NATURAL GAS EFFICIENCY AND CONSERVATION MEASURE RESOURCE ASSESSMENT

for the Residential and Commercial Sectors

Prepared for the

Energy Trust of Oregon, Inc.

By

Ecotope, Inc.

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NATURAL GAS EFFICIENCY AND CONSERVATION MEASURE RESOURCE ASSESSMENT

FOR THE RESIDENTIAL and COMMERCIAL SECTORS

Final Report, August, 2003

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1. Executive Summary

Ecotope, Inc. conducted a resource assessment to evaluate potential natural gas conservation measures that can be applied to the residential and commercial building stock serviced by Northwest Natural Gas (Northwest Natural). Conservation measures were developed from a variety of literature and from measures used in other natural gas conservation and efficiency programs throughout the country. The specific sources used for each measure are included in the individual workbooks. Measures were first reviewed for technical feasibility and appropriateness to the climate and local conditions. Applicable measures were then analyzed to calculate the potential life cycle costs and benefits, and to determine the technical potential for savings. For this analysis, the technical potential is defined as the total savings that could be expected if every building that could benefit from a particular measure is actually treated.

To accomplish this, we performed the following tasks:

1. Compiled a list of potential measures for review, based on applicability to the Northwest Natural service territory.

2. Conducted a life cycle cost/benefit analysis for each measure.

3. Calculated estimates of the buildings that could benefit from each of the measures, and of the existing building stock that had already been treated through utility programs or market forces.

1.1. Analysis Methodology

1.1.1. List of Measures

The initial list of measures for each sector considered as part of this review is included in the Appendices to this report. Measures were selected for inclusion on this list based on the following criteria:

- Reduces natural gas energy consumption without significantly reducing service or utility levels to end users;
- Currently commercially available or nearly so;
- Appropriate to the service territory, climate, and local building practice;
- For new construction or renovation, the measures are more efficient than energy code requirements;
- For which a delivery infrastructure exists or can be established.

1.1.2. Life Cycle Analysis

A cost-of-saved-energy (CSE) variable was used both to identify measures for further analysis and to rank the measures in order of cost-effectiveness. The CSE is not meant to describe the cost-effectiveness of the measures, since that is based on more detailed Energy Trust calculation methodologies and is outside the scope of this project. Instead, we used a levelized CSE of $.50 per therm saved as a rough indicator of the avoided cost of future gas resources. In some cases the authors elected to include measures of particular interest even though the CSE was well over the $.50 per therm saved threshold (e.g., residential retrofit windows). There are several reasons for these measures to be included in our review:

- They may be cost effective at a later time due to natural gas price forecast increases;
- The cost of the measure may decrease over time with increased availability, or reduced equipment and delivery costs;
- The consumer would perceive a benefit beyond energy efficiency and make a decision to use the measure with only modest incentives from a program.

We assumed a 3.0% discount rate, amortized over the life of the measure. To calculate the CSE, the present worth factor of both costs and savings are calculated for the life of the measure only. Costs were derived from literature reviews, manufacturer's data and previous Ecotope studies. Savings were generally derived from prototypical building simulation outputs and engineering calculations, sometimes supplemented with manufacturer data.

For new construction and the replacement market, the base case was assumed to be compliance with the prescriptive path in the Oregon Energy Code. For existing buildings, this study generally relied on published work conducted in the last decade that assessed building practices in Oregon and the rest of the Pacific Northwest to establish a base case or range of base case assumptions.

1.1.3. Technical Potential Savings Calculation

The technical potential savings calculation is the estimate of savings if the measure is applied to every building for which it was applicable. In cases where more than one mutually exclusive measure could potentially be applied to a specific building, the measure applicability was adjusted to avoid double counting between measures. In the residential sector, technical potential is expressed in number of households as well as therms of energy saved over the lifetime of the efficiency measure. In the commercial sector, technical potential is typically expressed as square footage as well as therms of energy saved over the lifetime of the efficiency measure. For equipment measures where square footage can be meaningless or misleading, as in cooking appliances, the technical potential is shown in units of equipment as well as therms of energy saved over the lifetime of the efficiency measure.

To calculate total life cycle program savings, the formula used was:

Total Lifecycle Savings = Total Annual Savings * Measure Life * Technical Potential.

