

King County Energize! Program Ductless Heat Pump Guidelines



Screening and Selection Criteria and Design Guidelines for Ductless Heat Pump Installations in the Skyway and White Center Unincorporated Areas Served by the Energize! Program

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EXECUTIVE SUMMARY

This report provides the King Count Energize! Program (Program) with recommendations for screening and selecting Program candidates and provides guidelines for common thermal load considerations, envelope improvements, and heat pump specifications.

Beyond the minimum program criteria, we recommend four screening criteria:

- 1) Existing heating system efficiency and prevalence
- 2) Year built or remodeled and likely envelop performance
- 3) Home layout and number of floors and rooms
- 4) Ducted or non-ducted approaches

While the Program may select participants based on need, the analysis supporting these criteria provides insight into the likelihood of encountering an ideal versus less-than-ideal oil heat conversion scenario. Applying the following prioritization based on the existing heating system, followed by the remaining criteria (in order), provides an ideal scenario: **single-story, 3-5 room homes with gravity or forced-air oil furnaces with or without envelope upgrades.**

- | | |
|-------------------------|--|
| 1) Gravity | 4) Heat Pump (homes in this category were likely mischaracterized by heat source or configuration) |
| 2) Forced Air | |
| 3) Floor-wall/Hot Water | |

These 593 homes would give the Program many straightforward retrofit options, including air handler retrofits, which provide the simplest, most comfortable, and highly efficient options (though these may be more expensive than DHPs). A short virtual or phone survey to confirm these characteristics can further qualify these candidates.

Additionally, we recommend that the program work with

- A weatherization program to identify weatherization and envelope improvement opportunities.
- An electrician to make recommendations on the home's electrical panel capacity to meet the heat pump's power and/or supplemental electric resistance heaters' electrical demands.
- An HVAC professional or Program consultant to conduct thermal load calculations for the home and specify the heat pump and its design configuration.

Finally, we recommend developing a load calculator and specification tool to streamline program delivery and accountability. The range of thermal load requirements should determine the design and retrofit approach and will impact Program cost and delivery. For example, single-head ductless heat pumps can serve small homes even with poor envelopes. In contrast, homes at the top of the Program size limit with envelope deficiencies may require insulation improvements to meet all loads with a heat pump or require supplemental heating. A method for ensuring that loads are satisfied with the proper approach but not over-specified will improve Program performance. Load calculations can also help determine likely dollar cost savings; at current electricity and heating oil rates **heating with electric resistance saves 24%, and heating with a heat pump saves 77% compared to heating oil on a \$/kBtu delivered basis.**

We have also provided several suggested program evaluation metrics to assist in gauging program performance.

INTRODUCTION

King County Energize! is a program to install heat pumps in 150 homes in the North Highline and Skyway-West Hill unincorporated areas. This report provides the King County Energize! Program (Program) with several tools to improve the selection of candidate single-family homes in the Skyway and White Center unincorporated area. Once a candidate is selected, the guidelines provide several recommended evaluation criteria for considering heat pump deployment and installations.

This set of recommendations provides the following:

- 1) Screening Criteria to assist in developing a pool of program candidates based on common single-family home configurations in the Skyway and White Center unincorporated area, with the intent of identifying a minimum set of ideal home configurations to serve as an initial screen in selecting candidate homes for the Program.
- 2) Candidate selection criteria based on site conditions, intended to further narrow the candidate pool based on HVAC type, configuration, ducting, envelop condition and insulation, load calculations, and likely ease of installation. Importantly, partnerships with a weatherization program and electrician are essential for this step.
- 3) Design recommendations based on three permutations of the selection criteria and thermal load calculations indicating a sufficient design approach and guidelines to meet heating needs with heat pumps and supplemental heating, where necessary.

Assumptions

The target single-family homes will:

- Be located in the Skyway or White Center unincorporated areas
- Be heated by home heating oil and electric resistance
- Be 1,350ft² or smaller.
- Have received envelope performance upgrades or are eligible to receive government insulation and weatherization assistance as part of this project.
- Be provided by King County with an on-site electrician and electrical upgrades where needed.

SCREENING CRITERIA

The following screening criteria can be used to evaluate potential homes with existing data and initial questionnaires administered by phone or virtually, minimizing initial interactions with the pool of candidate homes. Later in the document, the Program [Selection Criteria](#) recommends a site inspection to confirm candidate eligibility and inform design approaches. While the Program may choose to select participants based on need, the analysis supporting these criteria provides insight into the likelihood of encountering an ideal versus less-than-ideal oil heat conversion scenario.

Home Configuration and Baseline Heating System Criteria

To establish these criteria, we evaluated County Assessor GIS data of homes 1,350ft² or smaller in the Skyway and White Center unincorporated areas. Washington's first energy code was adopted by statute as a voluntary requirement in 1977. The State Building Code Act and State Energy Code Act (SECA) were

passed by the Washington legislature in 1985. Oil-heated homes in the Program service area were built before 1970, with the vast majority built during World War II and in the Post-war period between 1940-1960. Without an energy code, most of these homes were likely built without insulation.

Figure 1 displays HVAC systems in the Program's geographic focus area filtered to return only oil-heated homes, categorized by heating system type. We found that forced-air systems serve the vast majority of oil-heated homes. These systems deliver heat through ducts throughout a home, blowing heat directly into the space to be heated.

