Heat Pumps Potential for Energy Savings in New York State

Final Report

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NYSERDA Record of Revision

Heat Pumps Potential for Energy Savings
July 2014

Revision Date	Description of Changes	Revision on Page(s)
July 2014	Original Issue	Original Issue
January 2015	Provided additional definitions and detail on analytic approach.	1
January 2015	Provided additional detail on cost effectiveness methodology used in assessing the various heat pump technologies.	8
January 2015	Clarified criteria for selecting technologies for analysis.	17
January 2015	Added additional information clarifying the applicability of ground-source heat pumps in New York State.	21
January 2015	Edited desuperheater discussion to reflect additional citation.	29
January 2015	Edited text to better reflect use of ground-source heat pumps in large buildings.	29
January 2015	Edited market barriers to better reflect constraints on ground-source heat pumps.	30
March 2015	Revised measure characterizations for commercial ground-source heat pumps and VRF heat pumps.	All tables with commercial results and appendices

Heat Pumps Potential for Energy Savings
in New York State

Final Report

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Table of Contents

List of Tables

1   Introduction

Heat pumps are a category of space conditioning devices that can extract heat from a cold reservoir and move it to a hot reservoir. As such, heat pumps are basically air conditioners that can run in reverse in the winter to provide heating. Because heat pumps move heat as opposed to creating it, they can achieve a coefficient of performance (COP)[1] many times higher than 1.0, which is the theoretical maximum efficiency for typical combustion heat sources and traditional electric resistance heat.

This report provides an assessment of the potential for energy savings from heat pumps in New York State. Following this introduction, the report is comprised of the following sections:

- Results of the potential assessment.
- Methodology used for the assessment.
- Overview of selected heat pump technologies, their market status and ideal site characteristics for installation, and barriers to market adoption.

The assessment is limited to the implementation of heat pumps for providing both space heating and cooling in residential and commercial buildings. Three potential assessments were performed:

1. Technical potential for air source heat pumps.
2. Technical potential for ground source heat pumps.
3. Economic potential for air source and ground source heat pumps combined.

For this analysis, economic includes any heat pump project where the average benefits on a system level exceed the total costs of the project. For this type of analysis, the benefits are defined as the avoided costs of energy, which are distinct from the retail rates. Further, the analysis looks at both lost opportunity and retrofit projects. For lost opportunity projects, the baseline is defined as a system that complies with current energy code, which may be much more efficient than a typical existing system. For retrofit, the baseline is assumed to be the existing equipment for the remainder of its useful life, at which point a code compliant model is to be otherwise installed and savings go down. This method of analysis is significantly different than what is often done by a customer on site, who will calculate simple payback based on the performance of the existing equipment.

As a result, we are comparing the potential savings from a heat pump with the likely code compliant alternative, rather than quantifying the full savings customers would experience. Finally, the economic potential includes the most cost-effective measure, which is not necessarily the measure with the greatest savings. For example, even though a ground source heat pump will typically have higher savings than an air source heat pump, net benefits may be lower, if the cost premium is high enough. In this case, it is assumed that the air source heat pump will be installed.

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[1]   The coefficient of performance (COP) is the ratio of the heating or cooling energy pumped between reservoirs to the energy consumed.

Note that this assessment builds on work reported in the *Energy Efficiency and Renewable Energy Potential Study of New York State* (the EERE Potential Study), which was published in April 2014, is available on NYSERDA's website,[2] and referred to throughout this report. This assessment supplements the *EERE Potential Study* in several key ways:

- The EERE Potential Study did not include fuel switching, which provides the largest opportunities for energy savings from heat pumps. This assessment includes the fuel switching potential.
- The EERE Potential Study applied aggregated efficiency measures and thus did not provide heat pump-specific results.
- The EERE Potential Study included a separate "module" on heat pumps, but that only provided very high-level assessments of the technical potential for each of several heat pump technologies. This detailed assessment includes the integrated economic potential for heat pumps.

The Methodology section provides more information on the assumptions and approach used to carry out the assessment.

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[2] https://www.nyserda.ny.gov/Energy-Data-and-Prices-Planning-and-Policy/Energy-Prices-Data-and-Reports/EA-Reports-and-Studies/EERE-Potential-Studies.aspx

2   Results

2.1   Measure List and Cost-Effectiveness

The list of heat pump (HP) measures and their cost-effectiveness are provided in the appendices. The total resource costs and benefits shown in Appendix A represent the discounted costs and benefits over the life of the HP measure. A measure with positive net benefits (benefits minus costs) is considered to be cost-effective. Some measures have negative costs, which reflect that the HP equipment costs less than the corresponding heating and cooling equipment. Many measures have negative benefits because the cost of increased electricity for heating is considered to be a negative benefit. Negative costs or benefits generally result in negative benefit-cost ratios (BCRs), which can be confusing. Cost-effectiveness is therefore indicated by gray shading, which indicates negative net-benefits.

As shown in Appendices A and B, cost-effectiveness of the fuel switching measures differs considerably between zones. Cost-effectiveness is heavily dominated by the heating impacts, including reduced fossil fuel use and increased electric heating. Fuel switching from petroleum fuels is the most cost-effective, due to their higher costs. Cooling impacts are relatively low since both baseline and efficient cooling is electric, so the same electric avoided costs apply to the relatively small difference in usage.

New York City is generally the least cost-effective for several reasons: highest equipment and labor costs; most expensive winter electric avoided costs, and thus the highest penalty for increased electric heating; and least expensive oil, and thus the lowest benefits for decreased oil use. The Upstate zone is generally the most cost-effective due to lower equipment and labor costs, and the lowest winter electric costs.

Fuel switching from natural gas is not cost-effective for most of the HP measures, due to the relatively low cost of natural gas. Gas prices are forecast to escalate over the 20-year period, but not enough to overcome the cost-effectiveness hurdle for most gas measures (a few natural gas measures become cost effective starting in later years).

Appendix C provides measure cost-effectiveness for selected years throughout the 20-years study period. Appendix D provides measure descriptions and their characterizations for costs and savings.

2.2   Technical Air-Source Heat Pump Potential

The technical air-source potential was limited to air-source heat pumps, assuming installation of all applicable measures regardless of cost-effectiveness.

Tables 1 through 6 show the estimated potential for energy savings in various categories, for fuel switching and non-fuel switching measures, with the percent of the corresponding sales forecast saved, for selected years. Negative values indicate increased usage.

Table 1. Residential Space Heating/Cooling, Fuel Switching Measures

	2015	2025	2030	2034
Elec Cooling (GWh)	31	885	1,237	1,401
% of Res Cooling Forecast	1%	19%	25%	27%
Elec HP Space Heating (GWh)	(752)	(17,698)	(25,336)	(25,662)
% of Res Elec Forecast	-1%	-30%	-42%	-42%
Total Elec Space Htg Impact (GWh)	(722)	(16,813)	(24,099)	(24,261)
% of Res Elec Forecast	-1%	-28%	-40%	-40%
Gas Space Heating (BBtu)	5,310	142,714	215,413	236,396
% of Res Gas Space Heating Forecast	2%	53%	77%	84%
Oil Space Heating (BBtu)	2,463	58,230	86,303	88,209
% of Res Oil Space Heating Forecast	2%	52%	78%	81%

Table 2. Commercial Space Heating/Cooling, Fuel Switching Measures

	2015	2025	2030	2034
Elec Cooling (GWh)	33	583	578	585
% of Com Cooling Forecast	0%	4%	4%	4%
Elec HP Space Heating (GWh)	(556)	(10,655)	(15,193)	(15,141)
% of Com Elec Forecast	-1%	-9%	-12%	-12%
Total Elec Impact (GWh)	(523)	(10,072)	(14,615)	(14,555)
% of Com Elec Forecast	-1%	-9%	-12%	-11%
Gas Space Heating (BBtu)	5,567	121,182	182,510	195,100
% of Com Gas Space Heating Forecast	3%	61%	88%	94%
Oil Space Heating (BBtu)	1,570	28,619	41,929	43,412
% of Com Oil Space Heating Forecast	3%	61%	89%	94%

Table 3. Total Residential and Commercial Space Heating/Cooling, Fuel Switching Measures

	2015	2025	2030	2034
Elec Cooling (GWh)	63	1,468	1,815	1,986
% of Res & Com Cooling Forecast	0%	8%	9%	9%
Elec HP Space Heating (GWh)	(1,308)	(28,352)	(40,529)	(40,803)
% of Res & Com Elec Forecast	-1%	-16%	-22%	-21%
Total Elec Impact (GWh)	(1,245)	(26,884)	(38,714)	(38,816)
% of Res & Com Elec Forecast	-1%	-15%	-21%	-20%
Gas Space Heating (BBtu)	10,877	263,896	397,923	431,496
% of Res & Com Gas Space Htg Forecast	2%	56%	81%	88%
Oil Space Heating (BBtu)	4,033	86,849	128,232	131,621
% of Res & Com Oil Space Heating Forecast	3%	55%	81%	85%

Table 4. Residential Space Heating/Cooling, Non-Fuel Switching Measures

	2015	2025	2030	2034
Elec Cooling (GWh)	2	55	83	90
% of Res Cooling Forecast	0%	1%	2%	2%
Elec HP Space Heating (GWh)	42	898	1,263	1,233
% of Res Space Heating Forecast	1%	20%	28%	27%

Table 5. Commercial Space Heating/Cooling, Non-Fuel Switching Measures

	2015	2025	2030	2034
Elec Cooling (GWh)	3	57	77	80
% of Com Cooling Forecast	0%	0%	0%	0%
Elec Space Heating (GWh)	6	90	121	114
% of Com Space Heating Forecast	0%	3%	4%	4%

Table 6. Total Residential and Commercial Space Heating/Cooling, Non-Fuel Switching Measures

	2015	2025	2030	2034
Elec Cooling (GWh)	5	111	160	171
% of Res & Com Cooling Forecast	0%	1%	1%	1%
Elec Heat Pump Space Heating (GWh)	47	988	1,384	1,347
% of Res & Com Space Heating Forecast	1%	14%	19%	18%

Notably, for fuel switching measures for space heating and cooling, for the total residential and commercial sectors:

- Cooling energy would be reduced by year 20 by about 2.0 terawatt hours (TWh), or 9% of the cooling energy forecast.
- Increased electric space heating of about 41 TWh, which would increase the total residential and commercial electric forecast by about 21%.
- Gas and petroleum fuel space heating would be reduced by 84% and 81%, respectively.

Non-fuel switching installation of heat pumps for space heating and cooling has much smaller potential than for fuel switching. Residential opportunities would reduce the electric space heating forecast by about 1.2 TWh, or 27% over 20 years, while the cooling forecast would be reduced by about 90 gigawatt hours (GWh), or 2%. Commercial opportunities would reduce the electric space heating forecast by about 114 GWh, or 4%, with essentially no reduction in the cooling forecast. These savings are a small fraction of the potential savings from fuel switching. As noted in the Methodology (Section 3), heat pump measures were only applied to spaces that have both space heating and cooling. Also, the assessment for non-fuel switching measures was done at a high level and thus may not reflect all energy efficiency opportunities. The targets for fuel switching from gas and petroleum fuel space heating are based on the applicability factors described in the Methodology section (under "Applicability"), which limit the amount of heating energy to which heat pumps apply. Measure penetrations were set to meet these targets, within the limits described in the Measure Penetrations section, under Methodology.

The potential for water heating measures is detailed in Section 2.4.

2.3   Technical Ground-Source Heat Pump Potential

As noted in the methodology (Section 3), the ground-source technical potential was limited by the assumed applicability factors for ground source heat pump (GSHP) physical constraints. The potential savings are thus significantly lower than for the air-source heat pump (ASHP) potential. Tables 7 through 12 show the estimated potential for ground-source heat pump energy savings in various categories, for fuel switching and non-fuel switching measures, with the percent of the corresponding sales forecast saved, for selected years. Negative values indicate increased usage. Of note, gas and petroleum fuel space heating would be reduced by 47% and 51%, respectively.

Table 7. Residential Space Heating/Cooling, Fuel Switching Measures

	2015	2025	2030	2034
Elec Cooling (GWh)	29	717	1,012	1,250
% of Res Cooling Forecast	1%	15%	20%	24%
Elec HP Space Heating (GWh)	(206)	(4,808)	(6,789)	(8,105)
% of Res Elec Forecast	0%	-8%	-11%	-13%
Total Elec Space Htg Impact (GWh)	(177)	(4,091)	(5,778)	(6,855)
% of Res Elec Forecast	0%	-7%	-10%	-11%
Gas Space Heating (BBtu)	2,660	70,076	103,765	129,036
% of Res Gas Space Heating Forecast	1%	26%	37%	46%
Oil Space Heating (BBtu)	1,313	31,298	45,453	54,956
% of Res Oil Space Heating Forecast	1%	28%	41%	51%

Table 8. Commercial Space Heating/Cooling, Fuel Switching Measures

	2015	2025	2030	2034
Elec Cooling (GWh)	70	1,829	2,756	3,540
% of Com Cooling Forecast	1%	13%	18%	22%
Elec HP Space Heating (GWh)	(133)	(3,261)	(4,821)	(5,940)
% of Com Elec Forecast	0%	-3%	-4%	-5%
Total Elec Impact (GWh)	(62)	(1,432)	(2,065)	(2,400)
% of Com Elec Forecast	0%	-1%	-2%	-2%
Gas Space Heating (BBtu)	1,834	51,956	80,346	102,951
% of Com Gas Space Heating Forecast	1%	26%	39%	49%
Oil Space Heating (BBtu)	539	12,004	18,480	23,276
% of Com Oil Space Heating Forecast	1%	26%	39%	50%

Table 9. Total Residential and Commercial Space Heating/Cooling, Fuel Switching Measures

	2015	2025	2030	2034
Elec Cooling (GWh)	99	2,546	3,767	4,790
% of Res & Com Cooling Forecast	1%	13%	18%	22%
Elec HP Space Heating (GWh)	(339)	(8,069)	(11,610)	(14,045)
% of Res & Com Elec Forecast	0%	-5%	-6%	-7%
Total Elec Impact (GWh)	(239)	(5,523)	(7,843)	(9,255)
% of Res & Com Elec Forecast	0%	-3%	-4%	-5%
Gas Space Heating (BBtu)	4,495	122,032	184,111	231,987
% of Res & Com Gas Space Htg Forecast	1%	26%	38%	47%
Oil Space Heating (BBtu)	1,852	43,302	63,933	78,231
% of Res & Com Oil Space Heating Forecast	1%	27%	41%	51%

Table 10. Residential Space Heating/Cooling, Non-Fuel Switching Measures

	2015	2025	2030	2034
Elec Cooling (GWh)	2	55	83	90
% of Res Cooling Forecast	0%	1%	2%	2%
Elec HP Space Heating (GWh)	42	898	1,263	1,233
% of Res Space Heating Forecast	1%	20%	28%	27%

Table 11. Commercial Space Heating/Cooling, Non-Fuel Switching Measures

	2015	2025	2030	2034
Elec Cooling (GWh)	3	57	77	80
% of Com Cooling Forecast	0%	0%	0%	0%
Elec Space Heating (GWh)	6	90	121	114
% of Com Space Heating Forecast	0%	3%	4%	4%

Table 12. Total Residential and Commercial Space Heating/Cooling, Non-Fuel Switching Measures

	2015	2025	2030	2034
Elec Cooling (GWh)	5	111	160	171
% of Res & Com Cooling Forecast	0%	1%	1%	1%
Elec Heat Pump Space Heating (GWh)	47	988	1,384	1,347
% of Res & Com Space Heating Forecast	1%	14%	19%	18%

2.4   Economic Heat Pump Potential

The economic scenario considered both air-source and ground-source heat pumps. However, the air-source heat pumps were found to be more cost-effective for all applications, so the results presented below include no ground-source heat pumps. As noted above, the report used the Total Resource Cost test, which looks at average benefits at the system level compared to the costs of the project. Although the analysis determined that ASHPs are more cost-effective than GSHPs, this does not mean that ASHPs save more energy, just that the added cost of the GSHPs does not fully counteract the increased savings when compared to a high efficiency ASHP alternative. Further, the study looked at average costs and benefits; it is likely there will be specific instances where site-specific conditions mean that GSHPs would actually be more cost-effective than ASHPs, as well as providing larger savings.

Finally, both lost opportunity and retrofit measures were examined. Lost opportunity measures occur when existing equipment is at the end of its useful life and needs replacement. For these measures, the baseline is assumed to be minimally code compliant replacement equipment. This equipment is likely significantly more efficient than the old existing equipment (which is likely at least 20 years old). In retrofit projects existing equipment is replaced before the end of its useful life. For these projects, the baseline is the existing equipment only until the point in time at which it would have failed and needed replacement. At this time, the baseline shifts to become the minimally code-compliant and there is a corresponding drop in the savings. Note that these calculations are more complex than the simple payback often used by building owners and vendors to evaluate projects.

Most measures for fuel switching from natural gas were not cost-effective, due primarily to low avoided costs for gas.

For petroleum fuel measures, although some were not cost-effective in the early years, there are enough cost-effective measures to account for nearly all (99%) of the technical potential for petroleum fuel heating over 20 years.

Notably, for fuel switching measures for space heating and cooling, for the total residential and commercial sectors:

- Cooling energy in the residential sector would be reduced by year 20 by about 430 GWh, or 8% of the residential cooling energy forecast. However, commercial cooling energy would be increased by about 380 GWh (2% of the commercial cooling forecast) due to less efficient cooling by some heat pump equipment relative to standard cooling equipment.
- Increased electric space heating of about 10 TWh, which would increase the total residential and commercial electric forecast by about 5%.
- Gas and petroleum fuel space heating would be reduced by 3% and 78%, respectively.

Non-fuel switching installation of heat pumps for space heating and cooling has much smaller potential than for fuel switching. Residential opportunities would reduce the electric space heating forecast by about 1.2 TWh, or 26% over 20 years, while the cooling forecast would be reduced by about 86 GWh, or 2% of the forecast.

Commercial opportunities would reduce the electric space heating forecast by about 50 GWh, or 2%, with essentially no reduction in the cooling forecast. These savings are a small fraction of the potential savings from fuel switching. As noted in methodology (Section 3), heat pump measures were only applied to spaces that have both space heating and cooling. Also, the assessment for non-fuel switching measures was done at a high level and thus may not reflect all energy efficiency opportunities.

Water heating measures for fuel switching to heat pump water heaters (HPWHs) were limited to fuel switching from petroleum fuels. Water heating savings by year 20 were estimated at about 12 TBtu in the residential sector (50% of the residential water heating forecast by petroleum fuels), and 7 TBtu in the commercial sector (22% of commercial forecast). For both sectors combined these savings amount to 35% of the water heating forecast by petroleum fuels. Water heating savings by HPWHs replacing electric-resistance water heaters had lower potential than the fuel switching measures, estimated at about 590 GWh for the residential and commercial sectors by year 20, or 14% of the forecast for electric water heating.

Tables 13 through 18 present the results for the economic heat pump potential, for space heating and cooling.

Table 13. Residential Space Heating/Cooling, Fuel Switching Measures

	2015	2025	2030	2034
Elec Cooling (GWh)	10	265	377	428
% of Res Cooling Forecast	0%	6%	8%	8%
Elec HP Space Heating (GWh)	(238)	(5,057)	(7,179)	(7,018)
% of Res Elec Forecast	0%	-9%	-12%	-11%
Total Elec Space Htg Impact (GWh)	(229)	(4,792)	(6,801)	(6,591)
% of Res Elec Forecast	0%	-8%	-11%	-11%
Gas Space Heating (BBtu)	-	-	-	273
% of Res Gas Space Heating Forecast	0%	0%	0%	0%
Oil Space Heating (BBtu)	2,463	57,381	85,435	88,164
% of Res Oil Space Heating Forecast	2%	52%	77%	81%

Table 14. Commercial Space Heating/Cooling, Fuel Switching Measures

	2015	2025	2030	2034
Elec Cooling (GWh)	(24)	(227)	(351)	(382)
% of Com Cooling Forecast	0%	-2%	-2%	-2%
Elec HP Space Heating (GWh)	(129)	(1,976)	(2,882)	(2,880)
% of Com Elec Forecast	0%	-2%	-2%	-2%
Total Elec Impact (GWh)	(153)	(2,202)	(3,233)	(3,263)
% of Com Elec Forecast	0%	-2%	-3%	-3%
Gas Space Heating (BBtu)	633	6,663	11,361	13,099
% of Com Gas Space Heating Forecast	0%	3%	5%	6%
Oil Space Heating (BBtu)	1,028	21,033	31,457	32,806
% of Com Oil Space Heating Forecast	2%	45%	67%	71%

Table 15. Total Residential and Commercial Space Heating/Cooling, Fuel Switching Measures

	2015	2025	2030	2034
Elec Cooling (GWh)	(14)	38	26	45
% of Res & Com Cooling Forecast	0%	0%	0%	0%
Elec HP Space Heating (GWh)	(367)	(7,032)	(10,061)	(9,899)
% of Res & Com Elec Forecast	0%	-4%	-5%	-5%
Total Elec Impact (GWh)	(382)	(6,994)	(10,034)	(9,854)
% of Res & Com Elec Forecast	0%	-4%	-5%	-5%
Gas Space Heating (BBtu)	633	6,663	11,361	13,372
% of Res & Com Gas Space Htg Forecast	0%	1%	2%	3%
Oil Space Heating (BBtu)	3,491	78,414	116,892	120,970
% of Res & Com Oil Space Heating Forecast	2%	50%	74%	78%

Table 16. Residential Space Heating/Cooling, Non-fuel Switching Measures

	2015	2025	2030	2034
Elec Cooling (GWh)	2	51	78	86
% of Res Cooling Forecast	0%	1%	2%	2%
Elec HP Space Heating (GWh)	41	892	1,254	1,224
% of Res Space Heating Forecast	1%	20%	27%	26%

Table 17. Commercial Space Heating/Cooling, Non-fuel Switching Measures

	2015	2025	2030	2034
Elec Cooling (GWh)	2	24	34	35
% of Com Cooling Forecast	0%	0%	0%	0%
Elec Space Heating (GWh)	4	42	54	50
% of Com Space Heating Forecast	0%	2%	2%	2%

Table 18. Total Residential and Commercial Space Heating/Cooling, Non-fuel Switching Measures

	2015	2025	2030	2034
Elec Cooling (GWh)	4	75	112	120
% of Res & Com Cooling Forecast	0%	0%	1%	1%
Elec Heat Pump Space Heating (GWh)	45	934	1,309	1,274
% of Res & Com Space Heating Forecast	1%	13%	18%	17%

Tables 19 through 24 present the economic potential results for heat pump water heaters.

Table 19. Residential Water Heating, Fuel Switching Measures

	2015	2025	2030	2034
Elec Water Heating (GWh)	(98)	(992)	(1,008)	(892)
% of Res Water Heating Forecast	-2%	-31%	-30%	-26%
Oil Water Heating (BBtu)	1,081	12,051	13,240	12,445
% of Res Oil Water Heating Forecast	6%	54%	55%	50%

Table 20. Commercial Water Heating, Fuel Switching Measures

	2015	2025	2030	2034
Elec Water Heating (GWh)	(51)	(523)	(537)	(506)
% of Com Water Heating Forecast	-7%	-66%	-66%	-61%
Oil Water Heating (BBtu)	565	6,342	7,044	7,085
% of Com Oil Water Heating Forecast	2%	22%	23%	22%

Table 21. Total Residential and Commercial Water Heating, Fuel Switching Measures

	2015	2025	2030	2034
Elec Water Heating (GWh)	(149)	(1,515)	(1,545)	(1,398)
% of Res & Com Water Heating Forecast	-3%	-38%	-37%	-33%
Oil Water Heating (BBtu)	1,646	18,393	20,285	19,530
% of Res & Com Oil Water Heating Forecast	4%	36%	37%	35%

Table 22. Residential Water Heating, Non-fuel Switching Measures

	2015	2025	2030	2034
Elec Water Heating (GWh)	64	451	505	510
% of Res Elec Water Heating Forecast	2%	14%	15%	15%

Table 23. Commercial Water Heating, Non-fuel Switching Measures

	2015	2025	2030	2034
Elec Water Heating (GWh)	8	73	81	81
% of Com Water Heating Forecast	1%	9%	10%	10%

Table 24.Total Residential and Commercial Water Heating, Non-Fuel Switching Measures

	2015	2025	2030	2034
Elec Water Heating (GWh)	72	525	586	591
% of Res & Com Water Heating Forecast	1%	13%	14%	14%

Table 25 compares the economic potential scenario to the technical air-source potential scenario, for fuel-switching measures for space heating and cooling.