This analysis includes measures targeted to both new and existing stock. For existing stock, replacement opportunities were calculated separately from retrofit applications. Replacement opportunities are available when an existing building undergoes a major rehabilitation or expansion for purposes other than conserving energy, or when existing equipment nears the end of its useful life. These types of projects typically are subject to the current energy code; therefore, the costs and savings for this population is based on the increment over what would be installed in order to meet code. Retrofit opportunities are defined as projects undertaken in existing buildings for the sole purpose of reducing energy use. For this population, the total cost of the measure was used and savings were based on the improvement over the existing condition.

To allocate the commercial square footage into building use type, the analysis relied primarily on data collected from Northwest Natural, from the Baseline Survey conducted for the Northwest Energy Efficiency Alliance (the Alliance) in 2001, and from a detailed 1995 survey of commercial buildings in the Seattle area. Table 1.1 provides the results of our sector characterization for the commercial sector.

Table 1.1. Commercial Sector Area and EUI Estimates by End Use

End Use	Square Footage Estimate 2002 (1000 sf)	Energy Use Intensity (EUI) Estimate				
		Heating	Water Heat	Cooking	Misc	TOTAL
Assembly	9,207	35.9	8.1	1.5	0.0	45.5
Colleges	44,661	51.1	20.0	0.5	6.0	77.6
Grocery	20,610	34.1	7.3	10.8	0.0	52.2
Hospital	19,438	46.4	12.4	6.0	2.6	67.4
Hotel	13,170	32.7	33.6	17.3	6.7	90.3
Lab	21,868	74.7	55.6	0.0	33.0	163.3
Laundry	2,530	10.0	500.0	0.0	250.0	760.0
Motel	7,091	69.7	37.3	2.4	6.9	116.3
Office - Large	36,068	26.6	5.4	0.0	0.0	32.0
Office - Small	36,068	26.6	5.4	0.0	0.0	32.0
Rest-Fast Food	4,799	33.2	50.2	425.4	0.0	508.8
Rest-Full Serve	8,912	40.5	92.4	165.9	0.0	298.8
Retail - Large	51,525	24.1	2.0	0.0	2.5	28.6
Retail - Small	51,525	24.1	2.0	0.0	2.5	28.6
Schools - Primary	18,270	33.7	3.5	1.5	0.0	38.7
Schools - Secondary	18,270	44.0	5.2	1.4	5.2	55.8
Skilled Nursing	18,799	37.2	33.8	19.0	6.7	96.7
Warehouse	72,102	30.2	1.4	0.0	5.0	36.6
Other	49,874	36.5	5.1	1.5	12.0	55.1
Total:	**504,787**					

To allocate the residential population by building type, data supplied by the utility was supplemented with 2000 U.S. Census data. Table 1.2 shows the estimates of gas usage by building type in the residential sector.

Table 1.2: Residential Sector EUI Estimates by End Use

County	House-holds	Annual Therm Consumption			
		Single Family	Multi-Fam. (>5 units)	Manuf. Home	Total
Benton	8,765	6,587,961	118,548	83,210	6,789,719
Clackamas	60,841	46,922,434	468,964	724,475	48,115,873
Clatsop	5,734	4,448,402	32,012	68,663	4,549,077
Columbia	7,980	6,161,324	19,625	179,314	6,360,263
Hood River	1,733	1,341,923	7,652	34,802	1,384,377
Lane	44,098	33,708,726	330,776	731,081	34,770,583
Lincoln	3,830	2,884,827	17,074	91,718	2,993,619
Linn	10,644	8,106,968	48,508	245,409	8,400,885
Marion	38,147	29,227,767	295,966	568,739	30,092,472
Multnomah	136,226	103,565,371	1,814,209	452,815	105,832,395
Polk	9,172	7,084,616	45,776	132,535	7,262,927
Wasco	745	560,054	2,905	23,233	586,192
Washington	85,340	64,794,554	1,130,893	489,500	66,414,947
Yamhill	8,966	6,906,591	40,219	175,695	7,122,505
Totals	**422,218**	**322,301,516**	**4,373,126**	**4,001,190**	**330,675,832**

1.2. Commercial Sector Results

The measures with the most attractive CSE figures for the commercial sector were attic insulation, cooking, and HVAC control measures. Table 1.3 summarizes the annual therm savings available from the 10 most cost-effective measures.