Older ducted systems may have been converted from gravity systems, a technology invented in the late 1800s when coal was commonly used as a fuel for heating. Some of these systems were converted to oil heat, and most were subsequently converted to forced air. However, the data show that 17 of the 1048 systems are still gravity systems in the specified region (Figure 1).

Though rarely found, gravity heating systems are the least efficient furnaces still in use. They operate by warming surrounding air and ducts, which rises through a house into vents in the rooms to be heated. Because of their low efficiency, they may be the top priority for heat pump conversion.

While the chart presents 100% of the data returned by this initial filtering, anomalies in the data resulted in minor conflicting, contradictory, or overlapping indicators, including two instances of heat pumps that cannot use oil as a fuel source. Additionally, floor-wall and hot water systems likely use boilers to heat water that flows through radiators, baseboards, heated floors, or wall/ceiling panels, but electric resistance floor, panel, or ceiling systems may also be classified as floor-wall systems. In this case, because systems were filtered to return systems heated by oil only, these terms are likely used inconsistently or interchangeably by County Assessor staff when determining the home's heating system. Floor-wall/hot water systems are the second largest category and are likely the most efficient oil-heated system.

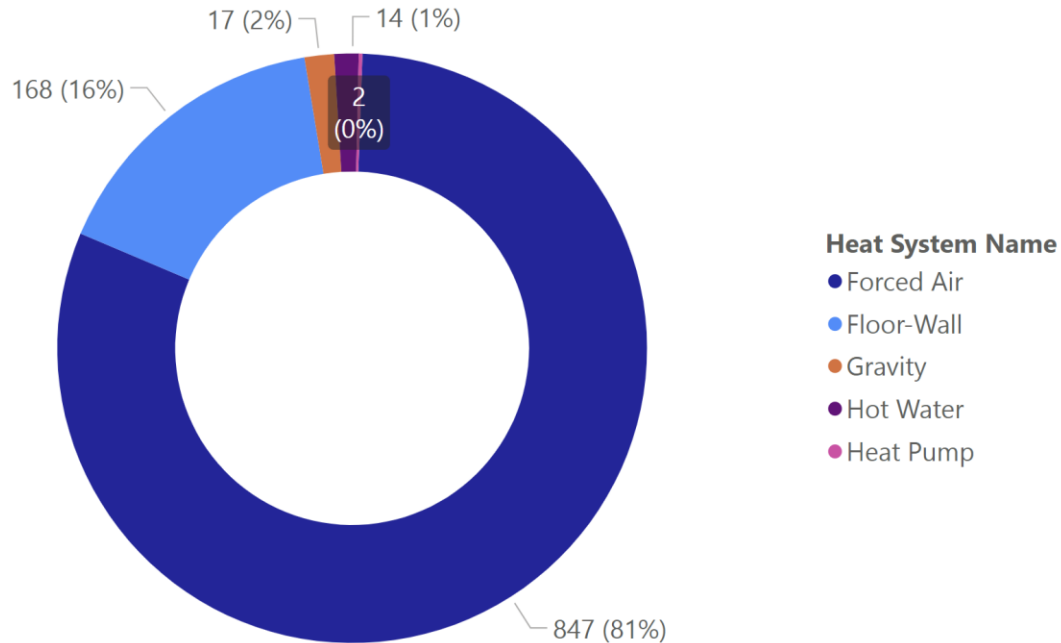


Figure 1. Number Homes by Heating System type

The heating system characteristics described above provide the Energize! Program with the following initial ideal prioritization of target homes from highest priority to lowest based on the heating system alone:

- 1) Gravity
- 2) Forced Air
- 3) Floor-wall/Hot Water
- 4) Heat Pump (homes in this category likely mischaracterized by heat source or configuration)

Vintage and Envelope Performance

Successful heat pump deployment typically requires some basic level of envelope efficiency to prevent heat losses that a heat pump system cannot surpass. Basic levels of building insulation, managed air infiltration rates, and reasonably good windows (or limited overall window area) are the typical methods for preventing these heat losses. A quick approximation of envelope heat loss rates will be necessary before heat pump systems are specified and deployed. Homes built more than 30 years ago are likely to have poor insulation characteristics, but those significantly remodeled in the past 30 years may have been subject to energy code requirements to provide envelope insulation upgrades.

Excessive envelope heat loss from lack of insulation, poor windows, or air leakage around doors and windows can lead to heat loss rates that exceed the ability of heat pump systems to keep up with heating loads or exceed the capacity of current home heat pump products. Poorly insulated envelopes can also lead to significant comfort issues in adjacent unheated rooms when served by ductless heat pumps (DHP).

Figure 2 below shows the vintage of homes built in the target geographical area. The vast majority of these homes were built over 60 years ago, at a time when building insulation was neither required nor commonly deployed. Generally, older homes have a greater propensity for lower insulation, but variability in the number and quality of home improvements also makes this a criterion that must be visibly confirmed. Therefore, for effective deployment of this program, targeted homes will either need to have undergone envelope performance and weatherization upgrades, or these upgrades will need to be undertaken as part of this project.

