vary greatly depending on region of the country.

Carrier. Carrier designed their first minisplit system in the mid 1980s (Carrier, unpublished interview). By the late 1980s, Carrier ceased manufacturing these systems due to poor sales and other logistical issues. Since that time, Carrier has been manufacturing all over the world. Currently, they are not manufacturing any DHPs in the U.S., but have manufacturing partners abroad. According to Carrier, the majority of the world uses ductless systems for residential applications, but over 90% of Carrier's ductless sales are in commercial applications. Carrier indicates their most popular

residential product is a high-wall style system ranging from 9,000-18,000 BTUs and is primarily used for add-ons and retrofits. Carrier's residential ductless systems account for less than 5% of its U.S. sales.

Trane. Trane has been involved in ductless products for over 20 years, primarily overseas (Trane, unpublished interview). At this time, Trane sells a very limited range of minisplits in the U.S. due to current product changeovers. Trane indicated their high wall, single-zone systems are the most popular with the price of these systems varying greatly by region.

Fujitsu. Almost 85% of Fujitsu's product line is heat pump inverter technology which allows for higher SEER products (Fujitsu, unpublished interview). Fujitsu's product line ranges from systems with 9,000 BTUs to 42,000 BTUs. Fujitsu remarked that their multi-zone systems are more popular than single-zone systems in the residential industry.

Market Trends

Market trends were determined through in-depth interviews with market actors and telephone and in-person focus groups with users and non-users.

In-depth interviews with market actors. Over the past few years, DHPs have been installed in a wide range of applications. According to a Fujitsu representative, the ductless industry has grown 28-32% a year for the past five years, and in the past year, unitary, ducted systems were down almost 19% while ductless systems were up 28% (Fujitsu, unpublished interview). Fujitsu reasoned that unitary systems have been more affected by the current housing market and economy, while minisplits have been able to differentiate themselves in the marketplace (Fujitsu, unpublished interview).

Ductless minisplits have not yet impacted the sales of traditional residential systems, but have the potential to do so in the near future according to a leading U.S. distributor (CFM Distributors, unpublished interview). Other manufacturer representatives disagree and see the DHP market completely separate from the traditional ducted market since DHPs have more targeted applications. According to a Mitsubishi Electric representative, DHPs are more commonly used for spot heating and cooling—not whole house heating and cooling—so it would be difficult to forecast the extent to which DHPs could compete with ducted systems (Mitsubishi Electric, unpublished interview).

Currently, single-zone units outsell multi-zone systems but distributors have started to notice increased adoption of multi-zone units (CFM Distributors, unpublished interview). As inverter technology becomes sophisticated, the amount of heat a ductless system produces increases, which may enhance the applicability of DHPs (Fujitsu, unpublished interview). Additionally, as more national advertising and DHP education occur, the residential DHP market will increase (Mitsubishi, unpublished interview). If the cost of ductless systems were also reduced, the ACCA speculates ductless manufacturers could substantially increase their market share (ACCA, unpublished interview).

Findings from telephone focus groups of builders using DHPs. When builders in a telephone focus group were asked if they would be building or remodeling more or fewer homes with DHPs in the future, two builders replied they would be building fewer homes. One reasoned that ducted systems prevailed in the industry, while another mentioned that a combination heating and air conditioning system was not necessary where he built homes. Builders in another telephone focus group hoped to build and remodel more homes with DHPs in the future but wanted more consumer feedback regarding the product before they implemented it in more homes.

Findings from telephone focus groups of contractors using DHPs. One DHP installer interviewed during a telephone focus group believed that residential DHP sales were dependent upon the retrofit and remodel market, since DHPs are often used in retrofit and remodel situations. This installer believed if the retrofit market went up, residential DHP sales would increase as well.

New Products

New products are constantly being developed by producers within the HVAC industry. According to Daikin AC, various manufacturers are currently improving a ducted-style unit for their ductless product line. Instead of a wall mount in the occupied space, a ducted-style unit is installed in a closet or dropped ceiling. The product is essentially out of sight of the consumer, leading to improved aesthetics.

In early 2008, Mitsubishi introduced its new hyper-heating inverter (H2i™) technology for select Mr. Slim® and CITY MULTI® VRFZ units. This new technology allows the system to run at full capacity in extremely cold temperatures unlike traditional heat pumps which require supplemental heat. A Mitsubishi representative said this new technology has the capability of functioning at 100% heating capacity at 5 degrees Fahrenheit and will operate effectively down to -13 degrees Fahrenheit. According to Mitsubishi Electric, the "patent-pending flash process cools the compressor which allows for higher compressor speeds at lower temperatures without overheating" which helps to overcome common heat pump issues like "decreases in low-side pressure, refrigerant mass flow rate, and operational capacity" (Mitsubishi Electric Press Release 2008). Mitsubishi's website mentions that this new technology is currently offered for "light commercial or institutional renovations or new construction projects." However, a Mitsubishi representative boasted this new system was placed in a public housing unit and when the outside temperature dropped down to near zero degrees Fahrenheit, the discharge temperatures were close to 100 degrees Fahrenheit with all residents reporting they were comfortable.

One HVAC installer interviewed during a telephone focus group reported using a product called AireShare to help heat and cool multiple rooms without adding a large number of DHP systems. AireShare consists of a fan motor mounted inside a 2x4 wall. With the flip of a switch, the systems can take heating or cooling from the main room, where the DHP indoor unit is located, and pump the air into another room. Aireshare systems are meant to complement a ductless minisplit system and can condition an entire house with only 3-4 units (HVAC Solutions Direct). This installer reported that manufacturers of this

product are currently trying to work with Mitsubishi to bring AireShare to the residential marketplace.

Homeowners Likely to Adopt DHPs

Findings from Secondary Literature Review

Homeowners looking to heat and cool single rooms. Many homeowners remodel attics or rooms above garages in order to make them into livable space. Home offices, increasingly popular home theaters, and other residential room additions are often the end result of such home improvement projects, yet in many instances the existing central system might not extend to these rooms (Skaer 2005). DHPs offer an alternative to ductwork extensions and lower capacity central systems while maintaining the performance of the original system. These ductless systems are easier to retrofit because they are only using small refrigerant lines instead of ducts (Roth, Westphalen, and Brodrick 2006)

Homeowners in coastal areas. Consumers living in coastal areas might also benefit from minisplit systems. Condenser motors situated horizontally prevent the system from catching water and debris, and plastic fan blades built to resist corrosion make DHPs suitable HVAC systems for coastal residences or homeowners worried about corrosion (Wardell 2005). Those living in humid climates would also benefit from DHPs, as these systems dehumidify the air regardless of temperature setting (Wardell 2005).

Consumers in moderate climates. Homeowners in moderate climates where the outside temperature does not regularly drop below freezing might be more likely to install DHPs. Since backup electric resistance heating or an additional separate heating system is necessary, homeowners in extremely cold temperatures might adopt these systems (Roth, Westphalen, and Brodrick 2006).

Unconventional spaces. Minisplits also provide an alternative for heating and cooling unconventional homes or homes where ducted systems are impossible, impractical, or too expensive to install (Skaer 2005). For example, DHPs should appeal to consumers living in historic or older homes without central ducts, since minisplit systems allow for cooling and heating capabilities through less invasive installation procedures. Owners of other residences where ductwork might be difficult to install like vacation homes and cabins should also consider DHPs (Skaer 2005).

Findings from In-Depth Interviews with Industry Experts

Homeowners looking to heat and cool single rooms. Industry experts agreed with existing literature and believed and homeowners looking to heat or cool a single room would benefit from minisplits. Home improvement projects and retrofits can be considered opportunities to implement DHP technology. In fact, Fujitsu believed retrofits were the primary market for DHP manufacturers (Fujitsu, unpublished interview) while Trane considered room additions as the principle market (Trane, unpublished interview). A representative from Thermal Supply, a distributor in the Pacific Northwest, found that most of their ductless residential sales were for both add-ons and retrofits (Thermal Supply, unpublished interview).

Furthermore, problems with ducted systems might occur when retrofitting or adding on to a home because the current system might not be large enough capacity to heat or cool the additional room (Trane, unpublished interview) or the additional room might cause performance in the central system to diminish (Thrifty Supply, unpublished interview). Using DHPs solves these problems with the added benefit of having a single location for maintenance work and installation (Heating, Air Conditioning and Refrigeration Distributors International, unpublished interview).

Unconventional spaces. With real estate prices increasing dramatically, many people are turning to smaller homes (e.g. apartments turned into condos). Such residences do not necessarily have central cooling and DHPs offer a small and compact solution to heating and cooling (Thermal Supply, unpublished interview). Additionally, applications for homeowners living in smaller residences like lofts or bungalows where simplicity is valued is another way DHPs are useful according to CFM Distributors (CFM Distributors, unpublished interview).