Table 25. Economic Potential as a Percentage of Technical Air-Source Potential, Space Heating, and Cooling Measures

Residential	2015	2025	2030	2034
Elec Cooling (GWh)	31%	30%	30%	31%
Elec Heat Pump Space Heating (GWh)	32%	29%	28%	27%
Total Electric Impact (GWh)	32%	29%	28%	27%
Gas Space Heating (BBtu)	0%	0%	0%	0%
Oil Space Heating (BBtu)	100%	99%	99%	100%

Commercial	2015	2025	2030	2034
Elec Cooling (GWh)	-73%	-39%	-61%	-65%
Elec Heat Pump Space Heating (GWh)	23%	19%	19%	19%
Total Electric Impact (GWh)	29%	22%	22%	22%
Gas Space Heating (BBtu)	11%	5%	6%	7%
Oil Space Heating (BBtu)	65%	73%	75%	76%

Total Residential & Commercial	2015	2025	2030	2034
Elec Cooling (GWh)	-23%	3%	1%	2%
Elec Heat Pump Space Heating (GWh)	28%	25%	25%	24%
Total Electric Impact (GWh)	31%	26%	26%	25%
Gas Space Heating (BBtu)	6%	3%	3%	3%
Oil Space Heating (BBtu)	87%	90%	91%	92%

3   Methodology

3.1   Methodology Overview

The scope of analysis was limited to heat pumps used for both space heating and cooling of residential and commercial buildings. While there are many special applications of heat pumps for various industrial processes, we did not include those applications in this study. There would be some potential for conventional space heating and cooling by heat pumps in the industrial sector, but that is a relatively small part of the industrial sector energy, and we did not include that in this study.

This assessment is built on the EERE Potential Study.[3] As for that study, this assessment used a top-down analysis starting with statewide usage forecasts for electricity, natural gas, and petroleum fuels.[4] The usage forecasts were disaggregated into annual energy usage by end use, including space heating and cooling as applicable to heat pumps. Individual heat pump measures were defined and characterized for their costs and energy savings (or increased usage) relative to baseline or standard equipment, and for its effective useful lifetime. The "applicability" of each measure, or the portion of the end-use energy to which each measure applies was also estimated as described in more detail later in this section. Depending on the potential scenario (technical or economic), appropriate market penetration percentages were assigned. These factors lead to Equation 1:

$$\text{Annual energy savings} = (\text{End-use Energy}) * (\text{Applicability}) * (\% \text{ Savings}) * (\% \text{ Penetration}) \qquad (1)$$

For example, consider a residential heat pump replacing a gas boiler and central air conditioning (CAC), for the new construction market, for the technical potential. For this case, the gas heating component might be:

- End-use energy = 1,000BBtu (total space heating by natural gas, year 1, for this zone, for new construction.
- Applicability = 80% (gas usage paired with AC) * 50% (portion associated with CAC) = 40%.
- Percent Savings = 100% (all of the natural gas is saved due to fuel switching to the heat pump).
- Percent Penetration = 100% (assume full market penetration of the new construction market).
- Annual gas savings = 1,000 BBtu * 40% * 100% * 100% = 400 BBtu.

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[3]   https://www.nyserda.ny.gov/Energy-Data-and-Prices-Planning-and-Policy/Energy-Prices-Data-and-Reports/EA-Reports-and-Studies/EERE-Potential-Studies.aspx

[4]   Petroleum fuels included heating oil, propane, and kerosene, and were assessed as a group rather than individually.

This same measure would have increased electric usage (kWh) for heating by the heat pump, estimated proportionately to the gas savings. In addition, there would be cooling savings for the efficient heat pump relative to the baseline CAC. The dollar benefits associated with energy savings (or increased usage) were determined by applying the avoided costs of energy supply for each fuel type and year of the measure's service lifetime.

The assessment was carried out separately for each of four analysis zones: Long Island (LI), New York City (NYC), Hudson Valley (HV), and Upstate New York (UP). Each zone was distinguished by its own:

- Usage forecast and energy disaggregation (electric, gas, petroleum fuels).
- Avoided costs of energy supply.
- Climatic conditions (e.g., full-load hours for space heating and cooling).
- Equipment and installation cost multipliers (based on RSMeans data).
- Electric load profiles (load shapes) for estimating the energy (kWh) saved in each energy costing period corresponding to the electric avoided costs.

This top-down methodology by analysis zone is described in detail the EERE Potential Study. Volume 1 describes the analysis zones, usage forecasts, end-use disaggregation, avoided costs, and the cost-effectiveness analysis methodology. Volume 2 describes the top-down methodology (see in particular the commercial sector "Overview of Approach" on page 39).

As for the EERE Potential Study, this assessment covered a 20-year period, but starting in 2015 rather than 2013. The avoided energy supply costs from the EERE Potential Study were used for this study, but were inflated from 2012 dollars to 2014 dollars.

The technical potential includes full market penetration all measures evaluated (while avoiding any double counting), regardless of whether they were cost effective, and ignoring other market barriers. The economic potential limits the analysis to measures found to be cost-effective based on New York's standard Total Resource Costs test (described in Volume 1 of the EERE Potential Study). Cost-effectiveness was evaluated for each zone and installation year of the 20-year study. Some measures were not cost-effective in year 1, but became cost-effective in future years.

Three potential assessments were performed:

- Technical potential for air source heat pumps.
- Technical potential for ground source heat pumps.
- Economic potential for air source and ground source heat pumps combined.

3.2 Measures Assessed

The assessment included the following categories of measures, which are summarized in Table 26.

Table 26. Categories Measured for the Assessment

End Use	Measure Category	Notes
Space Heating and Cooling	Fuel switching from gas or petroleum fuel space heating and electric cooling to heat pumps	This category has the highest potential for energy savings, and was assessed in greater detail than the other categories.
	Switching from resistance space heating and cooling to heat pumps	Assessed for the residential sector. Ignored for the commercial sector, which has relatively small usage of electric resistance heating.
	Installation of high-efficiency space heating and cooling heat pumps in place of standard-efficiency heat pumps	For the residential sector this was not found to be cost effective. For the commercial sector, assessed for installation of CEE Tier II heat pumps.
Water Heating	Fuel switching from fossil fuel (FF) heating to heat pump water heaters	High-level assessment using a single measure for switching from stand-alone FF water heaters to HPWHs. Fuel switching from gas was assumed not to be cost-effective.
	Installation of high-efficiency HPWHs in place of electric resistance water heaters	High-level assessment based on the findings of the EERE Potential Study.

3.2.1 Fuel Switching for Space Heating and Cooling

The assessment of fuel switching for space heating and cooling includes heat pump measures for new construction and retrofit. The retrofit measure characterizations assume that existing heating and cooling equipment has five years of remaining life, out of a 20-year life for heating equipment and a 15-year life for cooling equipment. The retrofit characterizations also include:

- A dollar benefit for a deferred replacement cycle for the existing heating and cooling equipment (which would have needed replacement in 5 years).
- A baseline shift when newer (generally more efficient) equipment would have been installed in 5 years.

In terms of measuring cost-effectiveness, these aspects of the retrofit characterizations put them on a par with replace-on-burnout measures, where the existing heating and cooling equipment would be at end-of-life. It would be relatively rare to have both the heating and cooling equipment reach end-of-life at the same time, hence the decision to treat all non-new-construction as retrofits. Also, because 100% of new construction opportunities were assumed to result in heat pump installations, these account for a substantial part of the total potential over the course of the 20-year study.

Table 27 and Table 28 summarize the combinations of source cooling equipment and heat-pump technologies included in the assessment for space heating and cooling. The heat pump technologies included:

- ASHP—Central, ducted Air-Source Heat Pumps, typically like central AC for residential, and unitary AC (e.g., roof-top units) for commercial.
- DMSHP—Ductless Mini Split Heat Pumps.
- VRF—Variable Refrigerant Flow Heat Pumps.
- GSHP—Ground Source Heat Pumps.

Where multiple HP technologies applied to given cooling equipment, the "Prioritized HP Technology" was the technology found to have the highest cost-effectiveness. As a result, the analysis does not attempt to quantify the maximum savings that can be captured cost-effectively, but rather the savings associated with doing the optimal measures based on maximum cost-effectiveness. The displaced fossil fuel for heating was the same regardless of the HP technology. For each of the three potential scenarios, the Prioritized HP Technology was used for all installations, and the less cost-effective options were excluded from the analysis.

Table 27. Residential Heat Pump Measures

	ASHP	DMSHP	VRF	GSHP	Prioritized HP Technology
Central AC	X	X		X	ASHP
Room AC		X			

Table 28. Commercial Heat Pump Measures

	ASHP	DMSHP	VRF	GSHP	Prioritized HP Technology
Unitary AC	X		X	X	ASHP
Chiller	X		X	X	VRF for Tech; VRF or ASHP for Economic*
Central AC		X			
Room AC		X			

*   The "Chiller to VRF" measure has higher savings, but there were cases where "Chiller to ASHP" passed cost-effectiveness while "Chiller to VRF" failed. Therefore, for the economic potential the VRF option was prioritized where it passes, and ASHP is otherwise selected where cost-effective.

Heat pumps were assumed to completely replace existing fossil-fuel based heating systems. In past practice for northern areas, existing heating systems were often left in place to handle peak loads. Otherwise, electric resistance coils were used to handle peak loads, which greatly reduced or even eliminated the efficient gains from the heat pump. With new "cold-climate" heat pumps, the need for backup heating is greatly reduced or eliminated. Measures for lower capacity heat pumps with backup heat were not included partly due to the complexity of these scenarios and a lack of data on their costs and benefits (characterizing them would necessitate modeling a variety of prototypical building for different configurations, beyond the scope of this study). More importantly, current installations are generally sized to eliminate the need for backup heat.

Measure costs reflect the expected need for distribution systems to support the heat pumps. Existing duct work, such as for central heating systems, was assumed to be reused with some modification. Some buildings would require expensive distribution system retrofits, particularly in place of existing hydronic distribution systems. While some hydronic systems are capable of being retrofit for use with hydronic heat pump systems, this is relatively rare and there is no data available to support an estimate for this special case.

For the technical potential, the highest-efficiency heat pumps were not necessarily assumed to be available on the market. For measure characterizations, the highest-efficiency equipment with reasonably good cost data available and with reasonably high installation rates was assumed. These characterizations made sense for the economic potential. Therefore, the technical potential would be somewhat higher if assuming the most efficient heat pumps available, regardless of their cost-effectiveness. At the same time, increasing heat pump COPs over time were assumed, which accounts for higher efficiency levels and greater savings potential in the future.

3.2.2 Water Heating Potential Assessment

Potential savings for heat pump HPWHs were assessed at a high-level. Fuel switching was assessed for switching from a stand-alone oil or propane hot water heater to a HPWH. Fuel switching from gas water heaters was assumed not to be cost-effective based on other studies, and was not assessed.

The potential for HPWHs for non-fuel switching applications was assessed at a high level based on the EERE Potential Study. The residential bundled water heating measures for that study included multiple energy efficiency opportunities, including source heating equipment (e.g., HPWHs), hot water distribution (e.g., pipe wrap), delivery equipment (e.g., low-flow equipment), and heat recovery. For the residential sector, 30% of the economic hot water electric energy savings was assumed to be attributed to hot water heat pumps, whether replacing electric resistance

hot water tanks or installing high-efficiency rather than standard efficiency heat pumps. For the commercial sector, about 10% of economic energy savings was estimated to be attributed to heat pumps. The lower percent of savings for the commercial sector is due to having much less electric resistance hot water, and higher standards for larger water heaters.[5] The EERE Potential Study did not estimate the technical potential, but this assessment roughly estimated that the technical potential would be 20% higher than the economic potential.

3.3   Measure Penetrations

Technical and economic potential scenarios typically ignore all market barriers. For this study, rather than assuming all applicable measures could be installed in year one, we roughly bounded the potential scenarios based on contractor and equipment availability. We assumed that high levels of annual market penetration could be achieved, but that it would take several years to ramp up to those levels as the contractor pool would grow over time in response to high demand for their services. By having measure penetrations ramp up over time, the impacts of measures installed in future years were assessed when the avoided energy supply costs are expected to be higher than today (see the EERE Potential Study for more detail on the avoided costs).

For the technical scenarios, measure penetrations were set to 100% for new construction (full market penetration), assuming there would be sufficient contractor availability for the relatively small new construction market. Retrofit measures started with 2% penetration, ramping up over about 10 years to a maximum of 9% annual penetration.

For the economic scenario, measure penetrations were set to 100% for new construction (full market penetration). Retrofit measures were set individually for those measures that passed cost-effectiveness, generally following the same ramp-up as for the technical scenarios, to a maximum of 9% penetration.

3.4   Applicability

"Applicability" is the portion of the end-use energy to which a measure applies. As previously noted, a measure's annual savings are calculated as Equation 1:

$$\text{Annual energy savings} = (\text{End-use Energy}) * (\text{Applicability}) * (\% \text{ Savings}) * (\% \text{ Penetration}) \qquad (1)$$

Applicability is thus a key factor limiting measure savings, and for preventing double-counting by different measures.

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[5]   For example, in 2015, ENERGY STAR® water heaters above 55 gallons (9% of the ENERGY STAR water heater market) must be HPWHs.

Assessing applicability for the fuel switching measures took place in several steps:

Step 1: Exclude street lighting and data center energy from the commercial energy available for HPs. Data centers are excluded as they do not have significant heating loads. The street lighting and data center loads were estimated by zone in the usage disaggregation from the EERE Potential Study.

Step 2: Include only fossil-fuel heating with corresponding cooling. Conditioned space with heating but no cooling is not applicable to HPs. For residential, the portion of fossil fuel heating with no cooling was estimated from the 2009 Residential Energy Consumption Survey (RECS) data for New York (released April 2013) and shown in Table 29. The commercial factors were estimated by professional judgment, relative to the residential factors.

Table 29. Portion of Fossil Fuel Heating Energy with No Corresponding Cooling

Zone	Residential	Commercial
New York City (NYC)	10%	0%
Long Island (LI)	15%	5%
Hudson Valley (HV)	15%	5%
Upstate (UP)	22%	15%

Step 3: Cooling energy was split between natural gas and petroleum fuel space heating, based proportionately on the split of gas and petroleum fuel space heating energy (MMBtu).

Step 4: Baseline cooling equipment applicability. The table below shows our assumptions for the breakout of cooling energy for the baseline cooling equipment. These were based largely on professional judgment, as there is no recent baseline study for New York. The 2009 RECS data, specific to New York, shows that 28% of air-conditioned households have central air conditioning (CAC). However, that doesn't indicate the cooling energy intensity of households with CAC versus those with other types of cooling equipment. Households with CAC account for an estimated 60% of the residential cooling load. The RECS data had no estimate of the number of households with heat pumps (not enough data), so it was estimated at 1%. The estimates for the commercial sector were made similarly, using the current 2003 Commercial Buildings Energy Consumption Survey (CBECS) data for the Northeast region (Table 30).

Table 30. Baseline Cooling Equipment Applicability Factors

Baseline Cooling Equipment	Residential	Commercial
Chiller	0%	30%
Unitary AC	0%	60%
Central AC	60%	3%
Room AC	39%	5%
Heat Pumps	1%	2%
Total	**100%**	**100%**

For the fuel switching measures, the Baseline Cooling Equipment Applicability Factors in Table 30 were also applied to the corresponding fossil fuel heating energy. For example, residential customers with CAC were estimated to account for 60% of the residential baseline cooling energy. Therefore, 60% of the residential cooling (kWh) energy and 60% of the residential natural gas heating (MMBtu) energy was assumed to apply to households with CAC and natural gas heating. (The other 40% would apply to households with other types of cooling equipment).

Step 5: Efficient Equipment Mutual Exclusion. Where multiple heat pump technologies apply to the same baseline cooling equipment, the choice of which to use is based on the cost-effectiveness. See the tables of residential and commercial efficiency measures in Section 3.2. For example, commercial buildings with fossil fuel heat and unitary AC could switch to ASHP, VRF, or GSHP. In this case, the ASHP results in the best overall cost-effectiveness, so it is prioritized as the measure of choice. The measures for switching to VRF or GSHP are excluded in this case.

The Efficient Equipment Mutual Exclusion also applies an applicability for GSHPs, to account for the fact that not all sites are suitable for GSHPs. New York's soil substrates and ground water resources are generally favorable for GSHP, but, some locations will be limited by small lot sizes, population density, or other physical factors. Vertical boreholes, either alone or combined with open loop, horizontal and pond loops, provide an option for small lot sizes and high population density. However, vertical boreholes cannot be used everywhere, and GSHP applications will be limited in densely populated areas with extensive underground infrastructure (e.g. Manhattan). Unfortunately, there is no data available by which to reliably estimate the applicability of GSHPs due to physical limitations. Professional judgment figured into estimating these factors, as shown in Table 31. These GSHP factors only affect the technical ground-source HP potential, since air-source HPs take priority for the other scenarios. However, these factors play a dominant role on the technical GSHP potential. The individual applicability factors are multiplied together to provide the total applicability.

Table 31. Ground Source Heat Pump Applicability Factors

Zone	Residential	Commercial
New York City (NYC)	30%	30%
Long Island (LI)	70%	70%
Hudson Valley (HV)	70%	70%
Upstate (UP)	80%	80%

3.5 Outlook for Decreased Cost and Increased Performance Over Time

Heat pumps have been improving in performance over recent years, and newer "cold-climate" heat pumps have opened up markets for heat pumps, including New York State.

The International Energy Agency (IEA) produced in 2011 a *Technology Roadmap: Energy-efficient Buildings: Heating and Cooling Equipment*,[6] which included cost and performance goals for heat pumps. Performance improvements were assumed to be equal to the lower end of these performance goals by 2030. For space and water heating, a 30% increase was assumed in heat pump Coefficient of Performance (COP) by 2030, which corresponds to a decrease in heat pump heating energy (kWh) of about 23%. For cooling, a modest increase in savings of 10% by 2030 (relative to 2015) was assumed, as baseline cooling equipment is expected to improve along with heat pump equipment. Incremental installed costs for heat pump measures was assumed to decrease by 5% (in real dollars) by 2030, relative to 2015 – a conservative estimate relative to the IEA's Technology Roadmap cost goals. These assumptions for changes over time to installed cost and performance were applied linearly between 2015 and 2030, continuing the same trends through 2034 (year 20).

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[6] https://www.iea.org/publications/freepublications/publication/buildings_roadmap.pdf

3.6 Other Methodology Issues

Exclusion of residual (#6) heating oil. Residual heating oil was excluded from the petroleum fuels due to its low avoided costs. As for natural gas, fuel switching from residual fuel oil heating to heat pumps is generally not cost-effective due to the relatively low benefits for reduced fuel usage. Thus, the aggregated petroleum fuels and their associated aggregate avoided costs were limited to distillate (#2), kerosene, and propane/LPG, all of which have relatively high avoided costs. Note that the petroleum fuels sales forecast still includes residual fuel oil. The petroleum fuels savings as a percent of forecast thus reflects the residual fuel oil in the forecast, though no heat pump measures were applied to petroleum fuels.

Building shell efficiency. Any increase in building shell efficiency over time was not assumed. With increased building shell efficiency, as could be driven by efficiency program efforts, the potential would be reduced due to reduced heating and cooling loads. Note that for buildings with poor air sealing or insulation it may be more cost-effective to do some weatherization first, so that a smaller HP could be purchased (or if pursuing a net-zero-energy home, weatherization makes it possible to run the HP with less solar panels) – but that assessment was beyond the scope of this project.

Potential for increased cooling loads due to promotion of heat pumps. In reality, as heat pumps become more available and cost-effective, some people without cooling may choose to install them when they would not otherwise have installed cooling. That is, as people become aware of the benefits of heat pumps, there may be market pressure to install new air conditioning earlier than would have occurred with conventional cooling equipment. This issue may be considered during an evaluation of heat pump programs.

4   Heat Pump Technologies

4.1   Overview

Heat pumps are often grouped into two distinct categories: air-source heat pumps (ASHP) and ground source heat pumps (GSHP). ASHPs use outdoor air as a thermal reservoir. This reservoir allows for simpler and less expensive installations, but ASHPs are also highly susceptible to reduced performance at lower air temperatures. Because the efficiency of heat pumps is inversely proportional to the difference in temperature between the hot and cold reservoirs, the heat pumps become less efficient as the temperature difference becomes larger. The difference in temperature between inside and outside is typically higher in the winter than in the summer, so this problem mainly impacts the heating season. In fact, for climates in much of New York, heat pumps may need an auxiliary heat source for the coldest nights. Conventional air source heat pumps commonly used in milder climates, for example, have a COP barely above 1 at 50 °F, and a lower temperature limit of 45 °F. However, heat pumps designed for improved cold weather performance has significantly increased in recent years, and now some ASHP models can provide space heating at a COP of 1.75 at 5 °F, and lower limit temperatures as low as -13 °F.[7]

GSHPs address the problem of cold weather performance by using the ground soil or a body of water as a heat reservoir, instead of the outdoor air. Ground temperatures in the U.S. stay at a fairly constant temperature throughout the year of between, depending on latitude, 45 to 75 °F.[8] Because the temperature difference between the ground and the desired set point remains fairly small all year, ground source heat pumps are able to achieve higher seasonal efficiencies than air source heat pumps. However, extra piping and digging expenses also mean that the installation costs for GSHPs are much higher than those for ASHPs.

Within each of these two broad categories, several distinct types of heat pumps exist. The following sections review several of these types of heat pumps, giving an overview of the technology, the market status and ideal site characteristics for installation, and barriers to market adoption of the technology.

4.2   Ductless Mini-Split

4.2.1 Overview

Ductless mini-splits are a type of air-source heat pump used primarily in residential and small commercial settings. Like standard central air conditioning (AC) units, ductless mini-splits have an outdoor compressor and an indoor air handler/evaporator connected by refrigerant lines. However, no ductwork is needed – instead, the evaporator units

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[7]   ETSAP and IRENA, p. 1.

[8]   http://energy.gov/energysaver/articles/geothermal-heat-pumps.

are typically located directly in the space to be cooled. Multiple indoor units can be connected to the same outdoor unit, allowing easy multi-zone control. Further, ductless mini-split units typically use inverter-driven variable speed compressors and multi-speed fans that allow for efficient part-load operation. This set-up means less cycling and thus a tighter indoor temperature range. The eliminated duct losses, efficient part load operation, and easy zone control combine to allow ductless mini-splits to achieve higher seasonal efficiencies than traditional central ACs; units can reach as high as a 26 Seasonal Energy Efficiency Ratio (SEER). The lack of duct losses that often degrade the system efficiency in ducted systems contribute to additional energy savings. On the heating side, with seasonal average COPs reaching 3.5, ductless mini-splits provide significant advantages over electric resistance heat, and potentially even over fossil fuel boilers and furnaces, for which the highest efficiencies are in the upper 90s not including any duct losses.