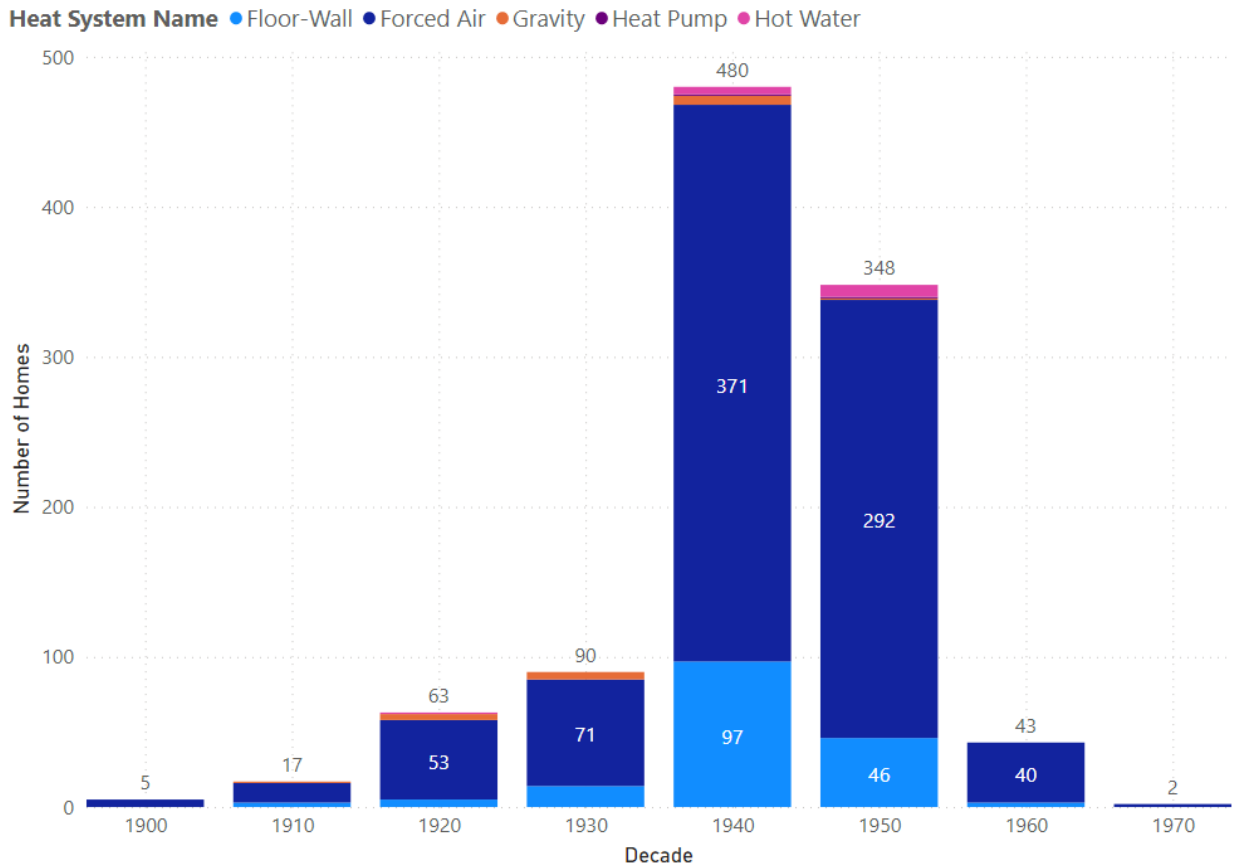


Figure 2. Count of heating systems in homes by decade

While conditions will vary across vintages, we recommend prioritizing the oldest homes first as a shortcut for exploring and identifying the lowest insulation quality. An older home will likely have more envelope issues, but maintenance quality highly impacts envelope condition; a house built in the 1960s may have worse insulation and windows than a well-maintained and upgraded home built in the 1910s. A questionnaire category that initially filters homes remodeled in the past 30 years would further improve this prioritization.

Layout & number of floors

The homes' physical configuration is a third criterion for prioritizing heat pump installation. The Program's top priority is to identify homes that can be served by single-headed ductless heat pumps that can serve most or all of the house. These homes will tend to be smaller homes with fewer rooms. Single-headed DHPs better serve single-story homes with simple geometry and few doors than those with more walls or floors. The thermal transmittance of interior walls is typically high, allowing heat to transmit through walls

from the room where the heat pump is located to other rooms over time passively. Still, proximity to the head will govern total warmth transmitted to a space. When exterior walls have poor insulation, closed doors will result in significantly cooler areas than the rest of the home. Reducing heat loss by improving insulation in exterior walls will improve single-head DHP performance. Supplemental electric resistance (ER) heaters can improve comfort in rooms with doors that are often closed (e.g., bedrooms, bathrooms, or finished basements) where a single head cannot serve. We provide more information regarding ER in the selection criteria and design sections. While heating with ER is far less efficient than heat pumps, it is still more energy efficient and cost-effective than oil heat.

Figure 3 categorizes single-story homes by the number of rooms. King County Assessor data provides bedroom and bathroom counts but does not provide a count of kitchen and living areas. To estimate the total number of rooms, we added the bedroom and bathroom counts, and because kitchen and living areas configurations are typically combined by an open format floorplan or an open doorway, we counted these areas as a single room, resulting in the following equation (*no. bedrooms + no. bathrooms*) + 1. Using this equation, a two-bedroom, single-bathroom home would have four rooms. Single-story, three-to-five-room homes provide a pool of candidates best served by single-head DHPs, though supplemental ER heat can expand this range.