Findings from Telephone Focus Groups of Consumers Living with DHPs

Electric bill savings. During telephone focus groups, consumers mentioned that people looking to save money on their electric bill might be interested in DHP technology. Many of these consumers living with DHPs reasoned that they initially agreed to have a system installed in their home because they were told it would save them money on their electric bill. With the potential to save hundreds of dollars each year, according to consumers interviewed, homeowners looking to save money on their electric bill would likely embrace such a product.

Energy conscious. Consumers interviewed in telephone focus groups believed an ideal DHP consumer would be someone who is educated about the product and concerned about energy efficiency. When first learning about DHPs, they were extremely interested in the energy efficiency ratings of the systems.

Homeowners looking to heat and cool single rooms. Many consumers who participated in telephone focus groups were motivated to install a DHP in their home as a solution to a problem. Their current HVAC system could not effectively heat or cool certain rooms which caused these rooms to go unused during extremely hot summer months and cold winter months. Since installation of their DHPs, they reported these rooms as more comfortable because of the zonal heating and cooling capabilities. Consumers looking to make a single room more comfortable may be interested in this product.

Combined heating and air conditioning system. Simply the notion of a non-ducted system that heats and cools was motivation to install these ductless systems according to consumers who participated in telephone focus groups. Their previous systems did not include air conditioning which made for extremely hot indoor temperatures during the summer months. Consumers looking for a combination product might be likely to adopt this product.

Findings from Focus Groups of Consumers Not Living with DHPs

Electric bill savings. Participants in in-person focus groups believed saving money on their energy bills each month was a crucial benefit of DHPs. They indicated consumers trying to save money would benefit from these systems since they seemed economical to run and cost-effective to install.

Energy conscious. Consumers participating in in-person focus groups also reported that homeowners interested in energy efficiency who were environmentally conscious would likely use this product. Since DHPs offer extensive energy efficiency benefits, a person concerned with this issue may have a higher likelihood of using this product in his or her home.

Combined heating and air conditioning system. Participants in focus groups liked the idea of having a combined heating and air conditioning system and believed this to be a benefit of DHPs.

Additional consumer characteristics. Consumers in in-person focus groups presented a wide array of additional characteristics of those they thought were most likely to adopt DHP technology. Participants noted that people of all age ranges might consider this product. Additionally, consumers indicated that potential DHP customers would be educated, willing to comprehend how the system functioned, financially able to invest upfront, and willing to embrace new technology. Homebuyers who have seen these systems in hotels or hospitals, or those who have previously installed extensive ductwork during major home renovations or remodels, may also see the benefit of these systems. Additional consumer characteristics include homeowners looking for a HVAC system that operates quietly, requires low maintenance, and a system where the indoor temperature can easily be programmed.

Findings from Telephone Focus Groups of Builders and Installers Using DHPs

Builders and installers who participated in telephone focus groups agreed that homeowners who were energy conscious would most likely adopt DHPs. These participants believed that consumers interested in energy efficiency and thus wanted to save money on their utility bills each month would likely adopt this product.

Compelling Value Propositions for Consumers

Findings from Secondary Literature Review

Energy efficiency. Minisplit systems boast high energy efficiency ratings with distribution losses ranging from 1-5%, compared to 30% losses for central systems (Toolbase Services). More conditioned air travels to the desired area of the home, increasing energy efficiency because the unit is not running for an extended period of time.

Most DHPs use R-410A, an ozone friendly refrigerant that absorbs and releases heat more efficiently than other refrigerants that deplete the ozone (Honeywell). Previously installed ducted systems that use other types of refrigerant cannot be updated to use R-410A due to design changes needed in compressors and piping (Toolbase Services). With a national trend towards energy efficiency, DHPs offer an ozone-friendly advantage over existing ducted systems which can add to its marketing value.

DHPs have the added benefit of only heating and cooling necessary areas of the home. For instance, ducted systems often have ductwork that runs in unconditioned spaces like attics and basements which sometimes lack sufficient insulation (Roth, Westphalen, and Brodrick 2006). This layout can drive up energy consumption within the home. DHPs only heat or cool occupied spaces which makes the units more energy efficient. Some manufacturers, such as Daikin, have a function that allows the system to adjust the temperature when no one is detected in the room (Grasso 2007). This provides heating and cooling only to occupied rooms, adding to the energy efficiency of the system. SEER ratings are very high because no air has to be moved through any ductwork.

Furthermore, DHPs cool smaller rooms more efficiently than ducted systems. The cooling capacity of DHPs starts as low as 9,000 BTU while the smallest cooling capacity for ducted systems generally starts at 18,000 BTU (Wardell 2005). This type of ducted central system is inefficient for an area smaller than 1,000 square feet (Wardell 2005), but a smaller conditioned area is ideal for a minisplit system. Consumers wishing to heat or cool smaller rooms more efficiently might value DHPs over more traditional central systems.

Outdoor units with modulating condenser motors also allow DHPs to condition a room more efficiently. Instead of turning on and off to maintain the temperature set by a central thermostat like ducted systems, ductless systems with modulating condenser motors vary the speed gradually to sustain the desired temperature. Less energy is used and wear and tear on the unit is reduced (Wardell 2005).

Since ductless minisplits have high energy efficiency ratings, government organizations are beginning to offer tax credits for qualifying homeowners. For instance, Oregon offers a Residential Tax Credit for homeowners using DHPs with variable speed compressors (Oregon Department of Energy Conservation Division 2008). The credit is approximately $200-$300 and the consumer supplies the ARI certificate.

Increased comfort. The ability of minisplits to precisely control the air temperature for each unit might add to the systems' value. DHPs are extremely efficient at providing spot cooling and heating to desired rooms since each wall unit uses a separate thermostat (Contractor 2006). Zone control features on the indoor wall units allow consumers to enjoy different temperatures in all rooms with mounted units (Roth, Westphalen, and Brodrick 2006). The systems' ability to moderate varying temperatures can provide consumers personal comfort and was the most compelling feature of the system according to one consumer interviewed.

Air quality. Improved air quality is another advantage of DHPs. Some systems include anti-allergy enzyme filters that improve air quality within the conditioned space (Grasso 2007). For instance, Mitsubishi Electric uses an artificial blue enzyme catalyst on the filter filaments in order to trap harmful microbes and reduce the proliferation of harmful allergens, germs, and other bacteria (Grasso 2007). Minisplit systems also boast lower air volumes which allow for greater dehumidification (Wardlaw Fuels). Additionally, an auto-louver function on the remote distributes and sweeps conditioned air around the room increasing the quality of the air (Siegel 2001).

Noise reduction. Minisplit systems offer greater noise reduction when compared to ducted systems. DHPs are designed to be as quiet as possible and as of 2001, DHP manufacturers reported decibel (dB) levels in the low 30s (Siegel 2001), while typical ducted systems rate around 80dB and ultra-quiet ducted systems only rate 69dB (Wardell 2005). Since DHPs do not have indoor air compressors or air traveling through ceiling ducts, noise is not created by air being pushed through ductwork (Grasso 2007).

Also, DHPs use quieter indoor and outdoor fans (Roth, Westphalen, and Brodrick 2006). In residential areas where property lines are close to each other, the outdoor unit of these ductless systems may also offer a quieter solution. DHP outdoor units are less noisy than outdoor central units making them less of a disturbance to nearby neighbors (Wardlaw Fuels). Concentrated residential areas would benefit from these quieter systems.

Safety. DHPs are safer than in-window units. In minisplit systems, small holes are drilled in walls for refrigerant lines and electrical wires to pass, while in-window units require an open window that provides an easy entry point for intruders to enter the home (Ductless Depot).

Corrosion reduction. Coastal consumers may view corrosion reduction as an added benefit of minisplit systems. Friedrich offers DHPs with several features that prevent system corrosion from salty outdoor air including condenser motors oriented horizontally in order to prevent water and debris from entering the unit (Wardell 2005). The outdoor units also have plastic fan blades as opposed to typical metal blades found in ducted systems, as well as painted or powdered-coated base pans to prevent corrosion (Wardell 2005). Such product attributes would be of high value to those consumers trying to combat corrosion or living in a salty air environment.

Findings from In-Depth Interviews with Industry Experts

Energy efficiency. These ductless systems simply discharge air directly into the room which leads to better isolated efficiencies (CFM Distributors, unpublished interview). Additionally, the inverter technology found in DHPs allows the systems to reduce the amount of draw upon the electrical grid when compared to systems that are continuously turning on and off, according to a Mitsubishi Electric representative (Mitsubishi Electric, unpublished interview). Moreover, the electricity brought into the DHP system to provide heating and cooling is almost entirely used for the end purpose according to a Mitsubishi Electric representative.

Add-on capability. DHPs provide an easy way to add on to existing ducted systems. Currently, many builders are inappropriately making their ducted air conditioners larger than necessary to handle a 50-person load (Air Conditioning Contractors of America, unpublished interview). This type of load would only be most likely necessary a couple of times per year for the consumer, rendering it extremely inefficient for the remainder of the year. Adding a DHP as a secondary system for such larger events within the home would be a much more efficient option (Air Conditioning Contractors of America, unpublished interview).