In most areas of New York State, supplemental heating would likely be needed with ductless mini-splits. However, recent years have seen large advancements in cold-climate mini-splits, and units have recently become available that provide full heating capacity at 5 °F with COPs in the range of 1.5-1.8.[9]

4.2.2 Market Trends and Ideal Site Characteristics

Internationally, ductless mini-split heat pumps (DMSHPs) are not a new market, and in fact they are estimated to make up as much as 98% of the Asian residential HVAC market, and 50-70% of the European market.[10] Despite the international popularity, they have been slow to take hold in the U.S. market, and are thought to make up less than 5% of the residential market. However, U.S. adoption has recently been picking up, with an average annual growth rate of 12% for the past five years, despite a contracting overall Unitary HVAC market.[11]

Part of the reason for the slower uptake in the U.S. market is that ductless mini-splits have a higher first-cost than a traditional AC and furnace. A pilot program in Connecticut and Massachusetts found an average cost per ton of cooling for a ductless mini-split retrofit of $2,715.[12] This agrees closely with a case study done by the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy (EERE) in Austin, TX, which found a cost of $2,922 per ton.[13] The EERE Potential Study also found an incremental cost of $275 per ton, assuming both the furnace and the AC need to be retrofit in the base case. A comprehensive study in the Pacific Northwest finds a slightly higher incremental cost, estimating a 30% premium for DMSHPs.[14] However, given that a large portion of

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[9]   Roth, Sehgal and Akers 2013
[10]   NAHB Research Center 2008
[11]   Landwehr 2012
[12]   KEMA Inc. 2009
[13]   Roth, Sehgal and Akers 2013
[14]   NAHB Research Center 2008

the costs for DMSHPs are for labor and their relatively low acceptance in the marketplace, it is reasonable to expect that costs will come down as the technology becomes more well-known. Further, DMSHP systems are likely already cheaper than traditional ducted systems for retrofit add-ons in houses with pre-existing non-ducted systems, or for room additions or renovations where it is infeasible to extend the existing ductwork.

4.2.3 Market Barriers

As evidenced by very high penetration rates of DMSHPs in Europe and Asia, the market barriers preventing U.S. adoption of the technology should be addressable. These barriers include:

- **High first cost**: as mentioned above, first costs for DMSHPs are often higher than for traditional ducted systems when replacing existing equipment. However, the incremental cost will likely fall as DMSHPs gain more acceptance in the U.S.
- **Aesthetic concerns**: Many U.S homeowners do not like the aesthetics of having the indoor air handling unit right in the conditioned space, preferring to have the conditioned air enter through the nearly invisible vents typical of a ducted system. These concerns are likely to be mitigated with increased knowledge of the other comfort benefits of DMSHPs. In the Connecticut and Massachusetts pilot project, for example, 31 of 40 participants indicated that the DMSHP system worked better than their old one. Surveys for pilot projects have found that although many customers complain about the sight of the system at first, they gradually grew accustomed. Further, many high-end residential homes are now putting in DMSHPs with short ductwork in order to address these concerns.
- **Lack of awareness**: In the past, manufacturers have directed marketing materials exclusively to trade contractors. This means consumer awareness of the product is still very low.
- **Low temperature heating**: In the past, the low-temperature performance has been a significant barrier to adoption in cold climates. However, as previously discussed, this performance has improved significantly in recent years, and will likely continue to improve.
- **Uncertainty and lack of installers**: Many builders are reluctant to install DMSHPs due to uncertainty of market acceptance. Builders who do want to install DMSHPs often report having trouble finding an installer.[15]
- **Lack of contractor training**: DMSHPs require specialized training for proper installation, including how to size the system properly, and where to install the indoor AHUs. If this is not done properly, there will likely be issues with temperature and humidity control. Further, contractors are typically much more comfortable working with ducts than with refrigerant lines.

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[15]   Ibid.

4.3 Variable Refrigerant Flow Systems

4.3.1 Overview

Variable refrigerant flow (VRF) heat pumps are similar to mini-splits in that one outdoor compressor is connected to multiple indoor air handlers/evaporators. However, whereas mini-split (and multi-split) systems require separate refrigerant lines for each indoor unit, the variable refrigerant flow capability allows all indoor units to connect to the compressor via the same two refrigerant lines. Further, VRF systems are able to use heat recovery, enabling simultaneous heating and cooling by zone. With heat recovery, VRF systems will typically use three refrigerant lines: a liquid line, a hot gas line, and a suction line. An indoor unit requiring cooling will open the liquid and suction lines, and act as an evaporator, and a unit requiring heating will open its hot gas line and liquid line, and act as a condenser. Heat exchangers in the indoor units will transfer reject heat from units being cooled to the refrigerant line that is going to the zone to be heated. The waste heat can also potentially go to heat domestic hot water, or hot water for a separate hydronic heating system. Because the heat recovery gives energy savings to both the heated zones and the cooled zones, the effective COP may increase significantly.[16]

4.3.2 Market Status and Ideal Site Characteristics

Due to the VRF system's ability to efficiently provide tight zone-level temperature control to buildings with many zones, they are best suited to larger commercial and residential buildings that benefit from a high degree of individual zone control. Examples include offices, hospitals, large multifamily buildings, nursing homes, strip malls, and schools. If zones in the building are expected to have highly variable cooling/heating loads, or if heat for DHW is desired, it may be worth paying a premium for a VRF system with heat recovery. Costs for VRF systems are highly variable, and depend on many site-specific conditions. However, studies indicate that a VRF system typically costs 5-20% more than an equivalent standard HVAC system.[17] VRF systems are also a highly cost-effective retrofit on commercial buildings without a current cooling system.

Like ductless mini-split systems, the larger VRF systems also have much higher usage in Asia and Europe than in the U.S. In Japan, for example, VRF systems are used in about 50% of medium-sized commercial buildings, and 33% of large commercial buildings (greater than 70,000 square feet). Although U.S. penetration is starting to increase in sectors such as luxury high rises in New York, overall market share is very low. In 2007, less than 10,000 VRF systems were installed in the US.[18]

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[16]   Bhatia 2011

[17]   Ibid.

[18]   Amarnath and Blatt 2008

4.3.3 Market Barriers

Market Barriers to widespread adoption of VRF systems in the U.S. include:

- **High first cost**: In countries where VRF systems are well established, the higher equipment costs from VRFs are somewhat offset by lower labor costs. This is less true in the US, where most contractors are not familiar with VRFs.
- **Poor understanding of savings:** There is not much reliable third-party data available examining the performance and cost data of VRF systems in the U.S. Until this data is more widely available and accepted, risk-averse contractors and builders are unlikely to specify a VRF system.
- **Concerns about refrigerant leaks**: Because VRF systems have long lengths of refrigerant pipes, there has been concern relating to the potential for leaks. Installation must be performed in accordance with ASHRAE Standard 15-2007. As more contractors gain experience safely installing long refrigerant lines, this barrier should diminish in importance.
- **Manufacturer presence:** U.S. manufacturer presence and support for VRF systems has traditionally been very limited. This trend seems to be changing in recent years as Japanese manufactures have moved into the U.S. market space.
- **Ventilation requirements**: Depending on the design, a building with a VRF system may also need a dedicated ventilation system to comply with ASHRAE standard 62 requirements. This offsets part of the advantage of using a VRF system, as compared to systems that do not require dedicated outside air.
- **Lack of test rating procedures:** While Japan and Europe have well established rating systems for VRFs, there are no code compliance procedures certified by the ARI and approved by U.S. Department of Energy.

4.4 Ground-Source Heat Pumps

4.4.1 Overview

GSHPs use either the ground, or a nearby lake or other body of water as a heat reservoir. Because the ground temperature is relatively stable throughout the year, GSHPs provide an efficiency advantage over air-source heat pumps and have much better cold climate performance than air-source heat pumps. This advantage is demonstrated by their popularity in Scandinavian countries – 30% of Swedish houses have GSHPs, and there are an estimated 15,000 GSHP systems in Norway and 46,000 in Finland.[19]

There are two broad categories of GSHPs: open-loop systems and closed-loop systems. Open-loop systems pump water from a nearby lake, ocean, or river into a heat exchanger in the heat pump, and then discharge the water into the same body of water. Although installation costs are typically cheaper than for closed-loop systems, the site must be situated nearby an appropriate body of water. Local codes regarding groundwater discharge may further restrict possible installation sites.

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[19] Denali Commission 2011

A closed-loop system pumps a fluid with a low freezing temperature through the ground or body of water. As the fluid gets pumped through the pipe, it exchanges heat with the surrounding ground. The longer the pipe, the more heat will be exchanged; typical estimates call for about 1,000 feet per ton of heat pump capacity for horizontal loops, and 300-400 feet per ton for vertical loops. Horizontal systems are generally cheaper to install, and more cost-effective for residential installations, if sufficient space is available. In these systems, the piping is installed over a fairly large area, at a depth of between 4 and 6 feet below ground. Cold climate installations may need to go in at the deeper end of this range in order to avoid ground frost in the winter. Vertical systems are used more often for larger systems, where the amount of land area required for a horizontal system would be prohibitive. Vertical systems are far more expensive than horizontal systems, as they require piping to depths of 100 to 400 feet.

In recent years, direct exchange (DX) ground-source heat pumps have been gaining popularity. DX systems pump refrigerant directly through the ground loop, instead of using a secondary water/glycol loop. DX systems eliminate the water-to-refrigerant heat exchanger as well as water loop pumping, making them generally cheaper and more efficient than traditional GSHPs. However, there are potentially serious environmental concerns relating to the potential leakage of refrigerant into the groundwater, and the high cost of repairing such leaks.

Desuperheaters: A desuperheater is an auxiliary heat exchanger that captures heat from the hot refrigerant as it leaves the heat pump compressor and transfers it to the domestic hot water. Although desuperheaters are available for standard air source heat pumps and even central AC units, they most commonly come with GSHPs. Desuperheater costs range from around $400-$700, and can meet up to 50% of annual water heating demand.[20, 21, 22]

4.4.2 Market Status and Ideal Site Characteristics

GSHP installations in the U.S. have been rising rapidly in recent years. In 2005, there were only about 600,000 GHP units installed in the U.S.; however 2008 and 2009 both saw annual shipments of over 100,000, equaling more than 400,000 tons of capacity per year.[23, 24]

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[20]   Builder Guide 2003
[21]   Olszewski and Fontana, 1983,
[22]   http://www.igshpa.okstate.edu/geothermal/faq.htm
[23]   Liu 2010
[24]   Navigant Consulting, Inc. 2012

Despite the increase in installations, high first cost continues to be a significant barrier to GSHP penetration. Costs for GSHPs are highly variable, and dependent both on the soil type in the area and on the availability of drillers with the type of experience needed to drill for GSHP systems. Also, incremental costs tend to get smaller as the system gets larger (for the same type of GSHP system). A survey of the market in the Pacific Northwest found installation costs for a 2,000-square foot home to be between $10,000 and $14,000, and costs for a 4,000-square foot home to be $12,000 to $18,000.[25] For this reason, most systems installed are going into homes larger than 3,000 square feet. However, the same survey found that, if equipment were sold at cost, GSHPs would only be slightly more expensive than ASHPs for homes as small as 2,000 square feet. In contrast, a study from Oak Ridge National Laboratory estimated that the incremental cost of retrofitting a 3-ton GSHP system at more than double the costs of installing a CAC and gas furnace.[26]

Commercial installations of GSHPs are rarer than residential installations, due to more complex systems and higher costs. Cost premiums for commercial installations are also highly variable, but estimated at between 0 and 100%.[27] An ASHRAE study of a sample of GSHPs in commercial installation found an average installed cost of $7,694 per ton. However, the study also found that the ground loop portion only made up 25.5% of the total costs, implying that there is likely significant room for cost reduction on the actual HVAC components of GSHPs.

4.4.3 Market Barriers

The largest barrier to GSHP adoption is high first costs, as previously discussed. The two main factors contributing to higher first costs are complexities associated with the ground loop, and limited production volume of the other parts. One would expect both of these two go down as GSHPs gain market acceptance. Other barriers include:

- **Complexity**: The need for a ground loop adds significant complexity and risk to GSHP installations, and may necessitate site-specific design.
- **Economics compared to ASHPs**: Top of the line ASHPs may have more attractive economics than GSHPs, despite higher total savings from GSHPs. It may be especially true as advances in ASHPs make them more suitable for colder climates. The lifetime and payback period for GSHPs are also typically longer than for ASHPs.
- **Site limitations**: GSHP installation may be infeasible for a specific location, based on soil type, proximity to water, space constraints, and availability of drillers.
- **Limited number of qualified, trained installers**.
- **Potential for glycol or refrigerant leaks**.

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[25]   Regional Economic Research, Inc. 2010

[26]   Liu 2010

[27]   Regional Economic Research, Inc. 2010

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Appendix A: Measure Screening, Year One

Table A-1 shows the Total Resource costs, benefits, net benefits, and benefit-cost ratio (BCR) for each heat pump measure.

Measures with "oil" in the name actually refer to aggregated petroleum fuels (oil, kerosene, and propane).

Gray shading of BCRs indicates measures that did not pass cost-effectiveness in year one.

Primary Fuel: G = Gas, O = Petroleum Fuels, E = Electric

Zone: NYC = New York City, LI = Long Island, HV = Hudson Valley, UP = Upstate

Market: MD = Market Driven, RET = Retrofit, REPL = Natural Replacement

Table A-1. Total Resources Costs, Benefits, Net Benefits, and Benefit-Cost Ratio for Each Heat Pump Measure

#	Measure Name	Primary Fuel	Zone	Sector	Market	Total Resource Benefits	Total Resource Costs	Total Resource Net Benefits	Total Resource BCR
1	Com Boiler/unitary AC to ASHP - Gas Heat	G	NYC	Com	RET	$ 2,874,508,285	$ 11,086,130,944	$ (8,211,622,659)	0.26
2	Com Boiler/unitary AC to ASHP - Gas Heat	G	NYC	Com	NC	$ 12,957,458	$ 69,602,727	$ (56,645,270)	0.19
5	Com Boiler/unitary AC to ASHP - Oil Heat	O	NYC	Com	RET	$ 2,743,813,229	$ 2,421,472,288	$ 322,340,941	1.13
6	Com Boiler/unitary AC to ASHP - Oil Heat	O	NYC	Com	NC	$ 57,505,552	$ 24,507,670	$ 32,997,882	2.35
9	Com Boiler/Chiller to ASHP - Gas Heat	G	NYC	Com	RET	$ 19,979,059	$ 7,000,551,632	$ (6,980,572,574)	0.00
10	Com Boiler/Chiller to ASHP - Gas Heat	G	NYC	Com	NC	$ (15,722,575)	$ (25,112,517)	$ 9,389,942	0.63
13	Com Boiler/Chiller to ASHP - Oil Heat	O	NYC	Com	RET	$ 1,062,340,332	$ 1,529,085,473	$ (466,745,141)	0.69
14	Com Boiler/Chiller to ASHP - Oil Heat	O	NYC	Com	NC	$ 23,903,488	$ (9,206,445)	$ 33,109,933	-2.60
17	Com Boiler/CAC to DMSHP - Gas Heat	G	NYC	Com	RET	$ 189,322,479	$ 1,037,107,741	$ (847,785,262)	0.18
18	Com Boiler/CAC to DMSHP - Gas Heat	G	NYC	Com	NC	$ 1,556,817	$ 11,796,307	$ (10,239,490)	0.13
21	Com Boiler/CAC to DMSHP - Oil Heat	O	NYC	Com	RET	$ 138,205,941	$ 226,528,774	$ (88,322,833)	0.61
22	Com Boiler/CAC to DMSHP - Oil Heat	O	NYC	Com	NC	$ 3,002,554	$ 4,059,062	$ (1,056,509)	0.74
25	Com Boiler/RoomAC to DMSHP - Gas Heat	G	NYC	Com	RET	$ 312,368,837	$ 1,703,647,905	$ (1,391,279,068)	0.18
26	Com Boiler/RoomAC to DMSHP - Gas Heat	G	NYC	Com	NC	$ 3,521,363	$ 23,758,646	$ (20,237,283)	0.15
29	Com Boiler/RoomAC to DMSHP - Oil Heat	O	NYC	Com	RET	$ 244,558,122	$ 372,116,856	$ (127,558,734)	0.66
30	Com Boiler/RoomAC to DMSHP - Oil Heat	O	NYC	Com	NC	$ 5,206,662	$ 8,108,022	$ (2,901,359)	0.64
33	Com Boiler/Unitary AC to VRF - Gas Heat	G	NYC	Com	RET	$ 4,614,734,405	$ 13,283,680,919	$ (8,668,946,514)	0.35

#	Measure Name	Primary Fuel	Zone	Sector	Market	Total Resource Benefits	Total Resource Costs	Total Resource Net Benefits	Total Resource BCR
34	Com Boiler/Unitary AC to VRF - Gas Heat	G	NYC	Com	NC	$ 48,341,598	$ 123,208,392	$ (74,866,793)	0.39
37	Com Boiler/Unitary AC to VRF - Oil Heat	O	NYC	Com	RET	$ 3,123,919,629	$ 2,901,468,996	$ 222,450,632	1.08
38	Com Boiler/Unitary AC to VRF - Oil Heat	O	NYC	Com	NC	$ 65,794,560	$ 42,324,365	$ 23,470,195	1.55
41	Com Boiler/Chiller to VRF - Gas Heat	G	NYC	Com	RET	$ 1,444,159,596	$ 8,183,736,610	$ (6,739,577,014)	0.18
42	Com Boiler/Chiller to VRF - Gas Heat	G	NYC	Com	NC	$ 10,709,287	$ 14,945,582	$ (4,236,295)	0.72
45	Com Boiler/Chiller to VRF - Oil Heat	O	NYC	Com	RET	$ 1,373,414,928	$ 1,787,520,959	$ (414,106,030)	0.77
46	Com Boiler/Chiller to VRF - Oil Heat	O	NYC	Com	NC	$ 29,956,968	$ 5,243,984	$ 24,712,984	5.71
49	Com Boiler/Unitary AC to GSHP - Gas Heat	G	NYC	Com	RET	$ 5,148,499,457	$ 37,959,494,753	$ (32,810,995,296)	0.14
50	Com Boiler/Unitary AC to GSHP - Gas Heat	G	NYC	Com	NC	$ 43,871,037	$ 295,178,784	$ (251,307,747)	0.15
53	Com Boiler/Unitary AC to GSHP - Oil Heat	O	NYC	Com	RET	$ 4,611,380,860	$ 8,291,248,323	$ (3,679,867,463)	0.56
54	Com Boiler/Unitary AC to GSHP - Oil Heat	O	NYC	Com	NC	$ 93,303,606	$ 100,364,364	$ (7,060,758)	0.93
57	Com Boiler/Chiller to GSHP - Gas Heat	G	NYC	Com	RET	$ 926,413,969	$ 23,275,179,701	$ (22,348,765,732)	0.04
58	Com Boiler/Chiller to GSHP - Gas Heat	G	NYC	Com	NC	$ (6,468,564)	$ 116,299,970	$ (122,768,534)	-0.06
61	Com Boiler/Chiller to GSHP - Oil Heat	O	NYC	Com	RET	$ 1,945,764,262	$ 5,083,847,821	$ (3,138,083,558)	0.38
62	Com Boiler/Chiller to GSHP - Oil Heat	O	NYC	Com	NC	$ 38,734,031	$ 40,105,603	$ (1,371,571)	0.97
65	High-eff HP CEE Tier II -Cool	E	NYC	Com	RET	$ 65,617,863	$ 101,386,066	$ (35,768,203)	0.65
66	High-eff HP CEE Tier II -Cool	E	NYC	Com	NC	$ 527,180	$ 230,508	$ 296,672	2.29
67	High-eff HP CEE Tier II -Cool	E	NYC	Com	REPL	$ 2,094,593	$ 916,817	$ 1,177,777	2.28
71	Com Heat Pump Water Htr replace Oil	O	NYC	Com	NC	$ 18,411,733	$ 5,555,866	$ 12,855,866	3.31
72	Com Heat Pump Water Htr replace Oil	O	NYC	Com	REPL	$ 61,895,470	$ 18,677,382	$ 43,218,087	3.31
73	Res FF Heat/CAC to ASHP - Gas Heat	G	NYC	Res	RET	$ 643,042,026	$ 6,235,626,329	$ (5,592,584,304)	0.10
74	Res FF Heat/CAC to ASHP - Gas Heat	G	NYC	Res	NC	$ 7,829,108	$ 28,520,347	$ (20,691,239)	0.27
77	Res FF Heat/CAC to ASHP - Oil Heat	O	NYC	Res	RET	$ 3,008,407,013	$ 1,872,329,000	$ 1,136,078,013	1.61
78	Res FF Heat/CAC to ASHP - Oil Heat	O	NYC	Res	NC	$ 51,032,630	$ 9,476,183	$ 41,556,447	5.39
81	Res FFHeat/CAC to DMSHP - Gas Heat	G	NYC	Res	RET	$ 2,623,678,611	$ 11,005,734,067	$ (8,382,055,455)	0.24
82	Res FFHeat/CAC to DMSHP - Gas Heat	G	NYC	Res	NC	$ 22,207,776	$ 107,050,230	$ (84,842,454)	0.21
85	Res FFHeat/CAC to DMSHP - Oil Heat	O	NYC	Res	RET	$ 3,456,943,109	$ 3,304,616,725	$ 152,326,383	1.05
86	Res FFHeat/CAC to DMSHP - Oil Heat	O	NYC	Res	NC	$ 55,648,101	$ 35,527,318	$ 20,120,783	1.57
89	Res FFHeat/Room AC to DMSHP - Gas Heat	G	NYC	Res	RET	$ 1,555,795,304	$ 7,128,368,450	$ (5,572,573,145)	0.22
90	Res FFHeat/Room AC to DMSHP - Gas Heat	G	NYC	Res	NC	$ 16,266,924	$ 92,159,360	$ (75,892,436)	0.18
93	Res FFHeat/Room AC to DMSHP - Oil Heat	O	NYC	Res	RET	$ 2,297,109,407	$ 2,140,386,589	$ 156,722,818	1.07
94	Res FFHeat/Room AC to DMSHP - Oil Heat	O	NYC	Res	NC	$ 36,721,308	$ 30,566,119	$ 6,155,189	1.20
97	Res FF Heat/CAC to GSHP - Gas Heat	G	NYC	Res	RET	$ 4,683,666,534	$ 20,724,689,928	$ (16,041,023,394)	0.23
98	Res FF Heat/CAC to GSHP - Gas Heat	G	NYC	Res	NC	$ 39,426,609	$ 133,195,573	$ (93,768,963)	0.30
101	Res FF Heat/CAC to GSHP - Oil Heat	O	NYC	Res	RET	$ 6,026,791,357	$ 6,222,861,333	$ (196,069,976)	0.97