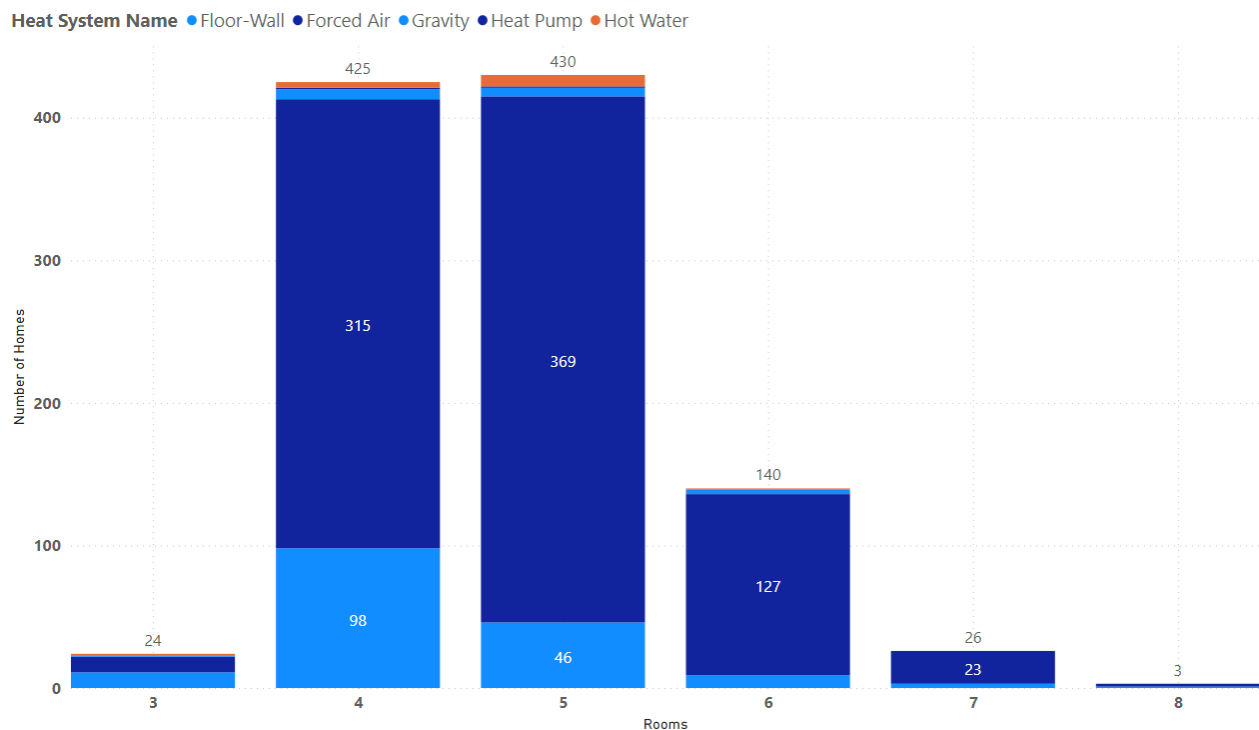


Figure 3. Single-story homes by the number of rooms

Ducted Heat Pumps

Including ducted configurations in the program is another strategy to increase heat pump deployment. Ducted heat pumps can be retrofitted into existing furnace/duct systems by replacing the furnace with a heating coil, including a fan that distributes heat into an existing duct system. Home configuration and system type data suggest a large pool of existing homes with larger footprints and ducted systems that might be targets of this type of installation.

With an initial Program target of 150 homes, retrofitting ducted systems with heat pumps may provide the program with a larger pool of candidates from which to select those with the greatest need— additionally, retrofitting forced-air systems results in improved comfort throughout larger homes with multiple stories via a single heat source without sacrificing significant system efficiency, especially when able to seal and insulate ducts. This approach also potentially improves efficiency where single-headed DHP deployments would require supplemental ER installations in remote rooms. Figure 4 describes the potential forced-air systems available for retrofit by the number of rooms (X-axis) and floors (quadrants). A house with 1.5 floors indicates partially finished floors, such as attics or basements.