Air quality. Daikin AC reported that these units are helpful in keeping dust out of the air stream in order to reduce allergy issues (Daikin AC, unpublished interview). This was seen as a compelling feature of the system.

Findings from Telephone Focus Groups of Consumers Living with DHPs

Energy efficiency. In addition to tax credits, rebate programs are also in effect because of DHP's energy efficiency capabilities. According to customers in telephone focus groups, a program was offered by the Bonneville Power Administration (BPA) in Oregon which gave qualified homeowners a $2,000 rebate towards the cost of DHP installation. According to customers participating in the program, qualifications included a designation as a large user of electricity with a low efficiency heat source. Consumers in the program who were interviewed mentioned that they are extremely satisfied with their DHPs and happy they participated in the rebate program. One consumer participating in the program commented that she wished she had known about these systems ten years ago. Many believed that offering more rebate programs and greater public dissemination of these financial incentives might promote increased DHP usage and adoption.

Utility bill savings. Consumers participating in telephone focus groups stated they saved money each month on their electric bill when compared with their bill using previous systems. One consumer participating in the BPA rebate program reported her electric bill dropped from $360 a month down to $60 a month after installing a DHP in her main living room. Other customers participating in the program who were interviewed reported a range of $60-$150 in monthly savings.

One consumer participating in the BPA DHP rebate program explained that when buying a home, the heat source is not usually a top priority for homebuyers. If consumers

upgraded their systems soon after purchase, they would very easily make a return on their investment from electric bill savings, according to this consumer. She reasoned it may cost more initially, but that money can easily be recouped in electricity bill savings over a period of time. When speaking with consumers living with DHPs, each person interviewed reported utility bill savings as a significant advantage of DHPs over other systems.

Increased comfort. Many consumers who participated in telephone focus groups who lived with DHPs agreed that these systems added quality comfort to their rooms and home. Their previous systems—like ceiling radiant heating, baseboard heating, and Cadet electric heaters—did not effectively heat the home. DHPs distribute the heat more evenly across a certain area when compared to these previous systems.

Air quality. One customer in Oregon reported that one of the top advantages of DHPs is the improvement of the indoor air quality within her home. Running a business out of her residence with different people constantly filtering in and out, this consumer appreciated her system's capability to reduce allergen levels and particles.

Noise reduction. Consumers living with DHPs who participated in telephone focus groups reported that the systems were quiet with one participant describing them as producing "background, white noise." One consumer joked that her refrigerator was louder than her DHP and believed it to be quieter than any forced air system she previously had in her home.

Safety. DHPs could be considered safer than other types of heating systems like Cadet heaters. One consumer living with a DHP system reported a fire had started in her home as a result of a child placing a box against a Cadet heater. She felt that DHPs were safer because they were out of reach of children.

Resale value of home. Two consumers living with DHPs believed that their system would add to the resale value of their home. The notion of removing an older system and replacing it with a DHP was thought to increase the technical heating and cooling capability of one's home and therefore improve the condition of the home. This enhancement would then increase the resale value according to these consumers.

Maintenance and service. Consumers living with DHPs reported few maintenance problems with their systems. Most commonly, consumers provided simple filter cleaning and washed the coils every few months, according to builders in telephone focus groups. Many consumers in these groups had not even performed this service with their system still performing effectively. Service issues that had arisen for these consumers included problems with temperature regulation, trouble setting the timer overnight, and thermostat issues.

Installation time. Consumers living with a single DHP system who participated in telephone focus groups indicated that it took less than a day for a contractor, two HVAC installers, and an electrician to install the system. One consumer living with multiple

units in his home said it took a week to install with two installers present but noted that this was the first residential DHP project for his installers. This shorter timeframe for installation might be a compelling benefit of the system when compared to lengthier installation times of ducted systems.

Reduction of greenhouse gases. When asked to respond to a statement that DHPs reduced greenhouse gases more than other HVAC systems, most consumers in the telephone focus groups agreed. However, many were unclear as to the actual meaning of the statement. One consumer in Oregon responded that greenhouse gases originated from the generation of energy and since her system used less energy, her personal greenhouse gas usage was reduced.

Findings from Focus Groups of Consumers Not Living with DHPs

Environmentally friendly. Consumers participating in in-person focus groups who were not currently using DHPs in their homes consistently indicated energy efficiency as a compelling reason to use these systems. The notion that DHPs were better for the environment because they used less energy was an extremely persuasive benefit according to these participants—they concluded that using DHPs would be environmentally responsible.

Utility bill savings. Consumers participating in in-person focus groups who did not own a DHP agreed with the DHP owners who participated in telephone focus groups. Consumers in all in-person groups consistently ranked saving money on utility bills as a top benefit of DHPs.

Increased comfort. In-person focus group participants not currently using DHPs in their homes regarded a DHP's ability to control heating and cooling in different areas or zones of the home to be a benefit of the product. This comfort customization feature, allowing homeowners to determine where and when to heat and cool a room, was highly regarded in these groups.

Air quality. Participants in in-person focus groups indicated that improved air quality and mold reduction were indeed added benefits of the system.

Noise reduction. Consumers participating in in-person focus groups also indicated quiet heating and cooling to be a valuable feature of these systems.

Safety. In-person focus group participants indicated safety was an added benefit of DHPs as well. Since DHPs are hung on walls, they would be out of reach of not only children, but also pets and would not be disturbed by furniture.

Resale value of home. Some in-person focus group participants not owning DHPs speculated that if product awareness was well entrenched among consumers, these systems would increase the resale value of the home. Another participant suggested DHPs were a way to modernize a home since windows would not be blocked by air conditioning units—a fact which might then increase the desirability of the home.

Installation. Consumers in in-person focus groups believed DHPs had advantages during the installation process as well. The idea that DHPs could be quickly and easily installed with less interruption to the homeowner was extremely attractive to participants. Additionally, some consumers in in-person focus groups thought that if installation was easier than other systems, perhaps DHPs could be installed by DIYers. If this was true, one participant mentioned this would be extremely beneficial since the homeowner would be able to install and maintain the system and would not have to call people at odd hours to service the equipment.

Livable space. Consumers participating in in-person focus groups regarded the idea that DHPs did not compromise the livable square footage of a home to be a compelling benefit of the product. Participants stressed the importance of having a HVAC system that did not impede on one's livable space like other systems might. Since DHPs could satisfy this preference, this may be a benefit to stress to potential consumers.

Barriers to Consumer Adoption

Findings from Secondary Literature Review

Aesthetics. Minisplit systems have an indoor unit that mounts to the wall of a room. Even though these units are meant to be discrete and blend with home décor (Grasso 2007) and are less obtrusive than PTAC or window units (Ductless Depot), they are not invisible like traditional ducted systems (Contractor 2006). Based upon secondary research, aesthetics are still considered a primary problem among consumers.

Refrigerant lines installed on the outside of the home can be aesthetically unpleasing as well. Varying colors and types of siding can cause difficulty when trying to hide refrigerant lines (Wardell 2005). Some contractors use white vinyl channels to encase the lines, making them less conspicuous than traditional copper piping (Wardell 2005). However, the lines are still readily apparent. With both the outdoor and indoor units potentially causing visual concerns, consumers may not opt for minisplit systems.

Cost. For an HVAC system in a new home, DHPs are typically more expensive than central ducted systems. Most systems cost about $1,500-$2,000 per ton of cooling capacity, which is 30% more than central systems and double the cost of similar capacity window units (Ductless Depot). Additionally, DHPs are still not considered typical practice in the US, so installation costs can be higher because of the limited number of qualified installers and smaller volumes of the product sold (Roth, Westphalen, and Brodrick 2006).

Minisplit systems may require the use of either a separate heating system or backup electric resistant heating in instances where ambient air drops below a certain temperature—although some participants in this project reported sufficient heating without a backup source. The requirement of an additional system can increase start-up costs and the use of backup electric heating in colder temperature increases operating costs (Roth, Westphalen, and Brodrick 2006). When retrofitting a home, the cost premium increases noticeably with a minisplit system (Roth, Westphalen, and Brodrick 2006). Existing ducted systems would only need new indoor and outdoor units while a new minisplit system would need refrigerant lines installed as well (Roth, Westphalen, and Brodrick 2006). Consumers might then choose to simply add on to existing ductwork instead of adding a new, ductless system.

Awareness of product. In the past, ductless manufacturers promoted their products exclusively to trade contractors. Therefore, consumer awareness of these products is still considerably low (Air Conditioning Contractors of America, unpublished interview). Manufacturers have begun to market these systems to consumers in an attempt to make the product demand consumer-driven instead of contractor-driven (Thermal Supply, unpublished interview).

Room type and size. Ductless systems are not designed for every room in a residence. Rooms that need consistently low temperatures like wine cellars are not ideal for DHP

usage (Wardlaw Fuels). Additionally, Samsung cautions that DHPs should be placed in computer rooms only with the addition of a low ambient kit (Wardlaw Fuels). These exceptions could prevent consumers from choosing this type of ductless system for either their entire home or rooms within their home.