#	Measure Name	Primary Fuel	Zone	Sector	Market	Total Resource Benefits	Total Resource Costs	Total Resource Net Benefits	Total Resource BCR
102	Res FF Heat/CAC to GSHP - Oil Heat	O	NYC	Res	NC	$ 92,469,053	$ 44,171,221	$ 48,297,832	2.09
105	Res Resist Heat/Room AC to DMSHP -Heat	E	NYC	Res	RET	$ 218,825,744	$ 151,013,938	$ 67,811,806	1.45
106	Res Resist Heat/Room AC to DMSHP -Heat	E	NYC	Res	NC	$ 4,108,647	$ 1,843,575	$ 2,265,072	2.23
109	Air Source Heat Pump ESTAR -Cool	E	NYC	Res	NC	$ 78,245	$ 97,875	$ (19,629)	0.80
110	Air Source Heat Pump ESTAR -Cool	E	NYC	Res	REPL	$ 291,378	$ 364,475	$ (73,097)	0.80
113	Res Heat Pump Water Htr replace Oil	O	NYC	Res	NC	$ 18,641,660	$ 5,330,303	$ 13,311,357	3.50
114	Res Heat Pump Water Htr replace Oil	O	NYC	Res	REPL	$ 91,557,365	$ 26,179,453	$ 65,377,912	3.50
116	Com Boiler/unitary AC to ASHP - Gas Heat	G	LI	Com	RET	$ 719,923,009	$ 2,427,998,945	$ (1,708,075,936)	0.30
117	Com Boiler/unitary AC to ASHP - Gas Heat	G	LI	Com	NC	$ 2,191,693	$ 9,079,646	$ (6,887,952)	0.24
120	Com Boiler/unitary AC to ASHP - Oil Heat	O	LI	Com	RET	$ 1,074,518,665	$ 755,210,678	$ 319,307,987	1.42
121	Com Boiler/unitary AC to ASHP - Oil Heat	O	LI	Com	NC	$ 9,284,268	$ 2,839,555	$ 6,444,713	3.27
124	Com Boiler/Chiller to ASHP - Gas Heat	G	LI	Com	RET	$ 80,032,998	$ 1,440,966,533	$ (1,360,933,535)	0.06
125	Com Boiler/Chiller to ASHP - Gas Heat	G	LI	Com	NC	$ (3,458,459)	$ (3,606,264)	$ 147,805	0.96
128	Com Boiler/Chiller to ASHP - Oil Heat	O	LI	Com	RET	$ 450,189,691	$ 448,201,724	$ 1,987,967	1.00
129	Com Boiler/Chiller to ASHP - Oil Heat	O	LI	Com	NC	$ 3,225,552	$ (1,129,042)	$ 4,354,593	-2.86
132	Com Boiler/CAC to DMSHP - Gas Heat	G	LI	Com	RET	$ 43,959,708	$ 242,173,728	$ (198,214,020)	0.18
133	Com Boiler/CAC to DMSHP - Gas Heat	G	LI	Com	NC	$ 322,890	$ 1,813,111	$ (1,490,221)	0.18
136	Com Boiler/CAC to DMSHP - Oil Heat	O	LI	Com	RET	$ 53,378,186	$ 75,326,303	$ (21,948,118)	0.71
137	Com Boiler/CAC to DMSHP - Oil Heat	O	LI	Com	NC	$ 530,421	$ 566,728	$ (36,307)	0.94
140	Com Boiler/RoomAC to DMSHP - Gas Heat	G	LI	Com	RET	$ 69,263,083	$ 398,676,847	$ (329,413,764)	0.17
141	Com Boiler/RoomAC to DMSHP - Gas Heat	G	LI	Com	NC	$ 728,243	$ 3,767,546	$ (3,039,302)	0.19
144	Com Boiler/RoomAC to DMSHP - Oil Heat	O	LI	Com	RET	$ 92,426,430	$ 124,005,413	$ (31,578,983)	0.75
145	Com Boiler/RoomAC to DMSHP - Oil Heat	O	LI	Com	NC	$ 943,162	$ 1,177,421	$ (234,259)	0.80
148	Com Boiler/Unitary AC to VRF - Gas Heat	G	LI	Com	RET	$ 1,046,896,382	$ 3,117,526,190	$ (2,070,629,808)	0.34
149	Com Boiler/Unitary AC to VRF - Gas Heat	G	LI	Com	NC	$ 8,775,517	$ 19,160,436	$ (10,384,919)	0.46
152	Com Boiler/Unitary AC to VRF - Oil Heat	O	LI	Com	RET	$ 1,176,221,256	$ 969,682,904	$ 206,538,352	1.21
153	Com Boiler/Unitary AC to VRF - Oil Heat	O	LI	Com	NC	$ 11,333,213	$ 5,989,024	$ 5,344,189	1.89
156	Com Boiler/Chiller to VRF - Gas Heat	G	LI	Com	RET	$ 342,424,213	$ 1,844,313,438	$ (1,501,889,226)	0.19
157	Com Boiler/Chiller to VRF - Gas Heat	G	LI	Com	NC	$ 1,496,243	$ 2,165,493	$ (669,251)	0.69
160	Com Boiler/Chiller to VRF - Oil Heat	O	LI	Com	RET	$ 531,804,491	$ 573,659,723	$ (41,855,232)	0.93
161	Com Boiler/Chiller to VRF - Oil Heat	O	LI	Com	NC	$ 4,767,222	$ 677,223	$ 4,089,999	7.04
164	Com Boiler/Unitary AC to GSHP - Gas Heat	G	LI	Com	RET	$ 1,208,533,504	$ 8,931,217,182	$ (7,722,683,678)	0.14
165	Com Boiler/Unitary AC to GSHP - Gas Heat	G	LI	Com	NC	$ 11,159,305	$ 47,047,951	$ (35,888,646)	0.24
168	Com Boiler/Unitary AC to GSHP - Oil Heat	O	LI	Com	RET	$ 1,779,710,485	$ 2,777,987,446	$ (998,276,961)	0.64
169	Com Boiler/Unitary AC to GSHP - Oil Heat	O	LI	Com	NC	$ 17,657,012	$ 14,702,137	$ 2,954,875	1.20

#	Measure Name	Primary Fuel	Zone	Sector	Market	Total Resource Benefits	Total Resource Costs	Total Resource Net Benefits	Total Resource BCR
172	Com Boiler/Chiller to GSHP - Gas Heat	G	LI	Com	RET	$ 271,804,498	$ 5,292,995,462	$ (5,021,190,964)	0.05
173	Com Boiler/Chiller to GSHP - Gas Heat	G	LI	Com	NC	$ 658,739	$ 17,647,779	$ (16,989,040)	0.04
176	Com Boiler/Chiller to GSHP - Oil Heat	O	LI	Com	RET	$ 786,445,377	$ 1,646,346,141	$ (859,900,764)	0.48
177	Com Boiler/Chiller to GSHP - Oil Heat	O	LI	Com	NC	$ 7,294,982	$ 5,516,471	$ 1,778,512	1.32
180	High-eff HP CEE Tier II -Cool	E	LI	Com	RET	$ 19,258,690	$ 40,225,690	$ (20,967,000)	0.48
181	High-eff HP CEE Tier II -Cool	E	LI	Com	NC	$ 170,530	$ 103,903	$ 66,627	1.64
182	High-eff HP CEE Tier II -Cool	E	LI	Com	REPL	$ 632,885	$ 385,411	$ 247,474	1.64
186	Com Heat Pump Water Htr replace Oil	O	LI	Com	NC	$ 2,889,676	$ 737,457	$ 2,152,218	3.92
187	Com Heat Pump Water Htr replace Oil	O	LI	Com	REPL	$ 23,823,851	$ 6,079,947	$ 17,743,904	3.92
188	Res FF Heat/CAC to ASHP - Gas Heat	G	LI	Res	RET	$ 124,652,084	$ 1,805,929,436	$ (1,681,277,352)	0.07
189	Res FF Heat/CAC to ASHP - Gas Heat	G	LI	Res	NC	$ 1,485,928	$ 8,244,626	$ (6,758,699)	0.18
192	Res FF Heat/CAC to ASHP - Oil Heat	O	LI	Res	RET	$ 1,665,616,178	$ 1,061,154,494	$ 604,461,683	1.57
193	Res FF Heat/CAC to ASHP - Oil Heat	O	LI	Res	NC	$ 28,364,956	$ 5,360,683	$ 23,004,273	5.29
196	Res FFHeat/CAC to DMSHP - Gas Heat	G	LI	Res	RET	$ 678,003,770	$ 3,191,236,488	$ (2,513,232,718)	0.21
197	Res FFHeat/CAC to DMSHP - Gas Heat	G	LI	Res	NC	$ 5,034,674	$ 30,990,130	$ (25,955,457)	0.16
200	Res FFHeat/CAC to DMSHP - Oil Heat	O	LI	Res	RET	$ 1,908,100,059	$ 1,875,153,522	$ 32,946,537	1.02
201	Res FFHeat/CAC to DMSHP - Oil Heat	O	LI	Res	NC	$ 30,601,512	$ 20,125,576	$ 10,475,936	1.52
204	Res FFHeat/Room AC to DMSHP - Gas Heat	G	LI	Res	RET	$ 387,129,222	$ 2,067,278,957	$ (1,680,149,735)	0.19
205	Res FFHeat/Room AC to DMSHP - Gas Heat	G	LI	Res	NC	$ 3,682,482	$ 26,711,604	$ (23,029,122)	0.14
208	Res FFHeat/Room AC to DMSHP - Oil Heat	O	LI	Res	RET	$ 1,262,516,395	$ 1,214,722,077	$ 47,794,317	1.04
209	Res FFHeat/Room AC to DMSHP - Oil Heat	O	LI	Res	NC	$ 20,131,864	$ 17,335,646	$ 2,796,218	1.16
212	Res FF Heat/CAC to GSHP - Gas Heat	G	LI	Res	RET	$ 1,122,755,969	$ 6,013,926,925	$ (4,891,170,956)	0.19
213	Res FF Heat/CAC to GSHP - Gas Heat	G	LI	Res	NC	$ 7,303,777	$ 38,593,891	$ (31,290,114)	0.19
216	Res FF Heat/CAC to GSHP - Oil Heat	O	LI	Res	RET	$ 3,277,072,402	$ 3,533,751,352	$ (256,678,951)	0.93
217	Res FF Heat/CAC to GSHP - Oil Heat	O	LI	Res	NC	$ 49,775,632	$ 25,044,096	$ 24,731,536	1.99
220	Res Resist Heat/Room AC to DMSHP -Heat	E	LI	Res	RET	$ 97,895,323	$ 73,559,704	$ 24,335,619	1.33
221	Res Resist Heat/Room AC to DMSHP -Heat	E	LI	Res	NC	$ 1,846,600	$ 898,208	$ 948,392	2.06
224	Air Source Heat Pump ESTAR -Cool	E	LI	Res	NC	$ 27,095	$ 39,472	$ (12,377)	0.69
225	Air Source Heat Pump ESTAR -Cool	E	LI	Res	REPL	$ 100,899	$ 146,988	$ (46,090)	0.69
228	Res Heat Pump Water Htr replace Oil	O	LI	Res	NC	$ 10,853,291	$ 2,690,508	$ 8,162,784	4.03
229	Res Heat Pump Water Htr replace Oil	O	LI	Res	REPL	$ 53,305,271	$ 13,214,262	$ 40,091,010	4.03
231	Com Boiler/unitary AC to ASHP - Gas Heat	G	HV	Com	RET	$ 407,771,252	$ 871,572,220	$ (463,800,969)	0.47
232	Com Boiler/unitary AC to ASHP - Gas Heat	G	HV	Com	NC	$ 1,636,180	$ 3,076,503	$ (1,440,323)	0.53
235	Com Boiler/unitary AC to ASHP - Oil Heat	O	HV	Com	RET	$ 835,371,076	$ 465,340,499	$ 370,030,577	1.80
236	Com Boiler/unitary AC to ASHP - Oil Heat	O	HV	Com	NC	$ 9,077,233	$ 2,043,258	$ 7,033,975	4.44

#	Measure Name	Primary Fuel	Zone	Sector	Market	Total Resource Benefits	Total Resource Costs	Total Resource Net Benefits	Total Resource BCR
239	Com Boiler/Chiller to ASHP - Gas Heat	G	HV	Com	RET	$ 43,265,251	$ 473,994,930	$ (430,729,680)	0.09
240	Com Boiler/Chiller to ASHP - Gas Heat	G	HV	Com	NC	$ (1,508,467)	$ (1,367,235)	$ (141,232)	1.10
243	Com Boiler/Chiller to ASHP - Oil Heat	O	HV	Com	RET	$ 331,928,829	$ 253,070,293	$ 78,858,536	1.31
244	Com Boiler/Chiller to ASHP - Oil Heat	O	HV	Com	NC	$ 3,296,446	$ (952,014)	$ 4,248,460	-3.46
247	Com Boiler/CAC to DMSHP - Gas Heat	G	HV	Com	RET	$ 26,674,090	$ 93,539,558	$ (66,865,468)	0.29
248	Com Boiler/CAC to DMSHP - Gas Heat	G	HV	Com	NC	$ 198,471	$ 698,202	$ (499,731)	0.28
251	Com Boiler/CAC to DMSHP - Oil Heat	O	HV	Com	RET	$ 43,378,554	$ 49,941,639	$ (6,563,085)	0.87
252	Com Boiler/CAC to DMSHP - Oil Heat	O	HV	Com	NC	$ 511,677	$ 453,319	$ 58,357	1.13
255	Com Boiler/RoomAC to DMSHP - Gas Heat	G	HV	Com	RET	$ 41,918,832	$ 154,378,390	$ (112,459,558)	0.27
256	Com Boiler/RoomAC to DMSHP - Gas Heat	G	HV	Com	NC	$ 427,894	$ 1,480,035	$ (1,052,142)	0.29
259	Com Boiler/RoomAC to DMSHP - Oil Heat	O	HV	Com	RET	$ 73,852,372	$ 82,424,056	$ (8,571,684)	0.90
260	Com Boiler/RoomAC to DMSHP - Oil Heat	O	HV	Com	NC	$ 904,642	$ 953,754	$ (49,112)	0.95
263	Com Boiler/Unitary AC to VRF - Gas Heat	G	HV	Com	RET	$ 575,656,029	$ 1,203,269,365	$ (627,613,336)	0.48
264	Com Boiler/Unitary AC to VRF - Gas Heat	G	HV	Com	NC	$ 4,678,719	$ 7,404,696	$ (2,725,977)	0.63
267	Com Boiler/Unitary AC to VRF - Oil Heat	O	HV	Com	RET	$ 925,006,317	$ 642,436,683	$ 282,569,634	1.44
268	Com Boiler/Unitary AC to VRF - Oil Heat	O	HV	Com	NC	$ 10,736,831	$ 4,816,197	$ 5,920,634	2.23
271	Com Boiler/Chiller to VRF - Gas Heat	G	HV	Com	RET	$ 180,645,216	$ 671,971,503	$ (491,326,287)	0.27
272	Com Boiler/Chiller to VRF - Gas Heat	G	HV	Com	NC	$ 789,225	$ 798,083	$ (8,858)	0.99
275	Com Boiler/Chiller to VRF - Oil Heat	O	HV	Com	RET	$ 405,277,268	$ 358,771,823	$ 46,505,444	1.13
276	Com Boiler/Chiller to VRF - Oil Heat	O	HV	Com	NC	$ 4,540,784	$ 531,537	$ 4,009,247	8.54
279	Com Boiler/Unitary AC to GSHP - Gas Heat	G	HV	Com	RET	$ 835,779,815	$ 3,492,000,770	$ (2,656,220,954)	0.24
280	Com Boiler/Unitary AC to GSHP - Gas Heat	G	HV	Com	NC	$ 7,563,794	$ 18,513,041	$ (10,949,247)	0.41
283	Com Boiler/Unitary AC to GSHP - Oil Heat	O	HV	Com	RET	$ 1,465,093,419	$ 1,864,411,625	$ (399,318,206)	0.79
284	Com Boiler/Unitary AC to GSHP - Oil Heat	O	HV	Com	NC	$ 17,251,203	$ 11,891,369	$ 5,359,834	1.45
287	Com Boiler/Chiller to GSHP - Gas Heat	G	HV	Com	RET	$ 271,407,471	$ 1,985,108,591	$ (1,713,701,120)	0.14
288	Com Boiler/Chiller to GSHP - Gas Heat	G	HV	Com	NC	$ 1,573,069	$ 6,736,093	$ (5,163,024)	0.23
291	Com Boiler/Chiller to GSHP - Oil Heat	O	HV	Com	RET	$ 654,338,377	$ 1,059,867,903	$ (405,529,526)	0.62
292	Com Boiler/Chiller to GSHP - Oil Heat	O	HV	Com	NC	$ 7,369,025	$ 4,382,415	$ 2,986,610	1.68
295	High-eff HP CEE Tier II -Cool	E	HV	Com	RET	$ 16,606,926	$ 40,525,412	$ (23,918,486)	0.41
296	High-eff HP CEE Tier II -Cool	E	HV	Com	NC	$ 137,820	$ 92,915	$ 44,905	1.48
297	High-eff HP CEE Tier II -Cool	E	HV	Com	REPL	$ 597,562	$ 403,342	$ 194,220	1.48
301	Com Heat Pump Water Htr replace Oil	O	HV	Com	NC	$ 2,780,507	$ 691,738	$ 2,088,769	4.02
302	Com Heat Pump Water Htr replace Oil	O	HV	Com	REPL	$ 18,018,075	$ 4,482,558	$ 13,535,517	4.02
303	Res FF Heat/CAC to ASHP - Gas Heat	G	HV	Res	RET	$ 123,823,486	$ 797,559,420	$ (673,735,934)	0.16
304	Res FF Heat/CAC to ASHP - Gas Heat	G	HV	Res	NC	$ 1,685,165	$ 3,615,042	$ (1,929,877)	0.47

#	Measure Name	Primary Fuel	Zone	Sector	Market	Total Resource Benefits	Total Resource Costs	Total Resource Net Benefits	Total Resource BCR
307	Res FF Heat/CAC to ASHP - Oil Heat	O	HV	Res	RET	$ 1,350,665,527	$ 879,166,438	$ 471,499,089	1.54
308	Res FF Heat/CAC to ASHP - Oil Heat	O	HV	Res	NC	$ 22,942,645	$ 4,408,957	$ 18,533,688	5.20
311	Res FFHeat/CAC to DMSHP - Gas Heat	G	HV	Res	RET	$ 409,082,043	$ 1,416,221,555	$ (1,007,139,512)	0.29
312	Res FFHeat/CAC to DMSHP - Gas Heat	G	HV	Res	NC	$ 3,253,801	$ 13,676,865	$ (10,423,065)	0.24
315	Res FFHeat/CAC to DMSHP - Oil Heat	O	HV	Res	RET	$ 1,597,228,992	$ 1,561,130,656	$ 36,098,336	1.02
316	Res FFHeat/CAC to DMSHP - Oil Heat	O	HV	Res	NC	$ 24,783,650	$ 16,651,967	$ 8,131,684	1.49
319	Res FFHeat/Room AC to DMSHP - Gas Heat	G	HV	Res	RET	$ 228,400,630	$ 917,837,189	$ (689,436,559)	0.25
320	Res FFHeat/Room AC to DMSHP - Gas Heat	G	HV	Res	NC	$ 2,337,781	$ 11,836,518	$ (9,498,737)	0.20
323	Res FFHeat/Room AC to DMSHP - Oil Heat	O	HV	Res	RET	$ 1,040,982,794	$ 1,011,751,140	$ 29,231,654	1.03
324	Res FFHeat/Room AC to DMSHP - Oil Heat	O	HV	Res	NC	$ 16,354,982	$ 14,397,997	$ 1,956,984	1.14
327	Res FF Heat/CAC to GSHP - Gas Heat	G	HV	Res	RET	$ 635,173,345	$ 2,677,236,611	$ (2,042,063,266)	0.24
328	Res FF Heat/CAC to GSHP - Gas Heat	G	HV	Res	NC	$ 4,115,902	$ 17,103,518	$ (12,987,616)	0.24
331	Res FF Heat/CAC to GSHP - Oil Heat	O	HV	Res	RET	$ 2,694,875,741	$ 2,951,173,941	$ (256,298,200)	0.91
332	Res FF Heat/CAC to GSHP - Oil Heat	O	HV	Res	NC	$ 39,287,112	$ 20,801,222	$ 18,485,890	1.89
335	Res Resist Heat/Room AC to DMSHP -Heat	E	HV	Res	RET	$ 94,196,782	$ 74,649,937	$ 19,546,844	1.26
336	Res Resist Heat/Room AC to DMSHP -Heat	E	HV	Res	NC	$ 1,763,347	$ 906,670	$ 856,677	1.94
339	Air Source Heat Pump ESTAR -Cool	E	HV	Res	NC	$ 22,400	$ 35,173	$ (12,773)	0.64
340	Air Source Heat Pump ESTAR -Cool	E	HV	Res	REPL	$ 83,415	$ 130,981	$ (47,566)	0.64
343	Res Heat Pump Water Htr replace Oil	O	HV	Res	NC	$ 7,944,914	$ 1,926,406	$ 6,018,508	4.12
344	Res Heat Pump Water Htr replace Oil	O	HV	Res	REPL	$ 39,020,957	$ 9,461,427	$ 29,559,530	4.12
346	Com Boiler/unitary AC to ASHP - Gas Heat	G	UP	Com	RET	$ 1,234,199,298	$ 3,117,768,246	$ (1,883,568,948)	0.40
347	Com Boiler/unitary AC to ASHP - Gas Heat	G	UP	Com	NC	$ 2,709,650	$ 9,151,158	$ (6,441,508)	0.30
350	Com Boiler/unitary AC to ASHP - Oil Heat	O	UP	Com	RET	$ 1,923,814,130	$ 663,333,105	$ 1,260,481,025	2.90
351	Com Boiler/unitary AC to ASHP - Oil Heat	O	UP	Com	NC	$ 22,329,984	$ 2,439,130	$ 19,890,854	9.15
354	Com Boiler/Chiller to ASHP - Gas Heat	G	UP	Com	RET	$ (27,986,250)	$ 1,631,015,428	$ (1,659,001,678)	-0.02
355	Com Boiler/Chiller to ASHP - Gas Heat	G	UP	Com	NC	$ (5,933,941)	$ (6,598,004)	$ 664,064	0.90
358	Com Boiler/Chiller to ASHP - Oil Heat	O	UP	Com	RET	$ 824,659,265	$ 347,013,133	$ 477,646,132	2.38
359	Com Boiler/Chiller to ASHP - Oil Heat	O	UP	Com	NC	$ 9,614,242	$ (1,805,111)	$ 11,419,353	-5.33
362	Com Boiler/CAC to DMSHP - Gas Heat	G	UP	Com	RET	$ 81,984,845	$ 369,810,779	$ (287,825,934)	0.22
363	Com Boiler/CAC to DMSHP - Gas Heat	G	UP	Com	NC	$ 415,105	$ 2,621,978	$ (2,206,874)	0.16
366	Com Boiler/CAC to DMSHP - Oil Heat	O	UP	Com	RET	$ 97,877,525	$ 78,680,554	$ 19,196,972	1.24
367	Com Boiler/CAC to DMSHP - Oil Heat	O	UP	Com	NC	$ 1,165,594	$ 688,961	$ 476,634	1.69
370	Com Boiler/RoomAC to DMSHP - Gas Heat	G	UP	Com	RET	$ 125,427,943	$ 612,030,592	$ (486,602,650)	0.20
371	Com Boiler/RoomAC to DMSHP - Gas Heat	G	UP	Com	NC	$ 996,070	$ 5,611,150	$ (4,615,081)	0.18
374	Com Boiler/RoomAC to DMSHP - Oil Heat	O	UP	Com	RET	$ 165,121,516	$ 130,214,987	$ 34,906,529	1.27