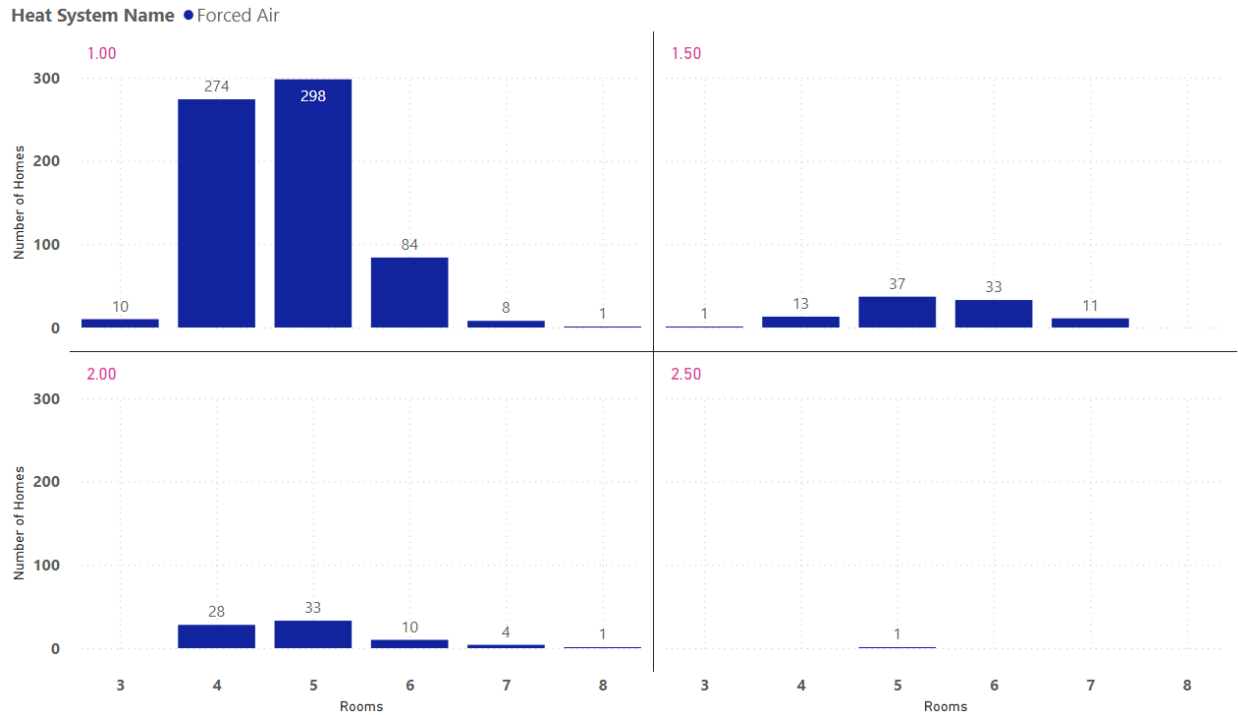


Figure 4. Homes with Forced Air systems by the number of rooms and floors. A house with 1.5 floors indicates partially finished floors, such as attics or basements.

An option to retrofit forced air systems with ducted split system heat pump systems adds more than 150 to the pool of ideal scenarios in homes with more than one story. It also offers a more comfortable and potentially more efficient option for larger single-story homes than single-headed systems can provide. Finally, adding an option to retrofit with ducted split system heat pump systems may allow the program to consider expanding the current limitation on home square footage in future iterations.

If the program chooses to consider ducted heat pump systems, a specific evaluation of duct condition and location would need to be part of the field evaluation to determine feasibility. Characteristics of the duct system or potential required upgrades are discussed later in this report.

SELECTION CRITERIA AND HEAT PUMP DESIGN

Site Inspection

The information above will allow program administrators to prioritize a subset of possible homes for further evaluation for participation in the Program. From this subset, target homes must be evaluated for suitability based on more specific design and performance criteria. These criteria will need to be verified by site inspection and include the following:

Electrical system capacity and suitability

A qualified inspector must verify that the home's electrical system has enough overall capacity for the heat pump system. In addition, older panels or overloaded panels may need to be upgraded, and circuit or panel space added to the system. It is anticipated that needed electrical system upgrades will be part of program deployment.

Envelope performance and thermal loads

As discussed above, envelope efficiency is critical for managing thermal load for effective and comfortable heat pump operation. Inspectors must verify that adequate insulation has been installed in the walls, floor, and ceiling. Some houses may require envelope upgrades and weatherization as part of program deployment.

Space for Outdoor Unit Installation

The outdoor unit of the heat pump system must be located in an area with plenty of airflow across the coils. The heat pump unit should not be directly adjacent to neighboring homes to limit noise disturbance. The total distance of refrigerant piping between indoor and outdoor units must be limited to within manufacturer guidelines. More information about these criteria is provided in the Design Guidelines section below.

Owner Coordination

The owner may have the opportunity to pursue envelope and other improvements beyond the minimum that reduce energy costs and improve comfort. We recommend that the program provide an opportunity to coordinate those improvements and DHP installation, connecting homeowners with other King County, state, and federal programs (e.g., King County Home Repair Loans & Grants) that can improve home efficiency and value.

Design Guidelines

In all scenarios, heat pump systems should be sized based on load calculations to provide 100 percent of the heating load at Seattle winter design conditions without ER backup. However, while addressing envelope and insulation deficiencies first is essential for load reduction, certain scenarios may require supplemental ER where a heat pump cannot meet the total heating load.

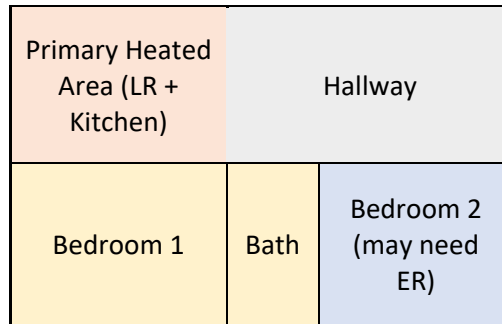
There are two scenarios to consider when replacing existing oil-fired systems.

Single Head Ductless Heat Pumps

Single-head DHP systems can provide a maximum of around 36,000 Btu/hr. For all **non-ducted heating systems**, single-headed DHP systems can meet home heating requirements when the home meets the following criteria, though supplemental ER will likely be required in rooms further away from the DHP head. Where multiple heads would benefit a home, we recommend the Program coordinate with the

homeowner to allow them to purchase additional heat pump capacity and/or heads to minimize costs related to mobilization and design.

- 1) Single story – Generally, single-head DHP systems should not be specified to heat homes with multiple floors. However, multiple heads or supplemental ER heating can be specified to meet the remaining heating load.
- 2) Separation criteria – rooms should not be separated by more than an interior wall or door from the primary heated area. They should also be no more than one room from the primary heated area. Rooms with additional separation may require supplemental ER heating to meet the heating load. Figure 5 provides an example floor plan describing the separation criteria of a single-story home.