Samsung also stresses the importance of choosing the correct capacity DHP for the desired space. Short cycling due to air recirculation can occur when a large capacity unit is placed in a small room and can lead to system reliability problems (Wardlaw Fuels). Consumers must be sure that they are choosing an appropriate system for the size of the room. If reliability problems arise due to issues in sizing, DHP's reputation might be diminished.

Findings from In-Depth Interviews with Industry Experts

Aesthetics. If price were equivalent, aesthetics would probably be the biggest disadvantage of DHPs to consumers according to CFM Distributors (CFM Distributors, unpublished interview). Many consumers spend a large amount of time and money on their homes and do not want such a large unit on their wall (CFM Distributors, unpublished interview).

In an attempt to approve the aesthetics, manufacturers have begun making the indoor units much smaller. Currently, these units are approximately half the size of what they were five years ago, which eases the impact to the consumer (Fujitsu, unpublished interview). Regardless, minisplit systems are substantially more visible than their ducted counterparts—a fact which might be a significant barrier to widespread U.S. DHP adoption.

It is necessary to note that many DHP consumers are extremely satisfied with the aesthetics of the system according to some industry experts. A Mitsubishi Electric representative noticed that minisplit customers often complained at the sight of their system at first, but gradually grew accustomed to the look within a month of installation (Mitsubishi Electric, unpublished interview). A Home Energy Sciences representative emphatically agreed that consumers did not mind the look of their minisplit systems (Home Energy Sciences, unpublished interview).

Low temperature heating. Homeowners living in colder areas may choose not to implement DHP technology. A representative from Carrier stated that DHP systems will most likely be unable to compete with ducted systems because the U.S. is a gas heat market (Carrier, unpublished interview). Currently, ductless systems are not nearly as efficient as gas in cold weather because minisplits have rarely been engineered worldwide for low temperature heating (below 24 degrees Fahrenheit) (Carrier, unpublished interview). In temperatures below 24 degrees Fahrenheit, a supplemental heat source is needed to effectively heat the space.

Findings from Telephone Focus Groups of Consumers Living with DHPs

Cost. Consumers who participated in telephone groups speculated that systems typically cost anywhere from $2000-$4000. One consumer participating in a BPA rebate program mentioned that she might have reconsidered purchasing the system or might have saved more money to purchase the system if the rebate had not been offered. One consumer in a telephone focus group hypothesized that if systems eventually became more popular and were installed more frequently, the cost of these systems might decrease due to manufacturer competition. Otherwise, consumers may choose traditional ducted systems based on installation costs alone.

Awareness of product. Consumers living with DHPs who were interviewed agreed that these systems are not in widespread use. Most of these consumers were first introduced to the systems when they were picked to participate in a rebate program offered by their electric company. Others first heard about DHPs from friends in the residential heating and cooling business.

Consumers owning DHPs who participated in telephone focus groups mentioned that when new visitors first see their units, many do not know what the product is. After seeing and experiencing the capabilities of DHPs, their visitors often inquire about purchasing and installing a system of their own. Consumers living with DHPs who were interviewed also mentioned that the public needs to be better educated about these systems. They argued that if more consumers knew about DHPs in general, they would ask contractors to install them in their homes or remodeling projects. One consumer in a telephone focus group mentioned builders should be made more aware of these systems since they are often the people that decide which heat source to install in homes.

Another participant in BPA DHP rebate program suggested these systems should be available at local big-boxes and home and garden shows in order to guarantee maximum public exposure. These consumers believed monetary savings, convenience and comfort of the system, as well as the environmental benefits should be stressed to the public.

Lifestyle. Another type of lifestyle change may be necessary when using the remote control. One consumer in a telephone focus group mentioned that it was difficult at first to use a remote control for a heating and air conditioning system. She reported the remote must be pointed directly at the register in order to adjust the temperature. She believed this sensitivity to be a disadvantage of the system.

Aesthetics. Though a thorough review of existing literature detailed negative perceptions regarding aesthetics of DHPs, many consumers who participated in telephone focus groups living with DHPs did not agree. Many mentioned that they noticed the system at first but grew accustomed to the indoor aesthetics within a month, while another consumer believed it to be more aesthetically pleasing than her previous air conditioning unit. An Oregon consumer mentioned that when other people entered the room, their first comment referred to the warmth of the room, not to the appearance of the unit. However, other consumers in these telephone focus groups reported that visitors to their home often commented negatively on the outward appearance of their DHP system.

Findings from Focus Groups of Consumers Not Living with DHPs

Resale value of home. It is important to note that some participants in in-person focus groups questioned the prospect of DHPs adding to the resale value of the home. One consumer was uncertain every homeowner could keep up with the new technology of the system and believed there was risk associated with using a technology that was not widespread. Another participant flatly stated that a home with DHPs would never have the same value as a home with a forced air system.

Since these consumers viewed DHPs as more expensive than other systems because of initial costs, they regarded DHPs as an investment. When viewed in this manner, these consumers indicated that the investment might not be recouped since homeowners are often transient. One consumer wondered if a homeowner could break even after 3-5 years of purchasing DHPs. Other consumers in an in-person focus group mentioned that if they were to invest as much as $10,000 on their home, they would not put that money towards a DHP system. They reasoned there were better options on which to spend their money like kitchen or bathroom renovations. If this opinion is widespread, it may prove a barrier to widespread DHP adoption.

Aesthetics. Consumers participating in in-person focus groups, who had never seen DHPs before, consistently disliked the concept of a visible indoor unit hanging on the wall inside the home. They indicated the indoor unit seemed large and would rather it be invisible. They thought it would not fit in with the décor of most rooms. However, it was noted during in-person consumer focus groups that the outside unit blends well into the landscape and some appreciated the small size of the outdoor units.

Supplemental heating. Consumers in in-person focus groups disliked the idea of needing a supplemental heating system when using DHPs. They believed this would be a large barrier to widespread adoption of these systems and were confused as to why exactly an additional system would be necessary in bathrooms and bedrooms.

Awareness of product. Consumers in in-person focus groups also indicated a lack of awareness among the general public regarding DHPs and suggested HVAC contractors, realtors, and other stakeholders need to be better educated about the product.

Fuel preference. Some consumers in in-person focus groups believed that most homeowners have a preference for gas heating and not electric. One consumer believed gas to be more prestigious than electric heating especially when thinking about gas stoves. Consumer preference for gas may hinder adoption rates for DHPs.

System operation. Consumers participating in in-person focus groups who did not own DHPs were confused as to how the system operated. Many questions arose regarding how the system worked in general and more specifically, how it actually heats, cools, filters, and moves air throughout the entire house. Other questions centered on placement of the unit. Many participants were confused when they saw a picture of an indoor DHP unit placed high on a wall above a television. Many wondered if the unit had to be placed high on a wall, and if so, questioned how this could efficiently and effectively heat a

room if warm air rises. Also, participants speculated that every room in the house might not have an ideal DHP location and questioned the possibility of changing the location of DHPs post- installation.

Participants in these groups were also confused as to how the piping was run through walls, what coolant was used, and how the system was cleaned. Others questioned DHPs track records regarding maintenance. They wanted to know how long the product would last, the average period of warranty, and what maintenance schedules to expect.

Terminology. In-person consumer focus group participants were confused by terms related to DHP technology. The term "minisplit" was confusing for a few participants as was the term "energy efficient." For example, when given a list of DHP benefits, participants questioned which systems DHPs were compared with in order for DHPs to warrant the distinction as "more energy efficient."

Trusted Sources of Information for Consumers

Consumers in telephone focus groups. Consumers living with DHPs who participated in telephone focus groups reported trusting a variety of sources when learning about DHPs. Consumers overwhelming agreed that they trusted their HVAC contractors and those involved in rebate programs trusted their DHP consultant. One consumer mentioned she went to the Department of Energy's website to learn about DHPs and also read the DHP brochure three times. Another consumer reported *Consumer Reports* as a trusted source of information for this product. DHP manufacturer's websites were also trusted.

Consumers in in-person focus groups. Consumers participating in in-person focus groups also trusted *Consumer Reports*, HVAC contractors, and manufacturers such as Mitsubishi Electric, Lennox, Trane, and Carrier. Utility companies, builders, electricians, Better Business Bureau, and current DHP users were also viewed as trustworthy sources. Google was a trusted search engine while Wikipedia and websites focusing on green building and energy efficiency were also trusted. Information found in *Builder Magazine*, home shows, segments heard on the radio, specifically National Public Radio, were also trusted.

Compelling Value Propositions for Builders

Findings from Telephone Focus Groups of Builders Using DHPs

Green building programs. One builder in a telephone focus group reported building a model luxury home with 14 DHP units as a way of gaining LEED program certification for indoor air quality and energy efficiency. This builder speculated that DHPs will play a pivotal role in the future of green building. He hypothesized that DHPs would help residential developments become self-providing, net-zero communities because of the energy efficiency of the systems. If builders increased participation in green building programs, perhaps DHPs will gain more popularity. Another builder in a telephone focus group reported he was an Energy Star builder and implemented these systems for indoor air quality and energy efficiency purposes as well. Certification in various green building programs might compel other builders to use DHPs.