#	Measure Name	Primary Fuel	Zone	Sector	Market	Total Resource Benefits	Total Resource Costs	Total Resource Net Benefits	Total Resource BCR
375	Com Boiler/RoomAC to DMSHP - Oil Heat	O	UP	Com	NC	$ 2,007,384	$ 1,467,036	$ 540,348	1.37
378	Com Boiler/Unitary AC to VRF - Gas Heat	G	UP	Com	RET	$ 1,841,868,360	$ 4,764,885,257	$ (2,923,016,897)	0.39
379	Com Boiler/Unitary AC to VRF - Gas Heat	G	UP	Com	NC	$ 11,242,099	$ 28,033,076	$ (16,790,977)	0.40
382	Com Boiler/Unitary AC to VRF - Oil Heat	O	UP	Com	RET	$ 2,053,101,163	$ 1,013,771,994	$ 1,039,329,169	2.03
383	Com Boiler/Unitary AC to VRF - Oil Heat	O	UP	Com	NC	$ 24,227,088	$ 7,392,460	$ 16,834,628	3.28
386	Com Boiler/Chiller to VRF - Gas Heat	G	UP	Com	RET	$ 449,541,381	$ 2,547,529,925	$ (2,097,988,545)	0.18
387	Com Boiler/Chiller to VRF - Gas Heat	G	UP	Com	NC	$ 295,008	$ 3,022,474	$ (2,727,466)	0.10
390	Com Boiler/Chiller to VRF - Oil Heat	O	UP	Com	RET	$ 926,257,543	$ 542,009,797	$ 384,247,746	1.71
391	Com Boiler/Chiller to VRF - Oil Heat	O	UP	Com	NC	$ 10,980,381	$ 810,466	$ 10,169,915	13.55
394	Com Boiler/Unitary AC to GSHP - Gas Heat	G	UP	Com	RET	$ 2,925,690,713	$ 13,893,944,916	$ (10,968,254,202)	0.21
395	Com Boiler/Unitary AC to GSHP - Gas Heat	G	UP	Com	NC	$ 19,835,927	$ 69,565,844	$ (49,729,917)	0.29
398	Com Boiler/Unitary AC to GSHP - Oil Heat	O	UP	Com	RET	$ 3,367,522,630	$ 2,956,061,160	$ 411,461,470	1.14
399	Com Boiler/Unitary AC to GSHP - Oil Heat	O	UP	Com	NC	$ 39,725,258	$ 18,147,729	$ 21,577,529	2.19
402	Com Boiler/Chiller to GSHP - Gas Heat	G	UP	Com	RET	$ 920,000,839	$ 7,596,588,848	$ (6,676,588,009)	0.12
403	Com Boiler/Chiller to GSHP - Gas Heat	G	UP	Com	NC	$ 2,896,870	$ 25,079,643	$ (22,182,774)	0.12
406	Com Boiler/Chiller to GSHP - Oil Heat	O	UP	Com	RET	$ 1,568,266,284	$ 1,616,242,282	$ (47,975,998)	0.97
407	Com Boiler/Chiller to GSHP - Oil Heat	O	UP	Com	NC	$ 18,265,994	$ 6,598,793	$ 11,667,200	2.77
410	High-eff HP CEE Tier II -Cool	E	UP	Com	RET	$ 53,087,118	$ 128,204,094	$ (75,116,977)	0.41
411	High-eff HP CEE Tier II -Cool	E	UP	Com	NC	$ 343,110	$ 231,954	$ 111,156	1.48
412	High-eff HP CEE Tier II -Cool	E	UP	Com	REPL	$ 1,921,374	$ 1,301,114	$ 620,260	1.48
416	Com Heat Pump Water Htr replace Oil	O	UP	Com	NC	$ 7,743,122	$ 1,860,942	$ 5,882,180	4.16
417	Com Heat Pump Water Htr replace Oil	O	UP	Com	REPL	$ 49,517,999	$ 11,900,900	$ 37,617,099	4.16
418	Res FF Heat/CAC to ASHP - Gas Heat	G	UP	Res	RET	$ (104,939,915)	$ 4,668,715,849	$ (4,773,655,764)	-0.02
419	Res FF Heat/CAC to ASHP - Gas Heat	G	UP	Res	NC	$ (2,603,480)	$ 20,938,534	$ (23,542,014)	-0.12
422	Res FF Heat/CAC to ASHP - Oil Heat	O	UP	Res	RET	$ 5,767,144,815	$ 2,094,954,306	$ 3,672,190,509	2.75
423	Res FF Heat/CAC to ASHP - Oil Heat	O	UP	Res	NC	$ 98,783,525	$ 10,397,835	$ 88,385,690	9.50
426	Res FFHeat/CAC to DMSHP - Gas Heat	G	UP	Res	RET	$ 1,740,363,046	$ 8,342,060,757	$ (6,601,697,711)	0.21
427	Res FFHeat/CAC to DMSHP - Gas Heat	G	UP	Res	NC	$ 9,095,166	$ 79,576,285	$ (70,481,119)	0.11
430	Res FFHeat/CAC to DMSHP - Oil Heat	O	UP	Res	RET	$ 6,435,307,752	$ 3,743,264,030	$ 2,692,043,722	1.72
431	Res FFHeat/CAC to DMSHP - Oil Heat	O	UP	Res	NC	$ 104,474,381	$ 39,486,114	$ 64,988,267	2.65
434	Res FFHeat/Room AC to DMSHP - Gas Heat	G	UP	Res	RET	$ 890,774,746	$ 5,415,016,250	$ (4,524,241,505)	0.16
435	Res FFHeat/Room AC to DMSHP - Gas Heat	G	UP	Res	NC	$ 6,809,777	$ 69,520,948	$ (62,711,171)	0.10
438	Res FFHeat/Room AC to DMSHP - Oil Heat	O	UP	Res	RET	$ 4,178,961,859	$ 2,429,835,522	$ 1,749,126,337	1.72
439	Res FFHeat/Room AC to DMSHP - Oil Heat	O	UP	Res	NC	$ 68,311,263	$ 34,482,016	$ 33,829,247	1.98
442	Res FF Heat/CAC to GSHP - Gas Heat	G	UP	Res	RET	$ 2,826,792,062	$ 15,831,856,069	$ (13,005,064,006)	0.18

#	Measure Name	Primary Fuel	Zone	Sector	Market	Total Resource Benefits	Total Resource Costs	Total Resource Net Benefits	Total Resource BCR
443	Res FF Heat/CAC to GSHP - Gas Heat	G	UP	Res	NC	$ 9,928,558	$ 99,795,140	$ (89,866,583)	0.10
446	Res FF Heat/CAC to GSHP - Oil Heat	O	UP	Res	RET	$ 10,836,951,937	$ 7,104,098,025	$ 3,732,853,912	1.53
447	Res FF Heat/CAC to GSHP - Oil Heat	O	UP	Res	NC	$ 169,985,441	$ 49,493,926	$ 120,491,515	3.43
450	Res Resist Heat/Room AC to DMSHP -Heat	E	UP	Res	RET	$ 396,045,199	$ 348,593,112	$ 47,452,087	1.14
451	Res Resist Heat/Room AC to DMSHP -Heat	E	UP	Res	NC	$ 7,547,723	$ 4,279,586	$ 3,268,137	1.76
454	Air Source Heat Pump ESTAR -Cool	E	UP	Res	NC	$ 84,439	$ 141,277	$ (56,838)	0.60
455	Air Source Heat Pump ESTAR -Cool	E	UP	Res	REPL	$ 314,442	$ 526,102	$ (211,660)	0.60
458	Res Heat Pump Water Htr replace Oil	O	UP	Res	NC	$ 26,543,931	$ 6,239,125	$ 20,304,806	4.25
459	Res Heat Pump Water Htr replace Oil	O	UP	Res	REPL	$ 130,368,882	$ 30,643,079	$ 99,725,803	4.25

Appendix B: Measure Screening, Year One, BCR Comparison by Zone

Table B-1 shows the same Benefit-Cost Ratios (BCRs) as Appendix A, but consolidated for comparison of BCRs by zone.

Gray shading indicates measures that did not pass cost-effectiveness in year one.

      Primary Fuel: G = Gas, O = Petroleum Fuels, E = Electric

      Zone: NYC = New York City, LI = Long Island, HV = Hudson Valley, UP = Upstate

      Market: MD = Market Driven, RET = Retrofit, REPL = Natural Replacement

Table B-1. Benefit-Cost Ratios consolidated by Zone

#		Primary Fuel	Sector	Market	NYC	LI	HV	UP
1	Com Boiler/unitary AC to ASHP - Gas Heat	G	Com	RET	0.26	0.30	0.47	0.40
2	Com Boiler/unitary AC to ASHP - Gas Heat	G	Com	NC	0.19	0.24	0.53	0.30
5	Com Boiler/unitary AC to ASHP - Oil Heat	O	Com	RET	1.13	1.42	1.80	2.90
6	Com Boiler/unitary AC to ASHP - Oil Heat	O	Com	NC	2.35	3.27	4.44	9.15
9	Com Boiler/Chiller to ASHP - Gas Heat	G	Com	RET	0.00	0.06	0.09	-0.02
10	Com Boiler/Chiller to ASHP - Gas Heat	G	Com	NC	0.63	0.96	1.10	0.90
13	Com Boiler/Chiller to ASHP - Oil Heat	O	Com	RET	0.69	1.00	1.31	2.38
14	Com Boiler/Chiller to ASHP - Oil Heat	O	Com	NC	-2.60	-2.86	-3.46	-5.33
17	Com Boiler/CAC to DMSHP - Gas Heat	G	Com	RET	0.18	0.18	0.29	0.22
18	Com Boiler/CAC to DMSHP - Gas Heat	G	Com	NC	0.13	0.18	0.28	0.16
21	Com Boiler/CAC to DMSHP - Oil Heat	O	Com	RET	0.61	0.71	0.87	1.24
22	Com Boiler/CAC to DMSHP - Oil Heat	O	Com	NC	0.74	0.94	1.13	1.69
25	Com Boiler/RoomAC to DMSHP - Gas Heat	G	Com	RET	0.18	0.17	0.27	0.20
26	Com Boiler/RoomAC to DMSHP - Gas Heat	G	Com	NC	0.15	0.19	0.29	0.18
29	Com Boiler/RoomAC to DMSHP - Oil Heat	O	Com	RET	0.66	0.75	0.90	1.27
30	Com Boiler/RoomAC to DMSHP - Oil Heat	O	Com	NC	0.64	0.80	0.95	1.37
33	Com Boiler/Unitary AC to VRF - Gas Heat	G	Com	RET	0.35	0.34	0.48	0.39
34	Com Boiler/Unitary AC to VRF - Gas Heat	G	Com	NC	0.39	0.46	0.63	0.40
37	Com Boiler/Unitary AC to VRF - Oil Heat	O	Com	RET	1.08	1.21	1.44	2.03
38	Com Boiler/Unitary AC to VRF - Oil Heat	O	Com	NC	1.55	1.89	2.23	3.28
41	Com Boiler/Chiller to VRF - Gas Heat	G	Com	RET	0.18	0.19	0.27	0.18
42	Com Boiler/Chiller to VRF - Gas Heat	G	Com	NC	0.72	0.69	0.99	0.10
45	Com Boiler/Chiller to VRF - Oil Heat	O	Com	RET	0.77	0.93	1.13	1.71
46	Com Boiler/Chiller to VRF - Oil Heat	O	Com	NC	5.71	7.04	8.54	13.55
49	Com Boiler/Unitary AC to GSHP - Gas Heat	G	Com	RET	0.14	0.14	0.24	0.21
50	Com Boiler/Unitary AC to GSHP - Gas Heat	G	Com	NC	0.15	0.24	0.41	0.29
53	Com Boiler/Unitary AC to GSHP - Oil Heat	O	Com	RET	0.56	0.64	0.79	1.14
54	Com Boiler/Unitary AC to GSHP - Oil Heat	O	Com	NC	0.93	1.20	1.45	2.19
57	Com Boiler/Chiller to GSHP - Gas Heat	G	Com	RET	0.04	0.05	0.14	0.12
58	Com Boiler/Chiller to GSHP - Gas Heat	G	Com	NC	-0.06	0.04	0.23	0.12

#		Primary Fuel	Sector	Market	NYC	LI	HV	UP
61	Com Boiler/Chiller to GSHP - Oil Heat	O	Com	RET	0.38	0.48	0.62	0.97
62	Com Boiler/Chiller to GSHP - Oil Heat	O	Com	NC	0.97	1.32	1.68	2.77
65	High-eff HP CEE Tier II -Cool	E	Com	RET	0.65	0.48	0.41	0.41
66	High-eff HP CEE Tier II -Cool	E	Com	NC	2.29	1.64	1.48	1.48
67	High-eff HP CEE Tier II -Cool	E	Com	REPL	2.28	1.64	1.48	1.48
71	Com Heat Pump Water Htr replace Oil	O	Com	NC	3.31	3.92	4.02	4.16
72	Com Heat Pump Water Htr replace Oil	O	Com	REPL	3.31	3.92	4.02	4.16
73	Res FF Heat/CAC to ASHP - Gas Heat	G	Res	RET	0.10	0.07	0.16	-0.02
74	Res FF Heat/CAC to ASHP - Gas Heat	G	Res	NC	0.27	0.18	0.47	-0.12
77	Res FF Heat/CAC to ASHP - Oil Heat	O	Res	RET	1.61	1.57	1.54	2.75
78	Res FF Heat/CAC to ASHP - Oil Heat	O	Res	NC	5.39	5.29	5.20	9.50
81	Res FFHeat/CAC to DMSHP - Gas Heat	G	Res	RET	0.24	0.21	0.29	0.21
82	Res FFHeat/CAC to DMSHP - Gas Heat	G	Res	NC	0.21	0.16	0.24	0.11
85	Res FFHeat/CAC to DMSHP - Oil Heat	O	Res	RET	1.05	1.02	1.02	1.72
86	Res FFHeat/CAC to DMSHP - Oil Heat	O	Res	NC	1.57	1.52	1.49	2.65
89	Res FFHeat/Room AC to DMSHP - Gas Heat	G	Res	RET	0.22	0.19	0.25	0.16
90	Res FFHeat/Room AC to DMSHP - Gas Heat	G	Res	NC	0.18	0.14	0.20	0.10
93	Res FFHeat/Room AC to DMSHP - Oil Heat	O	Res	RET	1.07	1.04	1.03	1.72
94	Res FFHeat/Room AC to DMSHP - Oil Heat	O	Res	NC	1.20	1.16	1.14	1.98
97	Res FF Heat/CAC to GSHP - Gas Heat	G	Res	RET	0.23	0.19	0.24	0.18
98	Res FF Heat/CAC to GSHP - Gas Heat	G	Res	NC	0.30	0.19	0.24	0.10
101	Res FF Heat/CAC to GSHP - Oil Heat	O	Res	RET	0.97	0.93	0.91	1.53
102	Res FF Heat/CAC to GSHP - Oil Heat	O	Res	NC	2.09	1.99	1.89	3.43
105	Res Resist Heat/Room AC to DMSHP -Heat	E	Res	RET	1.45	1.33	1.26	1.14
106	Res Resist Heat/Room AC to DMSHP -Heat	E	Res	NC	2.23	2.06	1.94	1.76
109	Air Source Heat Pump ESTAR -Cool	E	Res	NC	0.80	0.69	0.64	0.60
110	Air Source Heat Pump ESTAR -Cool	E	Res	REPL	0.80	0.69	0.64	0.60
113	Res Heat Pump Water Htr replace Oil	O	Res	NC	3.50	4.03	4.12	4.25
114	Res Heat Pump Water Htr replace Oil	O	Res	REPL	3.50	4.03	4.12	4.25

Appendix C: Measure Screening, BCRs for Selected Years

Table C-1 shows the Benefit-Cost Ratios (BCRs) for each measure for selected years.

Gray shading of BCRs indicates measures that did not pass cost-effectiveness.

Primary Fuel: G = Gas, O = Petroleum Fuels, E = Electric

Zone: NYC = New York City, LI = Long Island, HV = Hudson Valley, UP = Upstate

Market: MD = Market Driven, RET = Retrofit, REPL = Natural Replacement

Table C-1. Benefit-Cost Ratios by Zone for Selected Years

#	Measure Name	Primary Fuel	Zone	Sector	Market	2015	2020	2025	2030	2034
1	Com Boiler/unitary AC to ASHP - Gas Heat	G	NYC	Com	RET	0.26	0.29	0.31	0.32	0.35
2	Com Boiler/unitary AC to ASHP - Gas Heat	G	NYC	Com	NC	0.19	0.25	0.29	0.31	0.36
5	Com Boiler/unitary AC to ASHP - Oil Heat	O	NYC	Com	RET	1.13	1.21	1.27	1.32	1.36
6	Com Boiler/unitary AC to ASHP - Oil Heat	O	NYC	Com	NC	2.35	2.53	2.67	2.77	2.86
9	Com Boiler/Chiller to ASHP - Gas Heat	G	NYC	Com	RET	0.00	0.03	0.03	0.03	0.04
10	Com Boiler/Chiller to ASHP - Gas Heat	G	NYC	Com	NC	0.63	0.53	0.52	0.55	0.54
13	Com Boiler/Chiller to ASHP - Oil Heat	O	NYC	Com	RET	0.69	0.76	0.79	0.82	0.84
14	Com Boiler/Chiller to ASHP - Oil Heat	O	NYC	Com	NC	(2.60)	(2.84)	(3.00)	(3.10)	(3.19)
17	Com Boiler/CAC to DMSHP - Gas Heat	G	NYC	Com	RET	0.18	0.20	0.22	0.24	0.26
18	Com Boiler/CAC to DMSHP - Gas Heat	G	NYC	Com	NC	0.13	0.16	0.18	0.21	0.23
21	Com Boiler/CAC to DMSHP - Oil Heat	O	NYC	Com	RET	0.61	0.65	0.69	0.73	0.76
22	Com Boiler/CAC to DMSHP - Oil Heat	O	NYC	Com	NC	0.74	0.80	0.85	0.89	0.93
25	Com Boiler/RoomAC to DMSHP - Gas Heat	G	NYC	Com	RET	0.18	0.20	0.23	0.25	0.28
26	Com Boiler/RoomAC to DMSHP - Gas Heat	G	NYC	Com	NC	0.15	0.17	0.20	0.22	0.25
29	Com Boiler/RoomAC to DMSHP - Oil Heat	O	NYC	Com	RET	0.66	0.70	0.75	0.79	0.82
30	Com Boiler/RoomAC to DMSHP - Oil Heat	O	NYC	Com	NC	0.64	0.69	0.74	0.78	0.81
33	Com Boiler/Unitary AC to VRF - Gas Heat	G	NYC	Com	RET	0.35	0.38	0.41	0.44	0.48
34	Com Boiler/Unitary AC to VRF - Gas Heat	G	NYC	Com	NC	0.39	0.44	0.50	0.55	0.60
37	Com Boiler/Unitary AC to VRF - Oil Heat	O	NYC	Com	RET	1.08	1.14	1.21	1.27	1.32
38	Com Boiler/Unitary AC to VRF - Oil Heat	O	NYC	Com	NC	1.55	1.67	1.77	1.86	1.92
41	Com Boiler/Chiller to VRF - Gas Heat	G	NYC	Com	RET	0.18	0.20	0.21	0.22	0.24
42	Com Boiler/Chiller to VRF - Gas Heat	G	NYC	Com	NC	0.72	0.86	0.98	1.04	1.15
45	Com Boiler/Chiller to VRF - Oil Heat	O	NYC	Com	RET	0.77	0.82	0.86	0.90	0.93
46	Com Boiler/Chiller to VRF - Oil Heat	O	NYC	Com	NC	5.71	6.13	6.48	6.73	6.93
49	Com Boiler/Unitary AC to GSHP - Gas Heat	G	NYC	Com	RET	0.14	0.15	0.17	0.19	0.21
50	Com Boiler/Unitary AC to GSHP - Gas Heat	G	NYC	Com	NC	0.15	0.18	0.22	0.27	0.30
53	Com Boiler/Unitary AC to GSHP - Oil Heat	O	NYC	Com	RET	0.56	0.59	0.62	0.66	0.68
54	Com Boiler/Unitary AC to GSHP - Oil Heat	O	NYC	Com	NC	0.93	0.99	1.06	1.12	1.16
57	Com Boiler/Chiller to GSHP - Gas Heat	G	NYC	Com	RET	0.04	0.05	0.06	0.08	0.09
58	Com Boiler/Chiller to GSHP - Gas Heat	G	NYC	Com	NC	(0.06)	(0.02)	0.01	0.05	0.08
61	Com Boiler/Chiller to GSHP - Oil Heat	O	NYC	Com	RET	0.38	0.41	0.43	0.45	0.47
62	Com Boiler/Chiller to GSHP - Oil Heat	O	NYC	Com	NC	0.97	1.04	1.11	1.17	1.21
65	High-eff HP CEE Tier II -Cool	E	NYC	Com	RET	0.65	0.66	0.70	0.76	0.81

#	Measure Name	Primary Fuel	Zone	Sector	Market	2015	2020	2025	2030	2034
66	High-eff HP CEE Tier II -Cool	E	NYC	Com	NC	2.29	2.37	2.60	2.87	3.06
67	High-eff HP CEE Tier II -Cool	E	NYC	Com	REPL	2.28	2.37	2.59	2.86	3.05
71	Com Heat Pump Water Htr replace Oil	O	NYC	Com	NC	3.31	3.77	4.08	4.27	4.39
72	Com Heat Pump Water Htr replace Oil	O	NYC	Com	REPL	3.31	3.77	4.08	4.27	4.39
73	Res FF Heat/CAC to ASHP - Gas Heat	G	NYC	Res	RET	0.10	0.14	0.18	0.20	0.25
74	Res FF Heat/CAC to ASHP - Gas Heat	G	NYC	Res	NC	0.27	0.41	0.52	0.60	0.73
77	Res FF Heat/CAC to ASHP - Oil Heat	O	NYC	Res	RET	1.61	1.73	1.83	1.92	1.99
78	Res FF Heat/CAC to ASHP - Oil Heat	O	NYC	Res	NC	5.39	5.80	6.15	6.42	6.64
81	Res FFHeat/CAC to DMSHP - Gas Heat	G	NYC	Res	RET	0.24	0.26	0.29	0.31	0.34
82	Res FFHeat/CAC to DMSHP - Gas Heat	G	NYC	Res	NC	0.21	0.25	0.29	0.32	0.36
85	Res FFHeat/CAC to DMSHP - Oil Heat	O	NYC	Res	RET	1.05	1.12	1.18	1.24	1.28
86	Res FFHeat/CAC to DMSHP - Oil Heat	O	NYC	Res	NC	1.57	1.68	1.78	1.86	1.93
89	Res FFHeat/Room AC to DMSHP - Gas Heat	G	NYC	Res	RET	0.22	0.25	0.27	0.30	0.33
90	Res FFHeat/Room AC to DMSHP - Gas Heat	G	NYC	Res	NC	0.18	0.21	0.24	0.27	0.30
93	Res FFHeat/Room AC to DMSHP - Oil Heat	O	NYC	Res	RET	1.07	1.15	1.21	1.27	1.31
94	Res FFHeat/Room AC to DMSHP - Oil Heat	O	NYC	Res	NC	1.20	1.29	1.37	1.43	1.48
97	Res FF Heat/CAC to GSHP - Gas Heat	G	NYC	Res	RET	0.23	0.25	0.27	0.29	0.31
98	Res FF Heat/CAC to GSHP - Gas Heat	G	NYC	Res	NC	0.30	0.35	0.40	0.45	0.50
101	Res FF Heat/CAC to GSHP - Oil Heat	O	NYC	Res	RET	0.97	1.02	1.07	1.11	1.15
102	Res FF Heat/CAC to GSHP - Oil Heat	O	NYC	Res	NC	2.09	2.22	2.33	2.44	2.51
105	Res Resist Heat/Room AC to DMSHP -Heat	E	NYC	Res	RET	1.45	1.47	1.53	1.59	1.58
106	Res Resist Heat/Room AC to DMSHP -Heat	E	NYC	Res	NC	2.23	2.26	2.34	2.42	2.41
109	Air Source Heat Pump ESTAR -Cool	E	NYC	Res	NC	0.80	0.85	0.92	1.00	1.06
110	Air Source Heat Pump ESTAR -Cool	E	NYC	Res	REPL	0.80	0.85	0.92	1.00	1.06
113	Res Heat Pump Water Htr replace Oil	O	NYC	Res	NC	3.50	3.92	4.24	4.45	4.59
114	Res Heat Pump Water Htr replace Oil	O	NYC	Res	REPL	3.50	3.92	4.24	4.45	4.59
116	Com Boiler/unitary AC to ASHP - Gas Heat	G	LI	Com	RET	0.30	0.31	0.35	0.40	0.44
117	Com Boiler/unitary AC to ASHP - Gas Heat	G	LI	Com	NC	0.24	0.27	0.36	0.46	0.55
120	Com Boiler/unitary AC to ASHP - Oil Heat	O	LI	Com	RET	1.42	1.50	1.60	1.69	1.75
121	Com Boiler/unitary AC to ASHP - Oil Heat	O	LI	Com	NC	3.27	3.47	3.70	3.93	4.07
124	Com Boiler/Chiller to ASHP - Gas Heat	G	LI	Com	RET	0.06	0.06	0.08	0.11	0.14
125	Com Boiler/Chiller to ASHP - Gas Heat	G	LI	Com	NC	0.96	1.00	0.97	0.90	0.82
128	Com Boiler/Chiller to ASHP - Oil Heat	O	LI	Com	RET	1.00	1.06	1.13	1.19	1.24
129	Com Boiler/Chiller to ASHP - Oil Heat	O	LI	Com	NC	(2.86)	(3.03)	(3.24)	(3.46)	(3.61)
132	Com Boiler/CAC to DMSHP - Gas Heat	G	LI	Com	RET	0.18	0.19	0.23	0.26	0.29
133	Com Boiler/CAC to DMSHP - Gas Heat	G	LI	Com	NC	0.18	0.20	0.25	0.30	0.34
136	Com Boiler/CAC to DMSHP - Oil Heat	O	LI	Com	RET	0.71	0.75	0.81	0.86	0.90
137	Com Boiler/CAC to DMSHP - Oil Heat	O	LI	Com	NC	0.94	1.00	1.09	1.17	1.22
140	Com Boiler/RoomAC to DMSHP - Gas Heat	G	LI	Com	RET	0.17	0.19	0.22	0.26	0.29
141	Com Boiler/RoomAC to DMSHP - Gas Heat	G	LI	Com	NC	0.19	0.22	0.26	0.31	0.35
144	Com Boiler/RoomAC to DMSHP - Oil Heat	O	LI	Com	RET	0.75	0.79	0.85	0.91	0.95
145	Com Boiler/RoomAC to DMSHP - Oil Heat	O	LI	Com	NC	0.80	0.86	0.94	1.01	1.05
148	Com Boiler/Unitary AC to VRF - Gas Heat	G	LI	Com	RET	0.34	0.36	0.41	0.45	0.49
149	Com Boiler/Unitary AC to VRF - Gas Heat	G	LI	Com	NC	0.46	0.51	0.60	0.69	0.75
152	Com Boiler/Unitary AC to VRF - Oil Heat	O	LI	Com	RET	1.21	1.29	1.37	1.46	1.51
153	Com Boiler/Unitary AC to VRF - Oil Heat	O	LI	Com	NC	1.89	2.02	2.18	2.32	2.42
156	Com Boiler/Chiller to VRF - Gas Heat	G	LI	Com	RET	0.19	0.20	0.22	0.25	0.27
157	Com Boiler/Chiller to VRF - Gas Heat	G	LI	Com	NC	0.69	0.76	0.95	1.16	1.34