Ducted Split System Heat Pumps

For **Forced Air** and **Gravity** systems, installing a split-system heat pump and vertical air handler to replace the furnace directly with a ducted heat pump system is the most straightforward approach. This approach ensures that the entire home is heated with the heat pump (minimizing or eliminating the need for supplemental ER) while also adding cooling for the whole home, a growing issue of climate equity. Additionally, the following considerations should be made:

- 1) Indoor Space Constraints – Evaluate the condition and location of the ducts. The following conditions should not be retrofitted with a ducted system:
 - a. Undersized ducts; the installer should confirm that ducts are adequately sized throughout the home
 - b. Ducts located in crawlspaces; though these ducts can be wrapped and insulated, they are more likely to degrade quickly.
 - c. Duct sealing and insulation; the installer should confirm that ducts can be sealed and insulated where needed. Blown-in wall insulation can be sufficient for ducts located in walls and ceilings.

Duct sealing should be a minimum requirement when ducts are not located in crawlspaces. Insulation should be applied as determined by the heating loss reductions needed for installing the heat pumps and based on program cost/benefit criteria.

- 2) Refrigerant piping – Routing may require drywall work, ceiling penetrations, and wall/roof waterproofing. This work should be coordinated with any insulation or other envelope work.

For all scenarios, the following conditions should be considered.

Outdoor Space Constraints – An installer must evaluate space constraints for outdoor units by following manufacturer guidelines to ensure:

- 1) The outdoor units have enough clearance between structures horizontally and vertically to operate properly
- 2) The chosen location for the outdoor units does not exceed manufacturer guidance on the maximum refrigerant piping length between indoor and outdoor units in terms of absolute distance and change in elevation.
- 3) Potential noise issues can be avoided related to outdoor unit placement

Ceiling fans – Fans destratify spaces, improve thermal distribution, reduce energy demands in winter, and improve comfort in all seasons.

Programmable thermostats – These controls allow occupant adjustability and should be pre-set with schedules to automatically return to a base setting after an occupant overrides it to prevent periods of over-cooling or heating.

Load Calculations

When evaluating design, consider that oil furnaces can range between 60,000 to 160,000 Btu/h. A single-head DHP cannot exceed roughly 36,000 Btu/hr. A split system heat pump air handler (ducted system) cannot exceed approximately 54,000 Btu/hr. Understanding the home's heating load will inform the minimum envelop upgrades required to size equipment properly and reduce energy bills. Houses with oil heat will almost certainly require envelope improvements to reduce heating loads.

The following scenarios offer insight into the heating load requirements for likely home configurations. This analysis uses a simple $U - \text{value} \times \text{Area}$ (UA)¹ calculation for each building assembly to determine the prototype home's overall UA. The total heat delivered by the heat pumps must exceed the heat loss.

Scenario 1: Single-story 1,350ft² uninsulated home

This scenario assumes that windows were weatherized, but no insulation was installed.

Main Floor Areas / Perimeters	Measurements	Assembly Type	U or F-Factor	UA
Heated Floor Area (sf)	1,350			
Perimeter (ft)	150			
Gross Wall Area (sf)	1,950			
Total Window Area (sf)	72	Single tight	1.100	79
Total Doors (sf)	40	Solid	0.540	22
Total Net Wall Area (sf)	1,838	2x4 R-0	0.200	368
Roof/Ceiling	1,350	R-5 Uninsulated	0.100	135
Slab on Grade (ft)		Slab R-0	1.000	0
Floor over Unheated Basement/Crawlspace (sf)	1,350	CS - R-0	0.200	270
Conditioned Volume (ft ³)	13,500			61
Total UA				934

¹ U-value is the rate of heat transfer per unit area per degree of temperature difference, and is the inverse of the R-value ($U=1/R$ and $R=1/U$).

The heating capacity in Btu/hr. is determined by multiplying the UA by the ΔT between the home's indoor air temperature setpoint (72°F) versus the outdoor design air temperature (24°F).

$$\Delta T = 72^{\circ}\text{F} - 24^{\circ}\text{F} = 48^{\circ}\text{F}$$

$$\Delta T \times \text{UA} = (48^{\circ}\text{F} \times 934) = 44,832 \text{ Btu/hr}$$

A safety factor of 125% is best practice to compensate for unknowns in UA calculations and outdoor air infiltration; therefore, a 3-ton (36,000 Btu/hr.) heat pump would satisfy roughly $\frac{2}{3}$ of the heating load. The remaining load could be satisfied with four supplemental 1.5KW baseboard ER heaters or improved insulation, as demonstrated below.

Scenario 2: Single-story 1,350ft² with minimal envelope improvements

This scenario assumes that the home was weatherized, the walls were insulated to R-11, and the ceiling below the roof was insulated to R-19. No other improvements were made.