Differentiation. Builders in telephone focus groups reported that offering residential DHPs in homes allowed their companies to stand-out from competition. DHPs, like other new technology, can differentiate one builder from another. One builder mentioned that he offered DHPs as an option to give customers design flexibility while another builder in a telephone focus group mentioned that he did not market DHPs specifically to customers but instead marketed them as a piece of the Energy Star package. Potential homebuyers were then specifically educated about the product by a sales agent further along in the buying process. The LEED builder interviewed used DHPs as a marketing tool in his model home. He reported that he hoped to have tours of the model home to teach members of the building community like architects, engineers, and realtors about DHPs with the hope the information would be passed along to consumers.

Customer satisfaction. Many builders who participated in telephone focus groups liked the ability to offer a quiet product that added even heating and cooling comfort to a person's home. DHPs allowed customers to have a more efficient heating and cooling system with zone control and also cut down on their electric bill each month. Many builders in telephone focus groups who built and/or remodeled homes with DHPs mentioned that by satisfying their customers and providing these DHP benefits, they get more business through customer referrals. Builders in telephone focus groups did not report any delays associated with DHP installation which contributed to the satisfaction of their consumers.

Supplemental heating. A few builders who participated in telephone focus groups reported that supplemental heating was not an issue as with other heat pumps because the efficiency of the systems did not drop off until around 17-15 degrees. One builder continued saying that backup, Cadet heating could be used on days or nights where the temperature would dip below that temperature. He stressed that this does not affect, in his mind, the overall benefits of the system. Another builder disagreed with the need for a backup system in colder temperatures. He reasoned that if the home's building envelope boasted less than one air exchange per 24 hour period through passive air, once the

envelope was heated to the desired temperature, passive air heat loss would not be an issue. If it did become an issue, he considered propane fireplaces located throughout the house to be sufficient to heat the home.

Cost. A few builders interviewed in telephone focus groups believed that installation costs were similar to those of traditional systems. One builder reasoned that higher installation costs were a result of inexperienced HVAC installers who were less educated about DHP systems.

Space constraints. Builders who participated in telephone focus groups also mentioned these systems were beneficial for areas with space constraints like condos. This was seen as a compelling reason to use these systems.

Findings from Focus Groups of Builders Not Using DHPs

Installation. Many builders participating in in-person focus groups believed the quick installation of DHPs to be a top reason to use these systems in residential construction. These builders believed that using DHPs would make scheduling other subcontractors easier and would allow for less time in the field. A one-day installation was viewed as much more desirable than installation that took a week.

Customer satisfaction. Builders participating in in-person focus groups agreed with builders in telephone focus groups and indicated that satisfying their customers was a compelling reason to use DHPs.

Builder characteristics. Builders in in-person focus groups believed builders constructing or remodeling smaller attached apartments, condominiums, and smaller homes would most likely adopt this product. One builder indicated that their customers do not choose what type of HVAC system is installed. Instead, this builder makes the decision for customers. Targeting these types of builders may be beneficial towards greater residential DHP adoption.

Barriers to Builder Adoption

Findings from Telephone Focus Groups of Builders Using DHPs

New technology. Builders in telephone focus groups commented that new technology is often difficult to introduce to those in the homebuilding industry because stakeholders are often fearful of change. Oftentimes, builders rely on dependable and proven techniques in residential homebuilding. Though DHPs have been around for over two decades, some builders interviewed believed that ducted systems were more reliable and proven from both a builder and consumer standpoint.

A builder who participated in a telephone focus group mentioned that it might be risky to introduce this product to consumers, thereby straying from something proven like a traditional system and aligning oneself with a questionable product. Another builder who participated in a telephone focus group speculated that even HVAC installers were wary of trying this new product because it deviates from the norm. These builders argued that because DHPs were a new product with new technology, widespread adoption might be hindered.

Finding a DHP installer. Builders interviewed in telephone focus groups reported difficulty finding installers who were willing to stand by their DHP product. When looking for a DHP installer, these builders often first approached their standard HVAC installer and inquired about the product. One builder in the group mentioned that his HVAC installer who uses DHPs and traditional systems often tries to talk him out of putting DHPs in homes because the installer doesn't believe they are as reliable.

Aesthetics. Builders in one telephone focus group believed appearance to be a disadvantage of these systems. Outside condensate lines are hard to hide according to these builders which made the outside of the house less appealing. Some builders interviewed also believed there is an economic stigma attached to these units whereas they would be more accepted in a condo than in a custom home. Ducted systems can be hidden and are more accepted by consumers according to these builders.

Product awareness. Some builders in telephone focus groups believed that there was a lack of DHP awareness. One builder in a telephone focus groups believed that architects, mechanical engineers, and design professionals should be the focus of marketing. He stressed a paradigm change was necessary because designers are so accustomed to designing homes with central systems. Other builders suggested manufacturers also need to target more HVAC installers. They also mentioned that consumer awareness regarding DHPs was low and would offer more DHPs if requested by customers.

Noise. Though some consumers living with DHPs who participated in telephone focus groups and information found in the secondary literature phase of this project suggested that DHPs offer noise reduction, it is important to note that some builders interviewed during telephone focus groups disagreed and believed that consumers

sometimes mentioned their DHP was louder than their previous systems because the DHP was located on a wall inside the room and not hidden. This might prevent builders from implementing DHP technology.

Heating during construction. One builder in the telephone focus group mentioned the need to provide an outside heat source during construction. When he builds condo units during the winter, the units need to be heated in order for the drywall to dry properly. When he uses forced air systems, they are functioning during this timeframe. When he uses DHPs in condo units, he incurs an added expense because he needs a heat trailer to run heat to each condo unit to help with the drying.

Humidity. One builder interviewed in a telephone focus group mentioned a problem with humidity. For instance, in humid climates like Florida and Texas, he noticed a problem with some DHPs causing humidity build-up in the room and leaving the room damp and sticky. This builder hypothesized that build-up may occur because the system may not have been designed correctly or because installers were not aware of the set point. Though dehumidification was previously stated as a selling point of the system for consumers in coastal areas, such discrepancy may deter builders from implementing DHP technology in humid climates.

Findings from Focus Groups of Builders Not Using DHPs

Aesthetics. Builders participating in in-person focus groups who did not build or remodel homes with DHPs also disliked the aesthetics of the indoor unit. They regarded the indoor units as unattractive after seeing a picture of the units hung on the wall and believed them to be bigger than air vents typically seen with traditional systems.

New technology. Some builders in in-person focus groups indicated that traditional systems work very well and require few callbacks. These builders did not see a reason to switch to a different system that incorporated fairly new technology.

Product awareness. Builders in in-person focus groups agreed that more education on the part of residential builders, architects, and decision-making customers is necessary in order to successfully bring this product to market. By introducing the product to these players within the homebuilding industry, product adoption may become more widespread. Increasing media coverage of this product would also increase public awareness according to this builder.

Colder climates. Additionally, some builders who participated in in-person focus groups indicated that heat pumps were more efficient in moderate climates while gas was more efficient in colder temperatures, lending credibility to the notion that homeowners living in milder climates might be more likely to adopt DHPs.

Humidity. One builder who participated in an in-person focus group mentioned that humidity is necessary in certain circumstances within a home. For example, some hardwood floors and furniture require humidification. If DHPs boast lower

dehumidification levels, builders may choose not to use these systems in homes that require certain levels of constant humidity.

Fuel choice. Some builders in in-person focus groups indicated that customers prefer gas to electric heating. Builders in these groups indicated that almost all homebuyers expect gas and very few actually request electric. Natural gas is cheaper and associated with luxury according to these builders. A few builders in these groups mentioned that when customers do request electric, they do so with the intention to implement solar technology. Customer preference for gas may hinder builder adoption of these ductless systems.

System operation. Like consumers, builders participating in in-person focus groups had questions regarding how DHPs worked. Specifically, these builders questioned how air was distributed, where the condensation traveled, and whether DHPs were self-contained units. Some builders in these groups questioned and even doubted the dissolution of hot and cold spots during the system's operation. When reacting to the DHP concept description during in-person focus groups, builders simply wanted more information and data regarding the product.

Learning About DHPs

Trusted Sources of Information

Builders in telephone focus groups. Builders in telephone focus groups reported trusting a variety of sources when learning about DHPs. Many trusted their HVAC professional installing the product. Others mentioned trusting their supplier, the National Association of Home Builders (NAHB), manufacturer's websites, buildingscience.com, and trade magazines such as the *Journal of Light Construction.* Builders in these groups mentioned they spent time researching the product before introducing it in homes.

Builders in in-person focus groups. Builders in in-person focus groups also trusted manufacturers as well trade magazines such as *Builder Insight, Builder Magazine, Green Builder, Custom Builder*, and *Spokane Home Builder*.