#	Measure Name	Primary Fuel	Zone	Sector	Market	2015	2020	2025	2030	2034
160	Com Boiler/Chiller to VRF - Oil Heat	O	LI	Com	RET	0.93	0.98	1.04	1.10	1.14
161	Com Boiler/Chiller to VRF - Oil Heat	O	LI	Com	NC	7.04	7.46	7.96	8.42	8.72
164	Com Boiler/Unitary AC to GSHP - Gas Heat	G	LI	Com	RET	0.14	0.15	0.18	0.20	0.22
165	Com Boiler/Unitary AC to GSHP - Gas Heat	G	LI	Com	NC	0.24	0.28	0.34	0.40	0.44
168	Com Boiler/Unitary AC to GSHP - Oil Heat	O	LI	Com	RET	0.64	0.68	0.72	0.76	0.79
169	Com Boiler/Unitary AC to GSHP - Oil Heat	O	LI	Com	NC	1.20	1.29	1.38	1.47	1.52
172	Com Boiler/Chiller to GSHP - Gas Heat	G	LI	Com	RET	0.05	0.06	0.08	0.09	0.11
173	Com Boiler/Chiller to GSHP - Gas Heat	G	LI	Com	NC	0.04	0.08	0.13	0.18	0.22
176	Com Boiler/Chiller to GSHP - Oil Heat	O	LI	Com	RET	0.48	0.51	0.54	0.57	0.59
177	Com Boiler/Chiller to GSHP - Oil Heat	O	LI	Com	NC	1.32	1.42	1.52	1.61	1.67
180	High-eff HP CEE Tier II -Cool	E	LI	Com	RET	0.48	0.51	0.53	0.55	0.56
181	High-eff HP CEE Tier II -Cool	E	LI	Com	NC	1.64	1.79	1.89	1.95	1.98
182	High-eff HP CEE Tier II -Cool	E	LI	Com	REPL	1.64	1.79	1.89	1.95	1.98
186	Com Heat Pump Water Htr replace Oil	O	LI	Com	NC	3.92	4.23	4.55	4.83	5.00
187	Com Heat Pump Water Htr replace Oil	O	LI	Com	REPL	3.92	4.23	4.55	4.83	5.00
188	Res FF Heat/CAC to ASHP - Gas Heat	G	LI	Res	RET	0.07	0.08	0.14	0.20	0.25
189	Res FF Heat/CAC to ASHP - Gas Heat	G	LI	Res	NC	0.18	0.22	0.39	0.60	0.78
192	Res FF Heat/CAC to ASHP - Oil Heat	O	LI	Res	RET	1.57	1.67	1.79	1.92	2.00
193	Res FF Heat/CAC to ASHP - Oil Heat	O	LI	Res	NC	5.29	5.62	6.04	6.44	6.72
196	Res FFHeat/CAC to DMSHP - Gas Heat	G	LI	Res	RET	0.21	0.23	0.26	0.30	0.33
197	Res FFHeat/CAC to DMSHP - Gas Heat	G	LI	Res	NC	0.16	0.18	0.23	0.29	0.34
200	Res FFHeat/CAC to DMSHP - Oil Heat	O	LI	Res	RET	1.02	1.08	1.15	1.22	1.27
201	Res FFHeat/CAC to DMSHP - Oil Heat	O	LI	Res	NC	1.52	1.62	1.73	1.84	1.91
204	Res FFHeat/Room AC to DMSHP - Gas Heat	G	LI	Res	RET	0.19	0.20	0.24	0.28	0.31
205	Res FFHeat/Room AC to DMSHP - Gas Heat	G	LI	Res	NC	0.14	0.16	0.20	0.24	0.28
208	Res FFHeat/Room AC to DMSHP - Oil Heat	O	LI	Res	RET	1.04	1.10	1.18	1.25	1.30
209	Res FFHeat/Room AC to DMSHP - Oil Heat	O	LI	Res	NC	1.16	1.24	1.33	1.41	1.46
212	Res FF Heat/CAC to GSHP - Gas Heat	G	LI	Res	RET	0.19	0.20	0.23	0.25	0.27
213	Res FF Heat/CAC to GSHP - Gas Heat	G	LI	Res	NC	0.19	0.23	0.28	0.34	0.38
216	Res FF Heat/CAC to GSHP - Oil Heat	O	LI	Res	RET	0.93	0.98	1.03	1.07	1.11
217	Res FF Heat/CAC to GSHP - Oil Heat	O	LI	Res	NC	1.99	2.10	2.22	2.33	2.40
220	Res Resist Heat/Room AC to DMSHP -Heat	E	LI	Res	RET	1.33	1.41	1.41	1.37	1.32
221	Res Resist Heat/Room AC to DMSHP -Heat	E	LI	Res	NC	2.06	2.17	2.17	2.10	2.02
224	Air Source Heat Pump ESTAR -Cool	E	LI	Res	NC	0.69	0.75	0.79	0.82	0.84
225	Air Source Heat Pump ESTAR -Cool	E	LI	Res	REPL	0.69	0.75	0.79	0.82	0.84
228	Res Heat Pump Water Htr replace Oil	O	LI	Res	NC	4.03	4.35	4.67	4.95	5.12
229	Res Heat Pump Water Htr replace Oil	O	LI	Res	REPL	4.03	4.35	4.67	4.95	5.12
231	Com Boiler/unitary AC to ASHP - Gas Heat	G	HV	Com	RET	0.47	0.51	0.56	0.62	0.67
232	Com Boiler/unitary AC to ASHP - Gas Heat	G	HV	Com	NC	0.53	0.63	0.76	0.89	1.00
235	Com Boiler/unitary AC to ASHP - Oil Heat	O	HV	Com	RET	1.80	1.91	2.03	2.13	2.21
236	Com Boiler/unitary AC to ASHP - Oil Heat	O	HV	Com	NC	4.44	4.75	5.07	5.36	5.54
239	Com Boiler/Chiller to ASHP - Gas Heat	G	HV	Com	RET	0.09	0.11	0.14	0.18	0.21
240	Com Boiler/Chiller to ASHP - Gas Heat	G	HV	Com	NC	1.10	1.08	1.03	0.94	0.85
243	Com Boiler/Chiller to ASHP - Oil Heat	O	HV	Com	RET	1.31	1.40	1.49	1.57	1.63
244	Com Boiler/Chiller to ASHP - Oil Heat	O	HV	Com	NC	(3.46)	(3.73)	(4.00)	(4.25)	(4.43)
247	Com Boiler/CAC to DMSHP - Gas Heat	G	HV	Com	RET	0.29	0.31	0.35	0.39	0.42
248	Com Boiler/CAC to DMSHP - Gas Heat	G	HV	Com	NC	0.28	0.33	0.39	0.44	0.49
251	Com Boiler/CAC to DMSHP - Oil Heat	O	HV	Com	RET	0.87	0.93	1.00	1.06	1.10

#	Measure Name	Primary Fuel	Zone	Sector	Market	2015	2020	2025	2030	2034
252	Com Boiler/CAC to DMSHP - Oil Heat	O	HV	Com	NC	1.13	1.22	1.31	1.40	1.46
255	Com Boiler/RoomAC to DMSHP - Gas Heat	G	HV	Com	RET	0.27	0.30	0.35	0.39	0.42
256	Com Boiler/RoomAC to DMSHP - Gas Heat	G	HV	Com	NC	0.29	0.33	0.39	0.44	0.48
259	Com Boiler/RoomAC to DMSHP - Oil Heat	O	HV	Com	RET	0.90	0.96	1.04	1.10	1.15
260	Com Boiler/RoomAC to DMSHP - Oil Heat	O	HV	Com	NC	0.95	1.03	1.11	1.18	1.23
263	Com Boiler/Unitary AC to VRF - Gas Heat	G	HV	Com	RET	0.48	0.52	0.58	0.63	0.67
264	Com Boiler/Unitary AC to VRF - Gas Heat	G	HV	Com	NC	0.63	0.71	0.81	0.91	0.98
267	Com Boiler/Unitary AC to VRF - Oil Heat	O	HV	Com	RET	1.44	1.54	1.64	1.73	1.79
268	Com Boiler/Unitary AC to VRF - Oil Heat	O	HV	Com	NC	2.23	2.40	2.57	2.72	2.82
271	Com Boiler/Chiller to VRF - Gas Heat	G	HV	Com	RET	0.27	0.29	0.32	0.35	0.38
272	Com Boiler/Chiller to VRF - Gas Heat	G	HV	Com	NC	0.99	1.16	1.40	1.64	1.84
275	Com Boiler/Chiller to VRF - Oil Heat	O	HV	Com	RET	1.13	1.20	1.27	1.34	1.38
276	Com Boiler/Chiller to VRF - Oil Heat	O	HV	Com	NC	8.54	9.14	9.73	10.26	10.61
279	Com Boiler/Unitary AC to GSHP - Gas Heat	G	HV	Com	RET	0.24	0.27	0.29	0.32	0.34
280	Com Boiler/Unitary AC to GSHP - Gas Heat	G	HV	Com	NC	0.41	0.47	0.54	0.60	0.65
283	Com Boiler/Unitary AC to GSHP - Oil Heat	O	HV	Com	RET	0.79	0.83	0.88	0.93	0.96
284	Com Boiler/Unitary AC to GSHP - Oil Heat	O	HV	Com	NC	1.45	1.55	1.66	1.75	1.81
287	Com Boiler/Chiller to GSHP - Gas Heat	G	HV	Com	RET	0.14	0.15	0.18	0.20	0.21
288	Com Boiler/Chiller to GSHP - Gas Heat	G	HV	Com	NC	0.23	0.29	0.36	0.42	0.47
291	Com Boiler/Chiller to GSHP - Oil Heat	O	HV	Com	RET	0.62	0.66	0.69	0.73	0.75
292	Com Boiler/Chiller to GSHP - Oil Heat	O	HV	Com	NC	1.68	1.80	1.91	2.02	2.09
295	High-eff HP CEE Tier II -Cool	E	HV	Com	RET	0.41	0.43	0.44	0.45	0.45
296	High-eff HP CEE Tier II -Cool	E	HV	Com	NC	1.48	1.56	1.62	1.64	1.64
297	High-eff HP CEE Tier II -Cool	E	HV	Com	REPL	1.48	1.56	1.62	1.64	1.64
301	Com Heat Pump Water Htr replace Oil	O	HV	Com	NC	4.02	4.37	4.71	4.99	5.15
302	Com Heat Pump Water Htr replace Oil	O	HV	Com	REPL	4.02	4.37	4.71	4.99	5.15
303	Res FF Heat/CAC to ASHP - Gas Heat	G	HV	Res	RET	0.16	0.19	0.25	0.31	0.36
304	Res FF Heat/CAC to ASHP - Gas Heat	G	HV	Res	NC	0.47	0.59	0.77	0.96	1.12
307	Res FF Heat/CAC to ASHP - Oil Heat	O	HV	Res	RET	1.54	1.65	1.77	1.88	1.96
308	Res FF Heat/CAC to ASHP - Oil Heat	O	HV	Res	NC	5.20	5.59	6.00	6.37	6.61
311	Res FFHeat/CAC to DMSHP - Gas Heat	G	HV	Res	RET	0.29	0.32	0.35	0.39	0.42
312	Res FFHeat/CAC to DMSHP - Gas Heat	G	HV	Res	NC	0.24	0.28	0.33	0.38	0.43
315	Res FFHeat/CAC to DMSHP - Oil Heat	O	HV	Res	RET	1.02	1.09	1.17	1.23	1.27
316	Res FFHeat/CAC to DMSHP - Oil Heat	O	HV	Res	NC	1.49	1.60	1.71	1.81	1.87
319	Res FFHeat/Room AC to DMSHP - Gas Heat	G	HV	Res	RET	0.25	0.28	0.31	0.35	0.38
320	Res FFHeat/Room AC to DMSHP - Gas Heat	G	HV	Res	NC	0.20	0.23	0.27	0.31	0.35
323	Res FFHeat/Room AC to DMSHP - Oil Heat	O	HV	Res	RET	1.03	1.10	1.17	1.24	1.29
324	Res FFHeat/Room AC to DMSHP - Oil Heat	O	HV	Res	NC	1.14	1.22	1.31	1.38	1.43
327	Res FF Heat/CAC to GSHP - Gas Heat	G	HV	Res	RET	0.24	0.26	0.28	0.31	0.33
328	Res FF Heat/CAC to GSHP - Gas Heat	G	HV	Res	NC	0.24	0.29	0.34	0.40	0.43
331	Res FF Heat/CAC to GSHP - Oil Heat	O	HV	Res	RET	0.91	0.96	1.01	1.06	1.09
332	Res FF Heat/CAC to GSHP - Oil Heat	O	HV	Res	NC	1.89	2.01	2.12	2.22	2.29
335	Res Resist Heat/Room AC to DMSHP -Heat	E	HV	Res	RET	1.26	1.30	1.30	1.28	1.24
336	Res Resist Heat/Room AC to DMSHP -Heat	E	HV	Res	NC	1.94	2.00	2.00	1.95	1.88
339	Air Source Heat Pump ESTAR -Cool	E	HV	Res	NC	0.64	0.68	0.71	0.73	0.73
340	Air Source Heat Pump ESTAR -Cool	E	HV	Res	REPL	0.64	0.68	0.71	0.73	0.73
343	Res Heat Pump Water Htr replace Oil	O	HV	Res	NC	4.12	4.48	4.81	5.09	5.25
344	Res Heat Pump Water Htr replace Oil	O	HV	Res	REPL	4.12	4.48	4.81	5.09	5.25

#	Measure Name	Primary Fuel	Zone	Sector	Market	2015	2020	2025	2030	2034
346	Com Boiler/unitary AC to ASHP - Gas Heat	G	UP	Com	RET	0.40	0.43	0.49	0.57	0.63
347	Com Boiler/unitary AC to ASHP - Gas Heat	G	UP	Com	NC	0.30	0.36	0.55	0.78	0.97
350	Com Boiler/unitary AC to ASHP - Oil Heat	O	UP	Com	RET	2.90	3.07	3.26	3.44	3.55
351	Com Boiler/unitary AC to ASHP - Oil Heat	O	UP	Com	NC	9.15	9.72	10.35	10.93	11.31
354	Com Boiler/Chiller to ASHP - Gas Heat	G	UP	Com	RET	(0.02)	(0.02)	0.02	0.08	0.14
355	Com Boiler/Chiller to ASHP - Gas Heat	G	UP	Com	NC	0.90	0.93	0.86	0.73	0.61
358	Com Boiler/Chiller to ASHP - Oil Heat	O	UP	Com	RET	2.38	2.51	2.67	2.83	2.93
359	Com Boiler/Chiller to ASHP - Oil Heat	O	UP	Com	NC	(5.33)	(5.65)	(6.03)	(6.40)	(6.64)
362	Com Boiler/CAC to DMSHP - Gas Heat	G	UP	Com	RET	0.22	0.24	0.28	0.33	0.37
363	Com Boiler/CAC to DMSHP - Gas Heat	G	UP	Com	NC	0.16	0.19	0.25	0.31	0.36
366	Com Boiler/CAC to DMSHP - Oil Heat	O	UP	Com	RET	1.24	1.33	1.42	1.50	1.56
367	Com Boiler/CAC to DMSHP - Oil Heat	O	UP	Com	NC	1.69	1.81	1.94	2.06	2.14
370	Com Boiler/RoomAC to DMSHP - Gas Heat	G	UP	Com	RET	0.20	0.23	0.27	0.32	0.36
371	Com Boiler/RoomAC to DMSHP - Gas Heat	G	UP	Com	NC	0.18	0.21	0.26	0.32	0.36
374	Com Boiler/RoomAC to DMSHP - Oil Heat	O	UP	Com	RET	1.27	1.36	1.45	1.54	1.60
375	Com Boiler/RoomAC to DMSHP - Oil Heat	O	UP	Com	NC	1.37	1.47	1.57	1.67	1.74
378	Com Boiler/Unitary AC to VRF - Gas Heat	G	UP	Com	RET	0.39	0.42	0.48	0.53	0.58
379	Com Boiler/Unitary AC to VRF - Gas Heat	G	UP	Com	NC	0.40	0.46	0.55	0.64	0.72
382	Com Boiler/Unitary AC to VRF - Oil Heat	O	UP	Com	RET	2.03	2.15	2.29	2.41	2.49
383	Com Boiler/Unitary AC to VRF - Oil Heat	O	UP	Com	NC	3.28	3.49	3.72	3.93	4.07
386	Com Boiler/Chiller to VRF - Gas Heat	G	UP	Com	RET	0.18	0.19	0.22	0.26	0.30
387	Com Boiler/Chiller to VRF - Gas Heat	G	UP	Com	NC	0.10	0.16	0.41	0.73	1.01
390	Com Boiler/Chiller to VRF - Oil Heat	O	UP	Com	RET	1.71	1.81	1.92	2.02	2.09
391	Com Boiler/Chiller to VRF - Oil Heat	O	UP	Com	NC	13.55	14.38	15.30	16.14	16.69
394	Com Boiler/Unitary AC to GSHP - Gas Heat	G	UP	Com	RET	0.21	0.24	0.27	0.30	0.32
395	Com Boiler/Unitary AC to GSHP - Gas Heat	G	UP	Com	NC	0.29	0.34	0.41	0.48	0.53
398	Com Boiler/Unitary AC to GSHP - Oil Heat	O	UP	Com	RET	1.14	1.21	1.27	1.33	1.37
399	Com Boiler/Unitary AC to GSHP - Oil Heat	O	UP	Com	NC	2.19	2.33	2.46	2.58	2.67
402	Com Boiler/Chiller to GSHP - Gas Heat	G	UP	Com	RET	0.12	0.14	0.16	0.19	0.21
403	Com Boiler/Chiller to GSHP - Gas Heat	G	UP	Com	NC	0.12	0.17	0.24	0.31	0.37
406	Com Boiler/Chiller to GSHP - Oil Heat	O	UP	Com	RET	0.97	1.03	1.08	1.13	1.16
407	Com Boiler/Chiller to GSHP - Oil Heat	O	UP	Com	NC	2.77	2.93	3.10	3.25	3.35
410	High-eff HP CEE Tier II -Cool	E	UP	Com	RET	0.41	0.44	0.46	0.46	0.46
411	High-eff HP CEE Tier II -Cool	E	UP	Com	NC	1.48	1.60	1.65	1.66	1.65
412	High-eff HP CEE Tier II -Cool	E	UP	Com	REPL	1.48	1.59	1.65	1.66	1.65
416	Com Heat Pump Water Htr replace Oil	O	UP	Com	NC	4.16	4.47	4.80	5.09	5.26
417	Com Heat Pump Water Htr replace Oil	O	UP	Com	REPL	4.16	4.47	4.80	5.09	5.26
418	Res FF Heat/CAC to ASHP - Gas Heat	G	UP	Res	RET	(0.02)	(0.00)	0.06	0.15	0.22
419	Res FF Heat/CAC to ASHP - Gas Heat	G	UP	Res	NC	(0.12)	(0.07)	0.15	0.44	0.69
422	Res FF Heat/CAC to ASHP - Oil Heat	O	UP	Res	RET	2.75	2.93	3.13	3.33	3.46
423	Res FF Heat/CAC to ASHP - Oil Heat	O	UP	Res	NC	9.50	10.11	10.80	11.47	11.92
426	Res FFHeat/CAC to DMSHP - Gas Heat	G	UP	Res	RET	0.21	0.23	0.27	0.32	0.36
427	Res FFHeat/CAC to DMSHP - Gas Heat	G	UP	Res	NC	0.11	0.14	0.20	0.27	0.34
430	Res FFHeat/CAC to DMSHP - Oil Heat	O	UP	Res	RET	1.72	1.83	1.94	2.05	2.12
431	Res FFHeat/CAC to DMSHP - Oil Heat	O	UP	Res	NC	2.65	2.82	3.00	3.17	3.29
434	Res FFHeat/Room AC to DMSHP - Gas Heat	G	UP	Res	RET	0.16	0.18	0.22	0.27	0.31
435	Res FFHeat/Room AC to DMSHP - Gas Heat	G	UP	Res	NC	0.10	0.12	0.17	0.22	0.27
438	Res FFHeat/Room AC to DMSHP - Oil Heat	O	UP	Res	RET	1.72	1.83	1.94	2.05	2.13

#	Measure Name	Primary Fuel	Zone	Sector	Market	2015	2020	2025	2030	2034
439	Res FFHeat/Room AC to DMSHP - Oil Heat	O	UP	Res	NC	1.98	2.11	2.25	2.38	2.47
442	Res FF Heat/CAC to GSHP - Gas Heat	G	UP	Res	RET	0.18	0.20	0.23	0.26	0.28
443	Res FF Heat/CAC to GSHP - Gas Heat	G	UP	Res	NC	0.10	0.15	0.21	0.28	0.33
446	Res FF Heat/CAC to GSHP - Oil Heat	O	UP	Res	RET	1.53	1.60	1.68	1.75	1.80
447	Res FF Heat/CAC to GSHP - Oil Heat	O	UP	Res	NC	3.43	3.62	3.81	3.98	4.10
450	Res Resist Heat/Room AC to DMSHP -Heat	E	UP	Res	RET	1.14	1.19	1.19	1.14	1.09
451	Res Resist Heat/Room AC to DMSHP -Heat	E	UP	Res	NC	1.76	1.85	1.84	1.77	1.68
454	Air Source Heat Pump ESTAR -Cool	E	UP	Res	NC	0.60	0.64	0.66	0.66	0.65
455	Air Source Heat Pump ESTAR -Cool	E	UP	Res	REPL	0.60	0.64	0.66	0.66	0.65
458	Res Heat Pump Water Htr replace Oil	O	UP	Res	NC	4.25	4.57	4.90	5.18	5.35
459	Res Heat Pump Water Htr replace Oil	O	UP	Res	REPL	4.25	4.57	4.90	5.18	5.35

Appendix D: Measure Characterizations

The heat pump measures are modeled with separate heating (MMBtu saved, saved or increased kWh) and cooling (saved or increased kWh) components.