Main Floor Areas / Perimeters	Measurements	Assembly Type	U or F-Factor	UA
Heated Floor Area (sf)	1,350			
Perimeter (ft)	150			
Gross Wall Area (sf)	1,950			
Total Window Area (sf)	72	Single tight	1.100	79
Total Doors (sf)	40	Solid	0.540	22
Total Net Wall Area (sf)	1,838	2x4 R-11	0.080	147
Roof/Ceiling	1,350	R-19 Standard	0.069	66
Slab on Grade (ft)		Slab R-0	1.000	0
Floor over Unheated Basement/Crawlspace (sf)	1,350	CS - R-0	0.200	270
Conditioned Volume (ft ³)	13,500			61
Total UA				645

$$\Delta T \times \text{UA} = (48^{\circ}\text{F} \times 645) = 30,960 \text{ Btu/hr}$$

Adding R-11 insulation to the walls and R-19 to the ceiling reduces the heating load to 30,960 Btu/hr. With a 125% safety factor, a 3-ton DHP would meet 93% of the heating load (38,700 Btu/hr.), likely within the margin of error to avoid supplemental ER beyond the occupant's choice of a portable space heater in the coldest areas of the home. Reducing the indoor setpoint from 72°F to 68°F further reduces the heating load to 28,380 Btu/hr., allowing the single DHP to meet 125% of the load in all scenarios (35,475 Btu/hr.).

Scenario 3: Small home with finished attic

This scenario assumes that windows were weatherized, but no insulation was installed.

Main Floor Areas / Perimeters	Measurements	Assembly Type	U or F-Factor	UA
Heated Floor Area (sf)	675			
Perimeter (ft)	104			
Gross Wall Area (sf)	1,040			
Total Window Area (sf)	60	Single tight	1.100	66
Total Doors (sf)	40	Solid	0.540	22
Total Net Wall Area (sf)	940	2x4 R-0	0.200	188
Roof (sf)	0	R-5 Uninsulated	0.100	0
Slab on Grade (ft)		Slab R-0	1.000	0
Floor over Unheated Basement/Crawlspace (sf)	675	CS - R-0	0.200	135
Conditioned Volume (ft ³)	6,750			30
Total UA				441

$$\Delta T = 72^{\circ}\text{F} - 24^{\circ}\text{F} = 48^{\circ}\text{F}$$

$$\Delta T \times \text{UA} = (48^{\circ}\text{F} \times 441) = 21,168 \text{ Btu/hr}$$

In this scenario, a 2-ton (24,000 Btu/hr.) heat pump would satisfy the heating load in most cases for the main floor.

A finished attic directly under the sloped roof adds 33% more heating load. The Washington State Residential Building Code limits the countable habitable space under sloped roofs to that with ceiling heights above 7 feet. Therefore, the attic described here would be represented by a fraction of the floor area in the county assessor data. However, the measured dimensions must be used when calculating heated floor area and volume.

Attic Areas / Perimeters	Measurements	Assembly Type	U or F-Factor	UA
Heated Floor Area (sf)	675			
Perimeter (ft)	147			
Gross Wall Area (sf)	250			
Total Window Area (sf)	12	Single tight	1.100	13
Total Doors (sf)	0	Solid	0.540	0
Total Net Wall Area (sf)	238	2x4 R-0	0.200	48
Roof (sf)	864	R-5 Uninsulated	0.100	86
Slab on Grade (ft)		Slab R-0	1.000	0
Floor over Unheated Basement/Crawlspace (sf)	0	CS - R-0	0.200	0
Conditioned Volume (ft ³)	3,375			0
Total UA				147

$$\Delta T = 72^{\circ}\text{F} - 24^{\circ}\text{F} = 48^{\circ}\text{F}$$

$$\Delta T \times \text{UA} = (48^{\circ}\text{F} \times 147) = 7,056 \text{ Btu/hr}$$

Two 1.5KW baseboard heaters would serve this load, providing 10,230 Btu/hr., but would provide no cooling to the space most likely to need it in the warmer months. Designs should only use ER supplementally where DHPs or ducted retrofits cannot serve the entire home.

Energize! Program Load Calculations and Heat Pump Specification

The above examples provide insight into the heating and envelope requirements for poorly insulated 1350ft² homes. However, variable home characteristics such as skylights, finished basements, multiple window/door qualities, and unusual geometries would benefit from a systematized method for determining home heat loss and the associated home heating requirements. Ecotope developed a basic calculator based on engineering calculations and standard heat conductivity factors for the examples above.

The cost and quality of envelope improvements, heat pump design and installation, and occupant comfort will drive program efficiency and effectiveness. **Finding the breakeven point between the cost of adding electric resistance versus envelope upgrades and ongoing energy costs related to operation and maintenance should inform Program decisions.** We recommend expanding the calculator developed for this project or similar into a tool to guide load calculations, heat pump specifications, and both capital and operations costs. This tool would improve program delivery and consistency, mitigating the risk of contractors over-sizing or under-sizing systems respective to envelop improvements or choosing supplemental ER when a ducted approach would be more efficient. Additionally, this tool could inform the Program and homeowner of the trade-offs between upfront capital costs and ongoing energy and maintenance costs.

Envelope

Perhaps the most important yet often overlooked step, envelope upgrades, and other energy efficiency measures should come before all other design, heating load sizing, or upgrade considerations. Before sizing heat pump equipment, the space should be reviewed to identify deficiencies in the envelope; minimizing air leaks, repairing or upgrading windows, and adding insulation where possible or required should be completed to reduce energy demand before sizing the system. The weatherization program representative should manage envelope considerations. State and local weatherization programs have thorough checklists, and the Program should confirm that, at minimum, the representative considered the following common envelope deficiencies.