Learning Process

Builders in telephone focus groups. Builders with DHP experience reported an easy learning process when first gathering information about DHPs. Many said it was a simple technology to learn and most gained information from their installer. One builder in a telephone focus group reported a slight learning curve because of the newness of the technology (e.g. the remote, learning how to adjust the system, etc.). They were motivated to learn about the product because of its ties to green building programs, dual heating and cooling features, and in some instances, they simply needed such a product to fit a specific application.

Builders in in-person focus groups. If they wanted to learn more about DHPs, builders in in-person focus groups who had never used DHPs indicated they would go to their HVAC contractor. If their contractor did not recommend the system, these builders would choose not to use DHPs in the homes they build and remodel. These builders also said they would go to governmental and energy rating websites and if they were truly interested in using them, they would go to various manufacturer's websites.

Compelling Value Propositions for HVAC Contractors

Findings from Secondary Literature Review

Installation. DHPs are ideal for residences that have limited installation space (Grasso 2007). Central systems require extensive ductwork throughout the home, while minisplit systems require only wire and piping to be run between the outdoor and indoor units (Grasso 2007). DHPs are relatively easy to install for those sufficiently trained (Toolbase Services), and installed systems seldom need callbacks (Smith 2007). Installation time typically ranges from 3-4 hours with two installers (Siegel 2001).

Another added benefit of DHPs involves the fact that an electrician must only visit once to install the outside electrical box since the system uses low voltage connections between the indoor and outdoor units (Skaer 2005). HVAC contractors can also complete the installation since fuse disconnects and conduits are rarely used (Skaer 2005).

System maintenance. Minisplits require simple maintenance tasks including a filter and condenser coil cleaning every three months in order to prevent system problems (Smith 2007). This task can easily be conducted by consumers without needing to call upon HVAC contractors; another added benefit of these ductless systems.

In order to better understand problems if they do arise, technologically advanced DHP systems are often equipped with self-diagnostic functions. Sensors embedded within the system are constantly monitoring humidity and temperature changes and sending information to the logic module. If problems with the system occur, the logic module displays a fault code that consumers can use to try to resolve the problem. If service does need to be called, technicians with diagnostic equipment can use the fault code to evaluate the problem more effectively (Contractor 2006). These self-diagnostic functions could be a selling point to contractors since they offer technicians an immediate understanding of the problem at hand.

Findings from In-depth Interviews with Industry Experts

Installation education. Manufacturers often offer training programs for contractors installing their DHP systems. Mitsubishi Electric's Diamond Dealer program offers accreditation to contractors who complete their certification course (Mitsubishi Electric, unpublished interview). Offered in multiple locations across the United States over a two-day period, this course introduces installers to the residential and light commercial Mr. Slim series, features of the systems, and installation and troubleshooting procedures (Mitsubishi Electric, unpublished interview). Mitsubishi Electric says this program provides contractors superior knowledge regarding minisplit systems and dramatically reduces installer callbacks (Mitsubishi Electric, unpublished interview). Mitsubishi also offers continuing education courses. Many HVAC installers who participated in telephone focus groups had participated in Mitsubishi Electric's training classes and were satisfied with the programs.

According to a Fujitsu representative, Fujitsu also offers 52 national training classes with an average of 60-100 attendees at each session (Fujitsu, unpublished interview). At the completion of the training, these installers can be considered qualified to install the manufacturer's product.

System Maintenance. DHPs are considered one of the most sophisticated types of HVAC systems in the world and are simple to troubleshoot, maintain, and install according to Home Energy Sciences (Home Energy Sciences, unpublished interview).

Option. Most contractors would view DHPs as a relatively new option within the HVAC industry according to the ACCA (Air Conditioning Contractors of America, unpublished interview). Contractors cannot survive on just one method or system, so many would welcome another method to sell to their clients. Contractors in telephone focus groups agreed and indicated that having an extra option was beneficial when you cannot put in ductwork. Therefore the ACCA believes that contractors would provide no real barrier to DHP adoption (Air Conditioning Contractors of America, unpublished interview).

Findings from Telephone Focus Groups of Contractors Using DHPs

Installation. HVAC installers interviewed in telephone focus groups mentioned a shorter installation timeframe when implementing DHP technology when compared to the time it takes to install a ducted system. A few installers also indicated that limited tools were needed for proper DHP installation. Necessary tools include HVAC tubing cutters, set of binders, crescent wrench, allen wrench, set of gauges, vacuum pump, and microngauge. HVAC installers in telephone focus groups reported a basic, 2-ton minisplit residential unit with electrical ranges from $3500-4500.

System maintenance. Though outdoor coil cleaning is needed occasionally, HVAC contractors who currently install DHPs and who participated in telephone focus groups reported rarely having serious problems with DHPs and on the uncommon occasion they do, there is a fundamental problem with that individual system. One contractor described the system as "either working or not." One builder in a telephone focus group who had used about 50 residential DHPs only had one system with a problem. When maintenance and service is needed, it is often a part of a maintenance and service agreement according to installers interviewed.

Application. HVAC contractors who install DHPs who participated in telephone focus groups believed that DHP systems help alleviate or solve a problem, and many reported that they first learned about DHPs because a situation arose where they needed a different type of system. These systems can be employed in areas where traditional ducted systems cannot go—a fact which could be considered a huge selling point when installers are faced with such a problem.

A minisplit's outdoor unit can also help alleviate problems. In the City of Seattle and in Portland, outdoor units must be at least 5 feet away from the property line. Two HVAC

installers in telephone focus groups mentioned that Mitsubishi Electric's ductless system can easily be applied to meet this criterion which is another advantage of the system.

Differentiation. HVAC contractors who currently offer residential DHPs who took part in telephone focus groups believed they were in the minority. That is, they believed most HVAC contractors do not know about this technology. Like builders, this offering allows their companies to differentiate themselves from others while offering a product that meets a certain need. This also allowed installers to satisfy their customers which was imperative since, according to one participant, 50-70% of his DHP business was based upon customer referrals.

Green building programs. Similar to builders, HVAC installers in telephone focus groups also mentioned LEED's residential green building program as motivation to use DHPs. One installer in Idaho reported gaining extra points towards certification for using DHPs in homes. This was considered an advantage of DHPs according to this installer.

Contractor characteristics. A typical DHP installer, according to one installer who participated in a telephone focus group, would be an employee of a company that was interested in satisfying the needs of the customer and who had time for training. He hypothesized that a DHP installer would not be an employee of a "mom and pop" business who primarily answered service calls.

Findings from Focus Groups of Contractors Not Using DHPs

Installation. Contractors in in-person focus groups who had never installed DHPs reported that an easy installation that was not labor intensive would be an extremely attractive benefit of the system.

System maintenance. Some HVAC contractors in in-person focus groups who were unfamiliar with DHPs also believed system maintenance was a compelling reason to use these systems. However these contractors predicted that if maintenance were required on DHP systems, costs would be the same as traditional systems, or higher because DHPs sometimes require multiple air handlers throughout the house and thus generate greater revenue.

Application. Contractors in in-person focus groups liked having another option for HVAC. This was perceived to be an attractive benefit of the system because this technology would make it possible to positively respond to the heating and cooling needs of customers where ductwork was impossible.

Rebate. Contractors in in-person focus groups liked the idea of a rebate for using DHPs. One contractor mentioned that an EnergyStar rebate would be a compelling reason to use these systems.

Barriers to Contractor Adoption

Findings from Secondary Literature Review

Installation. Installation of DHPs differs from ducted system installation and, consequently, DHP installers require specialized training. DHP installers must properly size each indoor unit and install each in an ideal location. Various issues can arise if ductless systems are improperly installed, including problems with temperature and humidity control and wasted energy due to incorrectly positioned air handlers that short-cycle (Ductless Depot). Qualified DHP installers are not nearly as prevalent as those trained to install ducted systems (Roth, Westphalen, and Brodrick 2006). Additionally, HVAC contractors are more comfortable working with ducts than refrigerant lines and will shy away from ductless systems (Heating, Air Conditioning and Refrigeration Distributors International, unpublished interview). The average HVAC contractor knows about ductless systems, but less than half of contractors have actually installed them (Air Conditioning Contractors of America, unpublished interview). Many contractors view DHPs as a last-resort option (Contractor 2006). Instead of installing DHPs based on their virtues, contractors will only install ductless systems if there are space limitations within the house or if there severe problems with the ductwork (Siegel 2001).

Cost. Higher DHP costs are also a factor. Often, residential contractors see minisplits as an added expense they are unwilling to pass onto their customers (Siegel 2001).

Refrigerant leakage. Another downside to ductless systems is the possibility of refrigerant leakage. In ductless systems, refrigerant is piped from an outdoor unit through small insulated refrigerant lines directly to each wall unit. These long, extended refrigerant lines increase the potential for refrigerant leaks which can lead to refrigerant volume loss and problems with the system's effectiveness (Roth, Westphalen, and Brodrick 2006). If contractors see this as a frequent problem in previously installed minisplit systems, they may choose not to install these ductless systems in other residences.