Table D-1 describes the measures assessed, and Table D-2 shows the combined costs and benefits for the two components of each heat pump measure.

Table D-1. Measure Descriptions

Meas #	Mkt	End Use	Measure Long Name	Heat Pump Technology	Heating Baseline	Cooling Baseline	Baseline Description	Units for Costs & Savings Values
594	Ret	Heating	Com Boiler/unitary AC to ASHP - Gas Heat	Air Source Heat Pump C&I Ret	Boiler C&I Ret	Unitary AC C&I Ret	Standard efficiency boiler (AFUE 0.85)	Per ton of heating
595	Ret	Cooling	Com Boiler/unitary AC to ASHP - Gas Cool	Air Source Heat Pump C&I Ret	Boiler C&I Ret	Unitary AC C&I Ret	Standard efficiency unitary AC (IPLV 10.7 for 15 ton, 9.7 for 25 ton)	Per ton of cooling
596	Ret	Heating	Com Boiler/unitary AC to ASHP - Oil Heat	Air Source Heat Pump C&I Ret	Boiler C&I Ret	Unitary AC C&I Ret	Standard efficiency boiler (AFUE 0.85)	Per ton of heating
597	Ret	Cooling	Com Boiler/unitary AC to ASHP - Oil Cool	Air Source Heat Pump C&I Ret	Boiler C&I Ret	Unitary AC C&I Ret	Standard efficiency unitary AC (IPLV 10.7 for 15 ton, 9.7 for 25 ton)	Per ton of cooling
594	MD	Heating	Com Boiler/unitary AC to ASHP - Gas Heat	Air Source Heat Pump C&I NC	Boiler C&I NC	Unitary AC C&I NC	Standard efficiency boiler (AFUE 0.85)	Per ton of heating
595	MD	Cooling	Com Boiler/unitary AC to ASHP - Gas Cool	Air Source Heat Pump C&I NC	Boiler C&I NC	Unitary AC C&I NC	Standard efficiency unitary AC (IPLV 13.0 for 15 ton, 12.7 for 25 ton)	Per ton of cooling
596	MD	Heating	Com Boiler/unitary AC to ASHP - Oil Heat	Air Source Heat Pump C&I NC	Boiler C&I NC	Unitary AC C&I NC	Standard efficiency boiler (AFUE 0.85)	Per ton of heating
597	MD	Cooling	Com Boiler/unitary AC to ASHP - Oil Cool	Air Source Heat Pump C&I NC	Boiler C&I NC	Unitary AC C&I NC	Standard efficiency unitary AC (IPLV 13.0 for 15 ton, 12.7 for 25 ton)	Per ton of cooling
598	Ret	Heating	Res FF Heat/CAC to ASHP - Gas Heat	Air Source Heat Pump Res Ret	gas furnace/boiler Res Ret	CAC Res Ret	Standard efficiency boiler/furnace (average AFUE 0.79)	Per ton of heating
599	Ret	Cooling	Res FF Heat/CAC to ASHP - Gas Cool	Air Source Heat Pump Res Ret	gas furnace/boiler Res Ret	CAC Res Ret	Standard efficiency CAC (SEER 10.0)	Per ton of cooling
600	Ret	Heating	Res FF Heat/CAC to ASHP - Oil Heat	Air Source Heat Pump Res Ret	oil furnace/boiler Res Ret	CAC Res Ret	Standard efficiency boiler/furnace (average AFUE 0.79)	Per ton of heating
601	Ret	Cooling	Res FF Heat/CAC to ASHP - Oil Cool	Air Source Heat Pump Res Ret	oil furnace/boiler Res Ret	CAC Res Ret	Standard efficiency CAC (SEER 10.0)	Per ton of cooling
598	MD	Heating	Res FF Heat/CAC to ASHP - Gas Heat	Air Source Heat Pump Res NC	gas furnace/boiler Res NC	CAC Res NC	Standard efficiency boiler/furnace (average AFUE 0.81)	Per ton of heating

Meas #	Mkt	End Use	Measure Long Name	Heat Pump Technology	Heating Baseline	Cooling Baseline	Baseline Description	Units for Costs & Savings Values
599	MD	Cooling	Res FF Heat/CAC to ASHP - Gas Cool	Air Source Heat Pump Res NC	gas furnace/boiler Res NC	CAC Res NC	Standard efficiency CAC (SEER 14.0)	Per ton of cooling
600	MD	Heating	Res FF Heat/CAC to ASHP - Oil Heat	Air Source Heat Pump Res NC	oil furnace/boiler Res NC	CAC Res NC	Standard efficiency boiler/furnace (average AFUE 0.81)	Per ton of heating
601	MD	Cooling	Res FF Heat/CAC to ASHP - Oil Cool	Air Source Heat Pump Res NC	oil furnace/boiler Res NC	CAC Res NC	Standard efficiency CAC (SEER 14.0)	Per ton of cooling
602	Ret	Heating	Com Boiler/Chiller to ASHP - Gas Heat	Air Source Heat Pump C&I Ret	Boiler C&I Ret	Chiller C&I Ret	Standard efficiency boiler (AFUE 0.85)	Per ton of heating
603	Ret	Cooling	Com Boiler/Chiller to ASHP - Gas Cool	Air Source Heat Pump C&I Ret	Boiler C&I Ret	Chiller C&I Ret	Standard efficiency chiller (COP 5 for 100 ton, 5.5 for 200 ton)	Per ton of cooling
604	Ret	Heating	Com Boiler/Chiller to ASHP - Oil Heat	Air Source Heat Pump C&I Ret	Boiler C&I Ret	Chiller C&I Ret	Standard efficiency boiler (AFUE 0.85)	Per ton of heating
605	Ret	Cooling	Com Boiler/Chiller to ASHP - Oil Cool	Air Source Heat Pump C&I Ret	Boiler C&I Ret	Chiller C&I Ret	Standard efficiency chiller (COP 5 for 100 ton, 5.5 for 200 ton)	Per ton of cooling
602	MD	Heating	Com Boiler/Chiller to ASHP - Gas Heat	Air Source Heat Pump C&I NC	Boiler C&I NC	Chiller C&I NC	Standard efficiency boiler (AFUE 0.85)	Per ton of heating
603	MD	Cooling	Com Boiler/Chiller to ASHP - Gas Cool	Air Source Heat Pump C&I NC	Boiler C&I NC	Chiller C&I NC	Standard efficiency chiller (IPLV 0.62 for 100 ton, 0.58 for 200 ton)	Per ton of cooling
604	MD	Heating	Com Boiler/Chiller to ASHP - Oil Heat	Air Source Heat Pump C&I NC	Boiler C&I NC	Chiller C&I NC	Standard efficiency boiler (AFUE 0.85)	Per ton of heating
605	MD	Cooling	Com Boiler/Chiller to ASHP - Oil Cool	Air Source Heat Pump C&I NC	Boiler C&I NC	Chiller C&I NC	Standard efficiency chiller (IPLV 0.62 for 100 ton, 0.58 for 200 ton)	Per ton of cooling
606	Ret	Heating	Res FFHeat/CAC to DMSHP - Gas Heat	Ductless Mini Split Res Ret	gas furnace/boiler Res Ret	CAC Res Ret	Standard efficiency boiler/furnace (average AFUE 0.79)	Per ton of heating
607	Ret	Cooling	Res FFHeat/CAC to DMSHP - Gas Cool	Ductless Mini Split Res Ret	gas furnace/boiler Res Ret	CAC Res Ret	Standard efficiency CAC (SEER 10.0)	Per ton of cooling
608	Ret	Heating	Res FFHeat/CAC to DMSHP - Oil Heat	Ductless Mini Split Res Ret	oil furnace/boiler Res Ret	CAC Res Ret	Standard efficiency boiler/furnace (average AFUE 0.79)	Per ton of heating
609	Ret	Cooling	Res FFHeat/CAC to DMSHP - Oil Cool	Ductless Mini Split Res Ret	oil furnace/boiler Res Ret	CAC Res Ret	Standard efficiency CAC (SEER 10.0)	Per ton of cooling
606	MD	Heating	Res FFHeat/CAC to DMSHP - Gas Heat	Ductless Mini Split Res NC	gas furnace/boiler Res NC	CAC Res NC	Standard efficiency boiler/furnace (average AFUE 0.81)	Per ton of heating
607	MD	Cooling	Res FFHeat/CAC to DMSHP - Gas Cool	Ductless Mini Split Res NC	gas furnace/boiler Res NC	CAC Res NC	Standard efficiency CAC (SEER 14.0)	Per ton of cooling
608	MD	Heating	Res FFHeat/CAC to DMSHP - Oil Heat	Ductless Mini Split Res NC	oil furnace/boiler Res NC	CAC Res NC	Standard efficiency boiler/furnace (average AFUE 0.81)	Per ton of heating

Meas #	Mkt	End Use	Measure Long Name	Heat Pump Technology	Heating Baseline	Cooling Baseline	Baseline Description	Units for Costs & Savings Values
609	Md	Cooling	Res FFHeat/CAC to DMSHP - Oil Cool	Ductless Mini Split Res NC	oil furnace/boiler Res NC	CAC Res NC	Standard efficiency CAC (SEER 14.0)	Per ton of cooling
610	Ret	Heating	Res FFHeat/Room AC to DMSHP - Gas Heat	Ductless Mini Split Res Ret	gas furnace/boiler Res Ret	Window units Res Ret	Standard efficiency boiler/furnace (average AFUE 0.79)	Per ton of heating
611	Ret	Cooling	Res FFHeat/Room AC to DMSHP - Gas Cool	Ductless Mini Split Res Ret	gas furnace/boiler Res Ret	Window units Res Ret	Standard efficiency room AC (EER 9.7)	Per ton of cooling
612	Ret	Heating	Res FFHeat/Room AC to DMSHP - Oil Heat	Ductless Mini Split Res Ret	gas furnace/boiler Res Ret	Window units Res Ret	Standard efficiency boiler/furnace (average AFUE 0.79)	Per ton of heating
613	Ret	Cooling	Res FFHeat/Room AC to DMSHP - Oil Cool	Ductless Mini Split Res Ret	gas furnace/boiler Res Ret	Window units Res Ret	Standard efficiency room AC (EER 9.7)	Per ton of cooling
610	MD	Heating	Res FFHeat/Room AC to DMSHP - Gas Heat	Ductless Mini Split Res NC	gas furnace/boiler Res NC	Window units Res NC	Standard efficiency boiler/furnace (average AFUE 0.81)	Per ton of heating
611	MD	Cooling	Res FFHeat/Room AC to DMSHP - Gas Cool	Ductless Mini Split Res NC	gas furnace/boiler Res NC	Window units Res NC	Standard efficiency room AC (EER 10.9)	Per ton of cooling
612	MD	Heating	Res FFHeat/Room AC to DMSHP - Oil Heat	Ductless Mini Split Res NC	oil furnace/boiler Res NC	Window units Res NC	Standard efficiency boiler/furnace (average AFUE 0.81)	Per ton of heating
613	MD	Cooling	Res FFHeat/Room AC to DMSHP - Oil Cool	Ductless Mini Split Res NC	oil furnace/boiler Res NC	Window units Res NC	Standard efficiency room AC (EER 10.9)	Per ton of cooling
614	Ret	Heating	Com Boiler/CAC to DMSHP - Gas Heat	Ductless Mini Split C&I Ret	Boiler C&I Ret	CAC C&I Ret	Standard efficiency boiler (AFUE 0.85)	Per ton of heating
615	Ret	Cooling	Com Boiler/CAC to DMSHP - Gas Cool	Ductless Mini Split C&I Ret	Boiler C&I Ret	CAC C&I Ret	Standard efficiency CAC (SEER 10.0)	Per ton of cooling
616	Ret	Heating	Com Boiler/CAC to DMSHP - Oil Heat	Ductless Mini Split C&I Ret	Boiler C&I Ret	CAC C&I Ret	Standard efficiency boiler (AFUE 0.85)	Per ton of heating
617	Ret	Cooling	Com Boiler/CAC to DMSHP - Oil Cool	Ductless Mini Split C&I Ret	Boiler C&I Ret	CAC C&I Ret	Standard efficiency CAC (SEER 10.0)	Per ton of cooling
614	MD	Heating	Com Boiler/CAC to DMSHP - Gas Heat	Ductless Mini Split C&I Ret	Boiler C&I NC	CAC C&I NC	Standard efficiency boiler (AFUE 0.85)	Per ton of heating
615	MD	Cooling	Com Boiler/CAC to DMSHP - Gas Cool	Ductless Mini Split C&I Ret	Boiler C&I NC	CAC C&I NC	Standard efficiency CAC (SEER 10.0)	Per ton of cooling
616	MD	Heating	Com Boiler/CAC to DMSHP - Oil Heat	Ductless Mini Split C&I Ret	Boiler C&I NC	CAC C&I NC	Standard efficiency boiler (AFUE 0.85)	Per ton of heating
617	MD	Cooling	Com Boiler/CAC to DMSHP - Oil Cool	Ductless Mini Split C&I Ret	Boiler C&I NC	CAC C&I NC	Standard efficiency CAC (SEER 10.0)	Per ton of cooling
618	Ret	Heating	Com Boiler/RoomAC to DMSHP - Gas Heat	Ductless Mini Split C&I Ret	Boiler C&I Ret	Window units C&I Ret	Standard efficiency boiler (AFUE 0.85)	Per ton of heating

Meas #	Mkt	End Use	Measure Long Name	Heat Pump Technology	Heating Baseline	Cooling Baseline	Baseline Description	Units for Costs & Savings Values
619	Ret	Cooling	Com Boiler/RoomAC to DMSHP - Gas Cool	Ductless Mini Split C&I Ret	Boiler C&I Ret	Window units C&I Ret	Standard efficiency window AC (EER 9.7)	Per ton of cooling
620	Ret	Heating	Com Boiler/RoomAC to DMSHP - Oil Heat	Ductless Mini Split C&I Ret	Boiler C&I Ret	Window units C&I Ret	Standard efficiency boiler (AFUE 0.85)	Per ton of heating
621	Ret	Cooling	Com Boiler/RoomAC to DMSHP - Oil Cool	Ductless Mini Split C&I Ret	Boiler C&I Ret	Window units C&I Ret	Standard efficiency window AC (EER 9.7)	Per ton of cooling
618	MD	Heating	Com Boiler/RoomAC to DMSHP - Gas Heat	Ductless Mini Split C&I Ret	Boiler C&I NC	Window units C&I NC	Standard efficiency boiler (AFUE 0.85)	Per ton of heating
619	MD	Cooling	Com Boiler/RoomAC to DMSHP - Gas Cool	Ductless Mini Split C&I Ret	Boiler C&I NC	Window units C&I NC	Standard efficiency window AC (EER 10.9)	Per ton of cooling
620	MD	Heating	Com Boiler/RoomAC to DMSHP - Oil Heat	Ductless Mini Split C&I Ret	Boiler C&I NC	Window units C&I NC	Standard efficiency boiler (AFUE 0.85)	Per ton of heating
621	MD	Cooling	Com Boiler/RoomAC to DMSHP - Oil Cool	Ductless Mini Split C&I Ret	Boiler C&I NC	Window units C&I NC	Standard efficiency window AC (EER 10.9)	Per ton of cooling
622	Ret	Heating	Com Boiler/Unitary AC to VRF - Gas Heat	VRF C&I Ret	Boiler C&I Ret	Unitary AC C&I Ret	Standard efficiency boiler (AFUE 0.85)	Per ton of heating
623	Ret	Cooling	Com Boiler/Unitary AC to VRF - Gas Cool	VRF C&I Ret	Boiler C&I Ret	Unitary AC C&I Ret	Standard efficiency unitary AC (IPLV 10.7 for 15 ton, 9.7 for 25 ton)	Per ton of cooling
624	Ret	Heating	Com Boiler/Unitary AC to VRF - Oil Heat	VRF C&I Ret	Boiler C&I Ret	Unitary AC C&I Ret	Standard efficiency boiler (AFUE 0.85)	Per ton of heating
625	Ret	Cooling	Com Boiler/Unitary AC to VRF - Oil Cool	VRF C&I Ret	Boiler C&I Ret	Unitary AC C&I Ret	Standard efficiency unitary AC (IPLV 10.7 for 15 ton, 9.7 for 25 ton)	Per ton of cooling
622	MD	Heating	Com Boiler/Unitary AC to VRF - Gas Heat	VRF C&I NC	Boiler C&I NC	Unitary AC C&I NC	Standard efficiency boiler (AFUE 0.85)	Per ton of heating
623	MD	Cooling	Com Boiler/Unitary AC to VRF - Gas Cool	VRF C&I NC	Boiler C&I NC	Unitary AC C&I NC	Standard efficiency unitary AC (IPLV 13.0 for 15 ton, 12.7 for 25 ton)	Per ton of cooling
624	MD	Heating	Com Boiler/Unitary AC to VRF - Oil Heat	VRF C&I NC	Boiler C&I NC	Unitary AC C&I NC	Standard efficiency boiler (AFUE 0.85)	Per ton of heating
625	MD	Cooling	Com Boiler/Unitary AC to VRF - Oil Cool	VRF C&I NC	Boiler C&I NC	Unitary AC C&I NC	Standard efficiency unitary AC (IPLV 13.0 for 15 ton, 12.7 for 25 ton)	Per ton of cooling
626	Ret	Heating	Com Boiler/Chiller to VRF - Gas Heat	VRF C&I Ret	Boiler C&I Ret	Chiller C&I Ret	Standard efficiency boiler (AFUE 0.85)	Per ton of heating
627	Ret	Cooling	Com Boiler/Chiller to VRF - Gas Cool	VRF C&I Ret	Boiler C&I Ret	Chiller C&I Ret	Standard efficiency chiller (COP 5 for 100 ton, 5.5 for 200 ton)	Per ton of cooling
628	Ret	Heating	Com Boiler/Chiller to VRF - Oil Heat	VRF C&I Ret	Boiler C&I Ret	Chiller C&I Ret	Standard efficiency boiler (AFUE 0.85)	Per ton of heating

Meas #	Mkt	End Use	Measure Long Name	Heat Pump Technology	Heating Baseline	Cooling Baseline	Baseline Description	Units for Costs & Savings Values
629	Ret	Cooling	Com Boiler/Chiller to VRF - Oil Cool	VRF C&I Ret	Boiler C&I Ret	Chiller C&I Ret	Standard efficiency chiller (COP 5 for 100 ton, 5.5 for 200 ton)	Per ton of cooling
626	MD	Heating	Com Boiler/Chiller to VRF - Gas Heat	VRF C&I NC	Boiler C&I NC	Chiller C&I NC	Standard efficiency boiler (AFUE 0.85)	Per ton of heating
627	MD	Cooling	Com Boiler/Chiller to VRF - Gas Cool	VRF C&I NC	Boiler C&I NC	Chiller C&I NC	Standard efficiency chiller (IPLV 0.62 for 100 ton, 0.58 for 200 ton)	Per ton of cooling
628	MD	Heating	Com Boiler/Chiller to VRF - Oil Heat	VRF C&I NC	Boiler C&I NC	Chiller C&I NC	Standard efficiency boiler (AFUE 0.85)	Per ton of heating
629	MD	Cooling	Com Boiler/Chiller to VRF - Oil Cool	VRF C&I NC	Boiler C&I NC	Chiller C&I NC	Standard efficiency chiller (IPLV 0.62 for 100 ton, 0.58 for 200 ton)	Per ton of cooling
630	Ret	Heating	Res FF Heat/CAC to GSHP - Gas Heat	GSHP Res Ret	gas furnace/boiler Res Ret	CAC Res Ret	Standard efficiency boiler/furnace (average AFUE 0.79)	Per ton of heating
631	Ret	Cooling	Res FF Heat/CAC to GSHP - Gas Cool	GSHP Res Ret	gas furnace/boiler Res Ret	CAC Res Ret	Standard efficiency CAC (SEER 10.0)	Per ton of cooling
632	Ret	Heating	Res FF Heat/CAC to GSHP - Oil Heat	GSHP Res Ret	oil furnace/boiler Res Ret	CAC Res Ret	Standard efficiency boiler/furnace (average AFUE 0.79)	Per ton of heating
633	Ret	Cooling	Res FF Heat/CAC to GSHP - Oil Cool	GSHP Res Ret	oil furnace/boiler Res Ret	CAC Res Ret	Standard efficiency CAC (SEER 10.0)	Per ton of cooling
630	MD	Heating	Res FF Heat/CAC to GSHP - Gas Heat	GSHP Res NC	gas furnace/boiler Res NC	CAC Res NC	Standard efficiency boiler/furnace (average AFUE 0.81)	Per ton of heating
631	MD	Cooling	Res FF Heat/CAC to GSHP - Gas Cool	GSHP Res NC	gas furnace/boiler Res NC	CAC Res NC	Standard efficiency CAC (SEER 14.0)	Per ton of cooling
632	MD	Heating	Res FF Heat/CAC to GSHP - Oil Heat	GSHP Res NC	oil furnace/boiler Res NC	CAC Res NC	Standard efficiency boiler/furnace (average AFUE 0.81)	Per ton of heating
633	MD	Cooling	Res FF Heat/CAC to GSHP - Oil Cool	GSHP Res NC	oil furnace/boiler Res NC	CAC Res NC	Standard efficiency CAC (SEER 14.0)	Per ton of cooling
634	Ret	Heating	Com Boiler/Unitary AC to GSHP - Gas Heat	GSHP C&I Ret	Boiler C&I Ret	Unitary AC C&I Ret	Standard efficiency boiler (AFUE 0.85)	Per ton of heating
635	Ret	Cooling	Com Boiler/Unitary AC to GSHP - Gas Cool	GSHP C&I Ret	Boiler C&I Ret	Unitary AC C&I Ret	Standard efficiency unitary AC (IPLV 10.7 for 15 ton, 9.7 for 25 ton)	Per ton of cooling
636	Ret	Heating	Com Boiler/Unitary AC to GSHP - Oil Heat	GSHP C&I Ret	Boiler C&I Ret	Unitary AC C&I Ret	Standard efficiency boiler (AFUE 0.85)	Per ton of heating
637	Ret	Cooling	Com Boiler/Unitary AC to GSHP - Oil Cool	GSHP C&I Ret	Boiler C&I Ret	Unitary AC C&I Ret	Standard efficiency unitary AC (IPLV 10.7 for 15 ton, 9.7 for 25 ton)	Per ton of cooling
634	MD	Heating	Com Boiler/Unitary AC to GSHP - Gas Heat	GSHP C&I NC	Boiler C&I NC	Unitary AC C&I NC	Standard efficiency boiler (AFUE 0.85)	Per ton of heating