Many older homes may have little to no insulation, and the energy performance of older windows and doors is much poorer than modern equivalents. In addition, envelope components age over time, resulting in component failures and stopgap repairs that compromise the home's thermal performance. When addressing the envelope, the first step should be repairing deficiencies. This step should be followed by introducing insulation where practical:

- **Walls** – blown insulation in walls to a minimum of R-11
- **Ceiling under roofs** – batt or loose insulation in attic spaces to a minimum of R-19 (ideally R-25)
- **Underfloor insulation** – rigid or batt insulation in accessible crawl and basement spaces to a minimum of R-11 (ideally R-19)
- **Windows** – upgrade windows with secondary glazing (storm windows or similar) or other units with a maximum total U-value of 0.65 (ideally no more than 0.55).

These guidelines are described in great detail below.

Windows

Maximize window energy performance to the extent practical. Window replacements are best, but storm windows, secondary glazing, and simple sealing and repairing can improve glazing performance. The program should evaluate the following for repair or replacement:

- Damaged or missing windows and door seals and sweeps that admit drafts;
- Single-paned windows;
- Cracked window unit seals that allow moisture to condense between panes;
- “Permanent” window AC units should be removed and windows repaired.

Insulation

Maximize insulation energy performance to the extent practical. Uninsulated walls should be insulated as a priority, but adding supplemental ER can also help meet the heating requirements of uninsulated areas of the house.

- **Ceiling under roofs** – If the ceiling is less than R-25, insulate to the highest value practical with batt or loose insulation in attic spaces.
- **Walls** – If wall cavities are less than R-15, insulate with blown-in or foam insulation to a minimum of R-11 or the highest value practical or install supplemental ER (or additional heads) in bedrooms with an exterior wall.
- **Basement/Crawlspace** – Seek opportunities to add insulation in basements and crawl spaces, insulating with rigid or batt insulation to a minimum of R-11 (ideally R-19 or higher).

Other Damage

- Repair roof and foundation leaks that damage insulation;
- Repair gaps in walls or glazing introduced by repairs, alterations, or damage;
- Remove and replace stopgap repairs and damaged/failed components.

PROGRAM EVALUATION

The following provides several suggestions for evaluating program effectiveness and efficiency. For example, the least energy-efficient homes will likely have the longest project timelines but may serve the populations with the greatest need. Evaluating success requires balancing project cost and timeline (efficiency) versus the opportunity to decarbonize home heating systems, improve energy efficiency, reduce pollution, reduce occupant costs, improve health, and increase home value (effectiveness).

Ongoing Costs

The ongoing fuel cost of heating systems with different fuel types or heating methods can be evaluated by comparing \$/kBtu produced by the system. The following table provides a conservative comparison between an 85% efficient oil heating system, a 98% efficient electric resistance (ER) system, and a 325% efficient heat pump system (at 42°F ambient air temperature, Seattle’s average winter temperature).

kBtu Cost Analysis	Heating Oil (gal)	ER (kWh)	HP (kWh)
\$/unit	\$ 5.62	\$ 0.12	\$ 0.12
kBtu/unit	137.381	3.412	3.412
Efficiency	85%	98%	325%
\$/kBtu	\$ 0.0481	\$ 0.0365	\$ 0.011
% Savings from Oil	0%	-24%	-77%

This analysis reveals that at current electricity and heating oil rates, compared to oil, heating with electric resistance saves 24%, and heating with a DHP saves 77%, \$/kBtu. Heat pump efficiencies range as high as 400% efficient at 42°F, and oil heating systems range between 65%-85% efficiency. Oil systems are rarely 85% efficient outside of brand-new systems. While heat pump cooling ability will add to electricity bills, the Seattle area has an average of ~90% more heating load than cooling load, though cooling loads are increasing as the climate warms.

Comparing heating system costs for Scenario 2 (above) on an average Seattle winter day (42°F ambient outdoor temperature), this home would save ~\$16/day by converting to a heat pump. In a week averaging 42°F outdoors, this home would save ~\$111.

$$17.85 \text{ kBtu/hr} \times 24 = 428.4$$

$$428.4 \text{ kBtu} * (\$0.048 - \$0.014) = \$15.90$$

Heating oil prices would need to drop to \$4.27/gallon to be at cost parity with electric resistance and \$1.85/gallon for cost parity with heat pumps in this scenario.

Evaluation Indicators

By requiring program participants to share energy consumption and cost data, the Program can discern several important outcomes, such as:

- Cost/Benefit
- Change in total energy consumption
- Change in EUI
- Estimated health and economic outcomes

Additional efficiency and effectiveness metrics include:

- Project time to completion
- Number of homes served against the target of 150
- Number of residents served
- Square Footage improved

CONCLUSION

The guidelines provided in this report enable the Energize! Program with baseline reference scenarios with recommendations for improving the successful conversion of oil-heated single-family homes to heat pumps in the Skyway and White Center unincorporated area of King County.

Beyond the minimum Program eligibility criteria, the Screening Criteria isolate home characteristics to create an initial prioritized list of candidates. Working with a weatherization program, electrician, and

heat pump installer, we recommend the Program use the Selection Criteria and Design Guidelines to conduct site evaluations, thermal load calculations, and heat pump specifications. Site condition evaluations should confirm Program eligibility via HVAC fuel, home size, and upgradability. The site evaluation also informs heat pump design and envelope improvement by confirming HVAC type and configuration and establishing the envelope conditions required for load calculations.

Additionally, this report provided several scenarios based on minimum selection criteria to indicate design approaches using heat pumps and supplemental heating recommendations to meet home heating loads likely to be found in the Program service area. While these scenarios provide a sufficient baseline for design and heat pump specification, we recommend developing a Program calculator and specification tool to standardize and simplify home heating load calculations and related heat pump sizing specifications.