Findings from In-Depth Interviews with Industry Experts

Number of components. Ductless systems require multiple units to heat or cool an entire home, a fact that creates the potential for numerous refrigerant leaks or drain overflows. In contrast, ducted systems with one A-coil in the basement have only one potential leakage area. The decentralized nature of ductless systems creates the opportunity for multiple units needing servicing, as opposed to just one central unit (Air Conditioning Contractors of America, unpublished interview).

Findings from Telephone Focus Groups of Contractors Using DHPs

Awareness. Current HVAC installers offering residential DHP installation believed that other installers, in general, were not familiar with the product. Some believed that other installers are not aware of it because they are scared of technology or did not want to spend money on training. Though many current installers interviewed reported enjoying the ability to differentiate themselves by offering the product, they

believed manufacturers should advertise by emphasizing energy efficiency and offer more training classes to HVAC installers.

Another HVAC contractor in a telephone focus group believed that oftentimes other installers were aware of DHPs but install them infrequently. This could cause problems with installers unable to gain proficiency in DHP installation. Better technical support should be available to those who install these systems infrequently according to this installer.

Application specific. Though residential DHP application can be considered an advantage or selling point in that they can be installed to solve a problem, the same reasoning can be used as a disadvantage of the system. Many HVAC installers in the telephone focus groups believed DHPs to be solely application specific. These installers first learned of DHPs during specific applications where traditional systems could not be used. Many commented these systems were appropriate in retrofits, add-ons, and historic applications but few had used them in new construction.

One installer in a telephone focus group believed this was a custom-type product only installed when the end-user was involved since the homeowner would be the person using the system and seeing the viability of it. He reported that production builders would not put these systems in their spec homes because it would not be cost-effective and because builders think the systems look cheap. However, this installer said he has returned to these homes once the owner has moved in and installed DHPs.

Aesthetics. HVAC installers who participated in telephone focus groups also reported aesthetics to be a disadvantage of DHPs. They mentioned customer resistance when first viewing the indoor wall unit with resistance fading away with time. Installers in the telephone groups also mentioned the unsightly aesthetics on the outside of the home, adding that it was difficult to conceal the condensate lines. One installer interviewed mentioned he tried to hide the lines in order to better satisfy his customers. However, these techniques can often add time and cost to the job.

Condensate pump. HVAC contractors who install DHPs and participated in telephone focus groups reported issues with condensate pumps when these systems are installed on inside walls. In traditional ducted systems, condensate pumps are located in the air handler away from the conditioned space. In DHPs, the condensate pump is also located in the air handler but inside the conditioned space and are therefore noisier than traditional systems. One HVAC installer who participated in a telephone focus group also mentioned that condensate pumps were often more challenging to install especially if the installer was inexperienced. Operating manuals for these condensate pumps are often written in non-English languages according to one installer, adding to the problem.

Supplemental heating. One contractor who installed DHPs reported that he did not sell DHPs as an energy-savings system because it cannot operate in all temperatures. This contractor indicated that at 19 degrees or below, baseboard heat was still necessary.

Findings from Focus Groups of Contractors Not Using DHPs

Installation. Some HVAC contractors who participated in in-person focus groups who had never installed a DHP system doubted the claims of easy installation. Some believed that quick and easy installation would only occur if one was installing them on outside walls. Another HVAC contractor doubted the system took a half-day to install. Instead, this contractor speculated installation would actually take two installers per day and per zone plus the cost of an electrician if high voltage wiring was necessary between indoor and outdoor units. Another HVAC contractor also questioned DHP's advertised easy installation and believed that contractors must be certain of proper DHP installation before even attempting installation. Regardless, these participants speculated that DHP installers would need practice in order to gain confidence to install such systems.

Awareness. Contractors in in-person focus groups also believed that more product awareness was necessary. These contractors also wanted free training including how DHPs are built and reasons for using the systems. They requested to speak directly with engineers to completely understand the functionality of the system in order to fully exploit the benefits. Contractors who participated in in-person focus groups suggested that manufacturers and distributors educate inspectors, architects, and designers as well as custom builders. Another contractor indicated that once other HVAC installers were aware of the product, they could push the product to builders.

Application specific. HVAC contractors participating in in-person focus groups believed retrofits to be the ideal application for these systems as well as historic homes, nursing homes, townhomes, home offices, computer rooms and bonus rooms.

Aesthetics. HVAC contractors who participated in in-person focus groups and who were unfamiliar with these systems reported the systems to be obtrusive and too large upon first glance. They also mentioned that consumers do not like "junk" going up the side of their homes. With possible unattractive visual characteristic of the system's appearance, HVAC installers may be less likely to offer these systems to customers or builders.

Supplemental heating. Many HVAC contractors who participated in in-person focus groups disliked the notion that supplementary heating was necessary in cold temperatures.

Cost. Some contractors in in-person focus groups doubted these systems were inexpensive in residential settings. They hypothesized that the cost of several consoles would be more expensive than the cost of traditional ductwork. Additionally, some of these contractors reported extra costs would be incurred due to redeveloping and redesigning homes with these systems.

Components. Some HVAC contractors in in-person focus groups worried that with so many indoor units comprised of blowers and coils, the system would be extremely fragile. The frailty of components coupled with potential system fragility may deter some contractors from installing the system.

System operation. Contractors who participated in in-person focus groups doubted some elements of the system's operation. For example, they still believed DHPs would produce uneven heating and cooling and doubted claims that the system used 75% less energy to produce the same heating and cooling results as baseboard heating and window unit air conditioners.

Trusted Sources of Information

Contractors using DHPs. Current HVAC installers offering DHPs who participated in telephone focus groups trusted their distributors and manufacturers of the product. The internet was also mentioned as a source of information. One installer mentioned he would type in "ductless heat pump" into a search engine in order to learn more about them. They expressed a wish for more continuing education classes and in-house training sessions with manufactures in order to learn about new products and technology within the DHP product category.

Contractors not using DHPs. HVAC contractors who do not currently install DHPs who participated in in-person focus groups also trusted a variety of sources including distributors, brand name suppliers, and utility commissions. Some of these contractors also trusted the Energy Trust of Oregon and believed that this organization inspired consumer confidence because it offered independent third party credibility.

Importance of brand

Brand was important according to HVAC installers in telephone focus groups. Many were willing to pay more money for a better system. One installer in a telephone group who had used multiple DHP brands, commented that certain manufacturers have parts that are harder to obtain while others had warranty issues. He reported that one must be selective when choosing a brand because of these problems. Participants in telephone focus groups were mixed as to whom chooses the brand of minisplit system. Some telephone focus group participants believed that customers often found installers on a manufacturer's website and therefore knew they wanted a certain brand. Others reported the decision regarding brand was made by the installer.

Compelling Value/Selling Propositions and Potential Barriers for Distributors

Findings from In-Depth Interviews with Industry Experts

Price. DHPs can be considered a more profitable product for distributors than unitary systems because of the price premium associated with them. Ductless systems provide more gross profit for distributors according to HARDI (Heating, Air Conditioning and Refrigeration Distributors International, unpublished interview).

Materials handling. HARDI notes that the handling of ductless systems is much easier for distributors when compared to traditional units (Heating, Air Conditioning and Refrigeration Distributors International, unpublished interview). Distributors are often concerned with limited warehouse space and delivery of large products like central, ducted systems. Smaller, compact DHPs may have material handling advantages for both distributors as well as installers (Heating, Air Conditioning and Refrigeration Distributors International, unpublished interview).

Current housing practices. In the U.S., most homes are typically built with central air conditioning. Ducted systems are part of the basic product offering and the home's HVAC system usually doesn't enter into consideration when consumers decide upon new home features (Trane, unpublished interview). Houses are typically built with a central air conditioner and one outdoor unit. According to Trane, this may change as VRF technology, which allows for multiple indoor units on a singular outdoor unit, increases in popularity.

Location. Certain geographic areas are more suitable for DHPs according to HARDI (Heating, Air Conditioning and Refrigeration Distributors International, unpublished interview). The Pacific coast, which is subject to an intense energy efficiency effort, would be a primary example of where distributors should sell DHPs. In areas such as the Midwest and parts of the South, where homes are more spread out, DHP distribution may be less widespread (Heating, Air Conditioning and Refrigeration Distributors International, unpublished interview).

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Appendix A: Examples of topics addressed during qualitative phase.

Expert and trade ally in-depth interviews.

Examples of topics addressed during expert or trade ally interviews:

1. Success of overseas DHP markets
2. Challenges the U.S. DHP industry faces
3. Advantages and disadvantages of DHPs over other HVAC systems
4. DHP consumer characteristics
5. Primary manufacturers of DHPs and those not manufacturing DHPs
6. U.S. DHP trends
7. Primary distribution methods and channels used for DHPs
8. Barriers and challenges with selling DHPs directly to consumers

DHP distributor in-depth interviews.