Meas #	Mkt	End Use	Measure Long Name	Heat Pump Technology	Heating Baseline	Cooling Baseline	Baseline Description	Units for Costs & Savings Values
635	MD	Cooling	Com Boiler/Unitary AC to GSHP - Gas Cool	GSHP C&I NC	Boiler C&I NC	Unitary AC C&I NC	Standard efficiency unitary AC (IPLV 13.0 for 15 ton, 12.7 for 25 ton)	Per ton of cooling
636	MD	Heating	Com Boiler/Unitary AC to GSHP - Oil Heat	GSHP C&I NC	Boiler C&I NC	Unitary AC C&I NC	Standard efficiency boiler (AFUE 0.85)	Per ton of heating
637	MD	Cooling	Com Boiler/Unitary AC to GSHP - Oil Cool	GSHP C&I NC	Boiler C&I NC	Unitary AC C&I NC	Standard efficiency unitary AC (IPLV 13.0 for 15 ton, 12.7 for 25 ton)	Per ton of cooling
638	Ret	Heating	Com Boiler/Chiller to GSHP - Gas Heat	GSHP C&I Ret	Boiler C&I Ret	Chiller C&I Ret	Standard efficiency boiler (AFUE 0.85)	Per ton of heating
639	Ret	Cooling	Com Boiler/Chiller to GSHP - Gas Cool	GSHP C&I Ret	Boiler C&I Ret	Chiller C&I Ret	Standard efficiency chiller (COP 5 for 100 ton, 5.5 for 200 ton)	Per ton of cooling
640	Ret	Heating	Com Boiler/Chiller to GSHP - Oil Heat	GSHP C&I Ret	Boiler C&I Ret	Chiller C&I Ret	Standard efficiency boiler (AFUE 0.85)	Per ton of heating
641	Ret	Cooling	Com Boiler/Chiller to GSHP - Oil Cool	GSHP C&I Ret	Boiler C&I Ret	Chiller C&I Ret	Standard efficiency chiller (COP 5 for 100 ton, 5.5 for 200 ton)	Per ton of cooling
638	MD	Heating	Com Boiler/Chiller to GSHP - Gas Heat	GSHP C&I NC	Boiler C&I NC	Chiller C&I NC	Standard efficiency boiler (AFUE 0.85)	Per ton of heating
639	MD	Cooling	Com Boiler/Chiller to GSHP - Gas Cool	GSHP C&I NC	Boiler C&I NC	Chiller C&I NC	Standard efficiency chiller (IPLV 0.62 for 100 ton, 0.58 for 200 ton)	Per ton of cooling
640	MD	Heating	Com Boiler/Chiller to GSHP - Oil Heat	GSHP C&I NC	Boiler C&I NC	Chiller C&I NC	Standard efficiency boiler (AFUE 0.85)	Per ton of heating
641	MD	Cooling	Com Boiler/Chiller to GSHP - Oil Cool	GSHP C&I NC	Boiler C&I NC	Chiller C&I NC	Standard efficiency chiller (IPLV 0.62 for 100 ton, 0.58 for 200 ton)	Per ton of cooling
642	Ret	Space Heating	Res Resist Heat/Room AC to DMSHP -Heat				Resistance heat, room AC meeting federal standards	1.5-ton unit
643	Ret	Cooling	Res Resist Heat/Room AC to DMSHP -Cool				Resistance heat, room AC meeting federal standards	1.5-ton unit
642	MD	Space Heating	Res Resist Heat/Room AC to DMSHP -Heat				Resistance heat, room AC meeting federal standards	40 kBtu/hr HP
643	MD	Cooling	Res Resist Heat/Room AC to DMSHP -Cool				Resistance heat, room AC meeting federal standards	40 kBtu/hr HP
177	MD	Cooling	High-efficiency Heat Pump CEE Tier II - Cool				Standard efficiency new unitary heat pump. Baseline efficiency will reflect weighted average by size and type.	per Ton

Meas #	Mkt	End Use	Measure Long Name	Heat Pump Technology	Heating Baseline	Cooling Baseline	Baseline Description	Units for Costs & Savings Values
177	RET	Cooling	High-efficiency Heat Pump CEE Tier II - Cool				Existing stock efficiency unitary heat pump. Existing stock efficiency will reflect weighted average by size and type.	per Ton
178	MD	Space Heating	High-efficiency Heat Pump CEE Tier II - Heat				Standard efficiency new unitary heat pump. Baseline efficiency will reflect weighted average by size and type.	per Ton
178	RET	Space Heating	High-efficiency Heat Pump CEE Tier II - Heat				Existing stock efficiency unitary heat pump. Existing stock efficiency will reflect weighted average by size and type.	per Ton
404	MD	Cooling	Air Source Heat Pump, Ducted, Energy Star				Standard efficiency, ducted, ASHP, 13 SEER, 11 EER	Per ton cooling
405	MD	Space Heating	Air Source Heat Pump, Ducted, Energy Star				Standard efficiency, ducted, ASHP, 7.7 HSPF	Per 1 kBtu heating capacity
430	MD	Water Heating	Res heat pump water heater for oil				Oil fired standalone DHW tank	Oil water heater
646	MD	Water Heating	Com heat pump water heater for oil				Oil fired standalone DHW tank	Oil water heater

Table D-2. Measure Costs and Savings

Meas #	Mkt	End Use	Measure Long Name	kWh Savings	% Savings (primary fuel)	Incre-mental Cost	Incremental Cost per kWh (or MMBtu) Saved	Base-line Equip. Life	Base line Equip. Age	Baseline Cost per kWh (or MMBtu) saved	Baseline shift savings factor (for RET)	Fossil Fuel (or Elec) Savings - increased use is negative (MMBtu/yr | kWh/yr)	Annual Fossil Fuel (or Elec) Savings - increased is negative (MMBtu/kWh | kWh/MMBtu saved)
594	Ret	Heating	Com Boiler/unitary AC to ASHP - Gas Heat		100%		$229.34	20	15	$36.00	100.0%	-547.4	-70.8
595	Ret	Cooling	Com Boiler/unitary AC to ASHP - Gas Cool		17%		$0.78	15	10	$3.65	-23.8%		
596	Ret	Heating	Com Boiler/unitary AC to ASHP - Oil Heat		100%		$229.34	20	15	$36.00	100.0%	-547.4	-70.8
597	Ret	Cooling	Com Boiler/unitary AC to ASHP - Oil Cool		17%		$0.78	15	10	$3.65	-23.8%		
594	MD	Heating	Com Boiler/unitary AC to ASHP - Gas Heat		100%		$96.53					-547.4	-70.8
595	MD	Cooling	Com Boiler/unitary AC to ASHP - Gas Cool		-5%		$0.33						
596	MD	Heating	Com Boiler/unitary AC to ASHP - Oil Heat		100%		$96.53					-547.4	-70.8
597	MD	Cooling	Com Boiler/unitary AC to ASHP - Oil Cool		-5%		$0.33						
598	Ret	Heating	Res FF Heat/CAC to ASHP - Gas Heat		100%		$132.61	23	18	$23.21	97.5%	-1633.4	-92.9
599	Ret	Cooling	Res FF Heat/CAC to ASHP - Gas Cool		33%		$0.45	15	10	$5.34	14.3%		
600	Ret	Heating	Res FF Heat/CAC to ASHP - Oil Heat		100%		$132.61	23	18	$23.21	97.5%	-1633.4	-92.9
601	Ret	Cooling	Res FF Heat/CAC to ASHP - Oil Cool		33%		$0.45	15	10	$5.34	14.3%		
598	MD	Heating	Res FF Heat/CAC to ASHP - Gas Heat		100%		$40.07					-1633.4	-95.3
599	MD	Cooling	Res FF Heat/CAC to ASHP - Gas Cool		7%		$0.14						
600	MD	Heating	Res FF Heat/CAC to ASHP - Oil Heat		100%		$40.07					-1633.4	-95.3
601	MD	Cooling	Res FF Heat/CAC to ASHP - Oil Cool		7%		$0.14						

Meas #	Mkt	End Use	Measure Long Name	kWh Savings	% Savings (primary fuel)	Incre-mental Cost	Incremental Cost per kWh (or MMBtu) Saved	Base-line Equip. Life	Base line Equip. Age	Baseline Cost per kWh (or MMBtu) saved	Baseline shift savings factor (for RET)	Fossil Fuel (or Elec) Savings - increased use is negative (MMBtu/yr | kWh/yr)	Annual Fossil Fuel (or Elec) Savings - increased is negative (MMBtu/kWh | kWh/MMBtu saved)
602	Ret	Heating	Com Boiler/Chiller to ASHP - Gas Heat		100%		$319.18	20	13	$36.00	100.0%	-547.4	-70.8
603	Ret	Cooling	Com Boiler/Chiller to ASHP - Gas Cool		-46%		$1.09	20	13	$(1.73)	124.0%		
604	Ret	Heating	Com Boiler/Chiller to ASHP - Oil Heat		100%		$319.18	20	13	$36.00	100.0%	-547.4	-70.8
605	Ret	Cooling	Com Boiler/Chiller to ASHP - Oil Cool		-46%		$1.09	20	13	$(1.73)	124.0%		
602	MD	Heating	Com Boiler/Chiller to ASHP - Gas Heat		100%		$(77.21)					-547.4	-70.8
603	MD	Cooling	Com Boiler/Chiller to ASHP - Gas Cool		-64%		$(0.26)						
604	MD	Heating	Com Boiler/Chiller to ASHP - Oil Heat		100%		$(77.21)					-547.4	-70.8
605	MD	Cooling	Com Boiler/Chiller to ASHP - Oil Cool		-64%		$(0.26)						
606	Ret	Heating	Res FFHeat/CAC to DMSHP - Gas Heat		100%		$232.01	23	18	$23.21	97.5%	-1388.4	-79.0
607	Ret	Cooling	Res FFHeat/CAC to DMSHP - Gas Cool		52%		$0.79	15	10	$3.40	45.5%		
608	Ret	Heating	Res FFHeat/CAC to DMSHP - Oil Heat		100%		$232.01	23	18	$23.21	97.5%	-1388.4	-79.0
609	Ret	Cooling	Res FFHeat/CAC to DMSHP - Oil Cool		52%		$0.79	15	10	$3.40	45.5%		
606	MD	Heating	Res FFHeat/CAC to DMSHP - Gas Heat		100%		$148.58					-1388.4	-81.0
607	MD	Cooling	Res FFHeat/CAC to DMSHP - Gas Cool		33%		$0.51						
608	MD	Heating	Res FFHeat/CAC to DMSHP - Oil Heat		100%		$148.58					-1388.4	-81.0
609	Md	Cooling	Res FFHeat/CAC to DMSHP - Oil Cool		33%		$0.51						
610	Ret	Heating	Res FFHeat/Room AC to DMSHP - Gas Heat		100%		$231.03	23	18	$23.21	97.5%	-1388.4	-79.0

Meas #	Mkt	End Use	Measure Long Name	kWh Savings	% Savings (primary fuel)	Incre-mental Cost	Incremental Cost per kWh (or MMBtu) Saved	Base-line Equip. Life	Base line Equip. Age	Baseline Cost per kWh (or MMBtu) saved	Baseline shift savings factor (for RET)	Fossil Fuel (or Elec) Savings - increased use is negative (MMBtu/yr | kWh/yr)	Annual Fossil Fuel (or Elec) Savings - increased is negative (MMBtu/kWh | kWh/MMBtu saved)
611	Ret	Cooling	Res FFHeat/Room AC to DMSHP - Gas Cool		54%		$0.79	9	4	$0.98	79.5%		
612	Ret	Heating	Res FFHeat/Room AC to DMSHP - Oil Heat		100%		$231.03	23	18	$23.21	97.5%	-1388.4	-79.0
613	Ret	Cooling	Res FFHeat/Room AC to DMSHP - Oil Cool		54%		$0.79	9	4	$0.98	79.5%		
610	MD	Heating	Res FFHeat/Room AC to DMSHP - Gas Heat		100%		$195.49					-1388.4	-81.0
611	MD	Cooling	Res FFHeat/Room AC to DMSHP - Gas Cool		48%		$0.67						
612	MD	Heating	Res FFHeat/Room AC to DMSHP - Oil Heat		100%		$195.49					-1388.4	-81.0
613	MD	Cooling	Res FFHeat/Room AC to DMSHP - Oil Cool		48%		$0.67						
614	Ret	Heating	Com Boiler/CAC to DMSHP - Gas Heat		100%		$407.77	20	15	$36.00	100.0%	-657.6	-85.0
615	Ret	Cooling	Com Boiler/CAC to DMSHP - Gas Cool		52%		$1.39	15	10	$1.51	45.5%		
616	Ret	Heating	Com Boiler/CAC to DMSHP - Oil Heat		100%		$407.77	20	15	$36.00	100.0%	-657.6	-85.0
617	Ret	Cooling	Com Boiler/CAC to DMSHP - Oil Cool		52%		$1.39	15	10	$1.51	45.5%		
614	MD	Heating	Com Boiler/CAC to DMSHP - Gas Heat		100%		$307.58					-657.6	-85.0
615	MD	Cooling	Com Boiler/CAC to DMSHP - Gas Cool		33%		$1.05						
616	MD	Heating	Com Boiler/CAC to DMSHP - Oil Heat		100%		$307.58					-657.6	-85.0
617	MD	Cooling	Com Boiler/CAC to DMSHP - Oil Cool		33%		$1.05						
618	Ret	Heating	Com Boiler/RoomAC to DMSHP - Gas Heat		100%		$401.10	20	15	$36.00	100.0%	-657.6	-85.0
619	Ret	Cooling	Com Boiler/RoomAC to DMSHP - Gas Cool		54%		$1.37	9	4	$0.44	79.5%		

Meas #	Mkt	End Use	Measure Long Name	kWh Savings	% Savings (primary fuel)	Incremental Cost	Incremental Cost per kWh (or MMBtu) Saved	Baseline Equip. Life	Baseline Equip. Age	Baseline Cost per kWh (or MMBtu) saved	Baseline shift savings factor (for RET)	Fossil Fuel (or Elec) Savings - increased use is negative (MMBtu/yr | kWh/yr)	Annual Fossil Fuel (or Elec) Savings - increased is negative (MMBtu/kWh | kWh/MMBtu saved)
620	Ret	Heating	Com Boiler/RoomAC to DMSHP - Oil Heat		100%		$401.10	20	15	$36.00	100.0%	-657.6	-85.0
621	Ret	Cooling	Com Boiler/RoomAC to DMSHP - Oil Cool		54%		$1.37	9	4	$0.44	79.5%		
618	MD	Heating	Com Boiler/RoomAC to DMSHP - Gas Heat		100%		$363.32					-657.6	-85.0
619	MD	Cooling	Com Boiler/RoomAC to DMSHP - Gas Cool		48%		$1.24						
620	MD	Heating	Com Boiler/RoomAC to DMSHP - Oil Heat		100%		$363.32					-657.6	-85.0
621	MD	Cooling	Com Boiler/RoomAC to DMSHP - Oil Cool		48%		$1.24						
622	Ret	Heating	Com Boiler/Unitary AC to VRF - Gas Heat		100%		$262.17	20	15	$36.00	100.0%	-504.0	-65.2
623	Ret	Cooling	Com Boiler/Unitary AC to VRF - Gas Cool		50%		$0.89	15	10	$1.24	57.9%		
624	Ret	Heating	Com Boiler/Unitary AC to VRF - Oil Heat		100%		$262.17	20	15	$36.00	100.0%	-504.0	-65.2
625	Ret	Cooling	Com Boiler/Unitary AC to VRF - Oil Cool		50%		$0.89	15	10	$1.24	57.9%		
622	MD	Heating	Com Boiler/Unitary AC to VRF - Gas Heat		100%		$159.89					-504.0	-65.2
623	MD	Cooling	Com Boiler/Unitary AC to VRF - Gas Cool		36%		$0.55						
624	MD	Heating	Com Boiler/Unitary AC to VRF - Oil Heat		100%		$159.89					-504.0	-65.2
625	MD	Cooling	Com Boiler/Unitary AC to VRF - Oil Cool		36%		$0.55						
626	Ret	Heating	Com Boiler/Chiller to VRF - Gas Heat		100%		$341.30	20	13	$36.00	100.0%	-504.0	-65.2
627	Ret	Cooling	Com Boiler/Chiller to VRF - Gas Cool		12%		$1.16	20	13	$6.91	4.3%		
628	Ret	Heating	Com Boiler/Chiller to VRF - Oil Heat		100%		$341.30	20	13	$36.00	100.0%	-504.0	-65.2

Meas #	Mkt	End Use	Measure Long Name	kWh Savings	% Savings (primary fuel)	Incre-mental Cost	Incremental Cost per kWh (or MMBtu) Saved	Base-line Equip. Life	Base line Equip. Age	Baseline Cost per kWh (or MMBtu) saved	Baseline shift savings factor (for RET)	Fossil Fuel (or Elec) Savings - increased use is negative (MMBtu/yr | kWh/yr)	Annual Fossil Fuel (or Elec) Savings - increased is negative (MMBtu/kWh | kWh/MMBtu saved)
629	Ret	Cooling	Com Boiler/Chiller to VRF - Oil Cool		12%		$1.16	20	13	$6.91	4.3%		
626	MD	Heating	Com Boiler/Chiller to VRF - Gas Heat		100%		$41.07					-504.0	-65.2
627	MD	Cooling	Com Boiler/Chiller to VRF - Gas Cool		1%		$0.14						
628	MD	Heating	Com Boiler/Chiller to VRF - Oil Heat		100%		$41.07					-504.0	-65.2
629	MD	Cooling	Com Boiler/Chiller to VRF - Oil Cool		1%		$0.14						
630	Ret	Heating	Res FF Heat/CAC to GSHP - Gas Heat		100%		$434.38	23	18	$23.21	97.5%	-823.5	-46.9
631	Ret	Cooling	Res FF Heat/CAC to GSHP - Gas Cool		65%		$1.48	15	10	$2.74	56.0%		
632	Ret	Heating	Res FF Heat/CAC to GSHP - Oil Heat		100%		$434.38	23	18	$23.21	97.5%	-823.5	-46.9
633	Ret	Cooling	Res FF Heat/CAC to GSHP - Oil Cool		65%		$1.48	15	10	$2.74	56.0%		
630	MD	Heating	Res FF Heat/CAC to GSHP - Gas Heat		100%		$183.42					-823.5	-48.0
631	MD	Cooling	Res FF Heat/CAC to GSHP - Gas Cool		51%		$0.63						
632	MD	Heating	Res FF Heat/CAC to GSHP - Oil Heat		100%		$183.42					-823.5	-48.0
633	MD	Cooling	Res FF Heat/CAC to GSHP - Oil Cool		51%		$0.63						
634	Ret	Heating	Com Boiler/Unitary AC to GSHP - Gas Heat		100%		$734.02	20	15	$36.00	100.0%	-390.0	-50.4
635	Ret	Cooling	Com Boiler/Unitary AC to GSHP - Gas Cool		64%		$2.51	15	10	$0.96	67.5%		
636	Ret	Heating	Com Boiler/Unitary AC to GSHP - Oil Heat		100%		$734.02	20	15	$36.00	100.0%	-390.0	-50.4
637	Ret	Cooling	Com Boiler/Unitary AC to GSHP - Oil Cool		64%		$2.51	15	10	$0.96	67.5%		

Meas #	Mkt	End Use	Measure Long Name	kWh Savings	% Savings (primary fuel)	Incre-mental Cost	Incremental Cost per kWh (or MMBtu) Saved	Base-line Equip. Life	Base line Equip. Age	Baseline Cost per kWh (or MMBtu) saved	Baseline shift savings factor (for RET)	Fossil Fuel (or Elec) Savings - increased use is negative (MMBtu/yr | kWh/yr)	Annual Fossil Fuel (or Elec) Savings - increased is negative (MMBtu/kWh | kWh/MMBtu saved)
634	MD	Heating	Com Boiler/Unitary AC to GSHP - Gas Heat		100%		$372.32					-390.0	-50.4
635	MD	Cooling	Com Boiler/Unitary AC to GSHP - Gas Cool		55%		$1.27						
636	MD	Heating	Com Boiler/Unitary AC to GSHP - Oil Heat		100%		$372.32					-390.0	-50.4
637	MD	Cooling	Com Boiler/Unitary AC to GSHP - Oil Cool		55%		$1.27						
638	Ret	Heating	Com Boiler/Chiller to GSHP - Gas Heat		100%		$934.89	20	13	$36.00	100.0%	-390.0	-50.4
639	Ret	Cooling	Com Boiler/Chiller to GSHP - Gas Cool		37%		$3.19	20	13	$2.13	70.5%		
640	Ret	Heating	Com Boiler/Chiller to GSHP - Oil Heat		100%		$934.89	20	13	$36.00	100.0%	-390.0	-50.4
641	Ret	Cooling	Com Boiler/Chiller to GSHP - Oil Cool		37%		$3.19	20	13	$2.13	70.5%		
638	MD	Heating	Com Boiler/Chiller to GSHP - Gas Heat		100%		$305.05					-390.0	-50.4
639	MD	Cooling	Com Boiler/Chiller to GSHP - Gas Cool		30%		$1.04						
640	MD	Heating	Com Boiler/Chiller to GSHP - Oil Heat		100%		$305.05					-390.0	-50.4
641	MD	Cooling	Com Boiler/Chiller to GSHP - Oil Cool		30%		$1.04						
642	Ret	Space Heating	Res Resist Heat/Room AC to DMSHP -Heat	9313.4	45%	$7,500	$0.69						
643	Ret	Cooling	Res Resist Heat/Room AC to DMSHP -Cool	1530.0	52%		$0.69						
642	MD	Space Heating	Res Resist Heat/Room AC to DMSHP -Heat	7488.0	58%	$4,000	$0.44						
643	MD	Cooling	Res Resist Heat/Room AC to DMSHP -Cool	1530.0	52%		$0.44						
177	MD	Cooling	High-efficiency Heat Pump CEE Tier II -Cool	187.2	11.3%	$175	$0.692						

Meas #	Mkt	End Use	Measure Long Name	kWh Savings	% Savings (primary fuel)	Incre-mental Cost	Incremental Cost per kWh (or MMBtu) Saved	Base-line Equip. Life	Base line Equip. Age	Baseline Cost per kWh (or MMBtu) saved	Baseline shift savings factor (for RET)	Fossil Fuel (or Elec) Savings - increased use is negative (MMBtu/yr | kWh/yr)	Annual Fossil Fuel (or Elec) Savings - increased is negative (MMBtu/kWh | kWh/MMBtu saved)
177	RET	Cooling	High-efficiency Heat Pump CEE Tier II -Cool	387.1	22.2%	$1,536	$3.151	15.00	9	2.25	51.0%		
178	MD	Space Heating	High-efficiency Heat Pump CEE Tier II -Heat	65.9	10.7%	$-	$0.692						
178	RET	Space Heating	High-efficiency Heat Pump CEE Tier II -Heat	100.5	14.5%	$-	$3.151	15.00	9	2.25	73.8%		
404	MD	Cooling	Air Source Heat Pump, Ducted, EnergyStar	48.3	10%	$137	$2.84						
405	MD	Space Heating	Air Source Heat Pump, Ducted, EnergyStar	8.65	6%	$11.42	$1.32						
430	MD	Water Heating	Oil to HP fuel Switch	20.35	100%	$950	$46.68					-1660.0	-81.6
646	MD	Water Heating	Com Heat Pump Water Htr replace Oil	20.35	100%	$950	$46.68					-1660.0	-81.6

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