Examples of topics addressed during distributor interviews included:

1. Length of time in DHP distribution
2. Benefits of a ductless system compared to traditional systems
3. Total DHP market size
4. DHP brands distributed
5. Price ranges of systems
6. Barriers to selling DHPs directly to customers
7. DHP consumer and builder characteristics
8. Compelling DHP benefits for customers
9. DHP sales trends
10. Challenges in bringing DHPs into the mainstream market

Active U.S. DHP manufacturer in-depth interviews.

Examples of topics addressed during active manufacturer interviews included:

1. Current products offered
2. Price ranges of systems
3. DHP sales
4. Primary manufacturers of DHPs and those not manufacturing DHPs
5. Distribution channels
6. DHP consumer characteristics
7. Challenges faced by the DHP industry in the U.S.
8. New DHP products

Third party DHP manufacturer in-depth interviews.

Examples of topics addressed during third party manufacturer interviews included:

1. Current products offered
2. Price ranges of systems

3. DHP sales
4. Distribution channels
5. Advantages and disadvantages of DHPs over other HVAC systems
6. Compelling DHP benefits for customers
7. DHP consumer and builder characteristics
8. Success of overseas DHP markets
9. Challenges in bringing DHPs into the mainstream market
10. New DHP products

Telephone Dyads/Triads or Telephone Focus Groups of DHP Users

Builder telephone dyads/triads.

Examples of topics covered in builder telephone focus groups included:

1. Current HVAC systems used
2. Advantages and disadvantages of DHPs when compared to traditional systems
3. Barriers to widespread DHP adoption
4. DHP awareness
5. Motivations to use DHPs
6. Learning about DHPs
7. Trusted sources of information
8. Applications best suited for DHPs
9. Cost
10. Compelling customer features of DHPs

HVAC contractor telephone dyads/triads.

Examples of topics included in the moderator guide included:

1. Current HVAC systems installed
2. Experiences with DHPs
3. Advantages and disadvantages of DHPs
4. Barriers to widespread DHP adoption
5. DHP awareness
6. DHP usage
7. Learning about DHPs and DHP installation
8. Trusted sources of information
9. Importance of brand
10. Applications best suited for DHPs

Appendix B: Concept Description for Consumer In-Person Focus Groups.

Ductless Heat Pump (DHP)

How it works:
A DHP is a heating and cooling system that does not require duct work in a home. The DHP consists of two components – An outdoor unit and an indoor unit. Additionally, an outdoor unit can support several indoor units (also called air-handlers) for different areas of the house. The outdoor unit sits on blocks or a small concrete slab outside of your home and is about the size of a large suitcase. This outdoor unit delivers power and coolant to the indoor unit/s that in a typical installation hangs on a wall or is recessed in a ceiling. The indoor unit is typically about the size of a computer printer (10”x8”x35”)

What it does:
DHPs can be configured to heat and cool an entire house. Each unit can heat and cool the main living area of your house. Bedrooms and bathrooms may need supplemental heating. DHPs typically use 75% less energy to produce a higher quality of heating and cooling than traditional baseboard heating and window unit air conditioners. DHPs also save resources by letting home owners heat and cool only the spaces being used as opposed to central systems that maintain the temperature in the entire house.

Appendix C: Concept Description for Builder In-Person Focus Groups.

Ductless Heat Pump (DHP)

How it works:
A DHP is a heating and cooling system that does not require duct work in a home. The DHP consists of two components – An outdoor unit and an indoor unit. Additionally, an outdoor unit can support several indoor units (also called air-handlers) for different areas of the house. The outdoor unit sits on blocks or a small concrete slab outside of the home and is about the size of a large suitcase. This outdoor unit delivers power and coolant to the indoor unit/s. In a typical installation the indoor unit hangs on a wall or is recessed in a ceiling. The indoor unit is typically about the size of a computer printer (10”x8”x35”)

DHPs are an economical heating and cooling choice for a new or existing home. They operate without ducts, thus do not require expensive ductwork installation so homes can be built less expensively. Their simple, unobtrusive installation makes scheduling with other subs (drywall and insulation) much easier, thus homes can be built faster. DHPs require one power supply to the outdoor unit only (the outdoor unit supplies power to the indoor unit). Installation is easy; a team of two can do an installation in about a day.

What it does:
DHPs can be configured to heat and cool an entire house. Each unit can heat and cool the main living area of the house. Bedrooms and bathrooms may need supplemental heating. Additionally, DHPs are relatively inexpensive and give builders the benefit of being able to offer home buyers air conditioning.

Appendix D: Concept Description for HVAC Installer In-Person Focus Groups.


Installer

How it works:
DHPs have two main components: an outdoor compressor/condenser and an indoor air handling unit. Additionally, an outdoor unit can support several indoor units (also called air-handlers) .Like central systems, a conduit, which houses the power cable, refrigerant tubing, and a condensate drain, links the indoor and outdoor unit. DHPs require 1 power supply to the outdoor unit only (the outdoor unit supplies power to the indoor unit). Installation is easy; an experienced team of two technicians can do an installation in about half a day.

What it does:
A mid-size DHP is designed to cool and heat up to 600 sq ft of an average insulated space or up to a 750 sq ft with a well insulated space. DHPs typically use 75% less energy to produce the same heating and cooling results as baseboard heating and window unit air conditioners.

General Specifications: [for one specific brand/model, but communicates general idea]
Cooling Capacity: 17,600 btu
Heating Capacity: 18,400 btu
Heating Operating Range 19 F to 75 F
Cooling Operating Range 64 F to 109 F
Seer:13
Moisture Removal: 3.17 pints per hour
Power Supply Voltage/Phase/Hz: 230 Volt / 1PH / 60Hz
Running AMPS: 6.5
Fuse or Circuit Breaker Capacity: 20
Operation Sound Indoor Unit, Hi 43 (dB-A) Low 39
Operation Sound Outdoor 54 (dB-A)
Refrigerant Type: **R-410A** ODP (Ozone Depletion Potential) =0 of HFC refrigerant is used
Refrigerant Piping Type: Flare Type
Refrigerant Piping Discharge (O/D Inches) : 3/8"
Refrigerant Piping Suction (O/D Inches) : 5/8"
Refrigerant Piping Max (Ft.) : 49'
Piping Elevation Difference Outdoor (Ft.) : 16'

Appendix E: Benefit Statements for Consumer In-Person Focus Groups.

DHP Benefits for Consumers

	Rank	Benefit	Rate
1		DHPs let you get rid of the existing electric heat in your home.	1 2 3 4 5 1= not at all appealing 5 = very appealing
2		DHPs include both heating and air conditioning in one system.	1 2 3 4 5
3		DHPs help lower monthly utility bills.	1 2 3 4 5
4		DHPs do not compromise the livable square footage of your home.	1 2 3 4 5
5		With DHPs, you can control the heating and cooling in different parts of your home to your liking.	1 2 3 4 5
6		DHPs are better for the environment because they use less energy.	1 2 3 4 5
7		DHPs provide both heating and cooling without ducts.	1 2 3 4 5
8		DHPs provide quiet heating and cooling (inside and outside).	1 2 3 4 5
9		DHPs provide you evenly distributed heating and cooling for better comfort.	1 2 3 4 5
10		The climate of your home can be adjusted with a remote control.	1 2 3 4 5

Appendix F: Benefit Statements for Builder In-Person Focus Groups.

DHP Benefits for Builders

	Rank	Benefit	Rate
1		DHPs do not require expensive ductwork installation.	1 2 3 4 5 1= not at all appealing 5= very appealing
2		DHPs are easy to install because they do not require ductwork.	1 2 3 4 5
3		DHPs allow you to build homes faster.	1 2 3 4 5
4		DHPs allow you to build homes for less cost.	1 2 3 4 5
5		DHPs provide both heating and cooling within one system.	1 2 3 4 5
6		DHPs are more energy efficient than traditional electric heat.	1 2 3 4 5
7		DHPs can be installed without the hassle of ductwork or duct sealing.	1 2 3 4 5
8		DHPs do not compromise the livable square footage of the home.	1 2 3 4 5
9		DHPS are better for the environment because they use less energy.	1 2 3 4 5
10		DHPs provide evenly distributed heating and cooling for better comfort.	1 2 3 4 5

Appendix G: Benefit Statements for HVAC Installer In-Person Focus Groups.

DHP Benefits for Installers

	Rank	Benefit	Rate
1		DHPs include both heating and cooling capability in one system.	1 2 3 4 5 1= not at all appealing 5= very appealing
2		DHPs are easy to install compared to ducted systems.	1 2 3 4 5
3		DHPs require less time to install than ducted systems.	1 2 3 4 5
4		DHPs are more energy efficient than traditional electric heat.	1 2 3 4 5
5		DHPs are less expensive to install.	1 2 3 4 5
6		DHPs are better for the environment because they use less energy.	1 2 3 4 5
7		DHPs do not compromise the livable square footage of the home.	1 2 3 4 5