Table 1.3. Ten Most Cost-Effective Commercial Measures

End Use	Measure	Sector	Measure Cost ($/sf)	Measure Savings (th/sf/yr)	Measure CSE ($/th)	Measure Life (yrs)	Annual Savings (th)
Insulation	Roof Insulation - Rigid R0-11	Retrofit	0.82	0.15	0.06	30	1,070,147
Cooking	Direct Fired Convection Oven	Replace	1,338	1,152	0.08	20	85
Cooking	Direct Fired Convection Oven	New	1,338	1,173	0.08	20	46
Insulation	Roof Insulation - Rigid R0-22	Retrofit	1.41	0.17	0.10	30	1,215,994
Cooking	Infrared Fryer	Replace	1,373	1,130	0.10	15	322
Cooking	Infrared Fryer	New	1,373	1,133	0.10	15	55
HVAC	Tune-Up	Retrofit	0.01	0.02	0.11	5	159,473
HVAC	Temperature Reset	Retrofit	0.03	0.03	0.12	10	739,326
HVAC	Steam Balance	Retrofit	0.06	0.04	0.12	15	477,173
Insulation	Roof Insulation - Attic R0-30	Retrofit	0.39	0.13	0.14	30	339,682
	Total:						**4,002,303**

Table 1.4 lists the ten measures that passed our CSE screen with the most total annual gas savings. When this variable is considered, HVAC measures are as significant as envelope measures. Envelope measures were defined as those impacting the building shell, including insulation and fenestration measures.

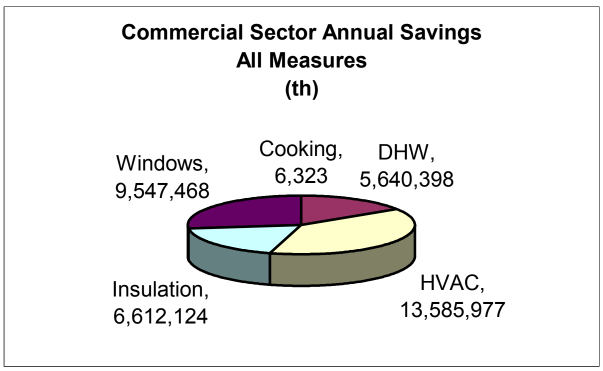
Table 1.4. Top Ten Commercial Measures by Total Annual Savings*

End Use	Measure	Sector	Measure Cost ($/sf)	Measure Savings (th/sf/yr)	Measure CSE ($/th)	Measure Life (yrs)	Annual Savings (th)
HVAC	DCV Controller & Sensor	Retrofit	0.20	0.09	0.18	15	1,832,481
HVAC	SPC Boiler - Near Condensing	Replace	0.16	0.03	0.42	20	1,305,314
Insulation	Wall Insulation - Blown R11	Retrofit	0.40	0.10	0.18	30	1,266,001
Insulation	Roof Insulation - Rigid R0-22	Retrofit	1.41	0.17	0.10	30	1,215,994
HVAC	Tune-Up	Retrofit	0.01	0.02	0.11	5	159,473
HVAC	Steam Balance	Retrofit	0.06	0.04	0.12	15	477,173

End Use	Measure	Sector	Measure Cost ($/sf)	Measure Savings (th/sf/yr)	Measure CSE ($/th)	Measure Life (yrs)	Annual Savings (th)
DHW	Recirc controls	Retrofit	0.17	0.05	0.37	10	1,072,835
Insulation	Roof Insulation - Rigid R0-11	Retrofit	0.82	0.15	0.06	30	1,070,147
HVAC	High Efficiency Unit Heater	Replace	0.29	0.06	0.34	18	976,499
	Total:						**9,375,917**

* Measures which passed CSE screen only.

The potential annual gas savings for all of the commercial measures we considered, assuming that the entire applicable population is treated, is about 35 million therms. However, that savings drops to about 17 million therms when only the measures that passed our CSE screen of $0.50/therm saved are considered. Figure 1.1 illustrates the impact of each measure class on the total savings available.



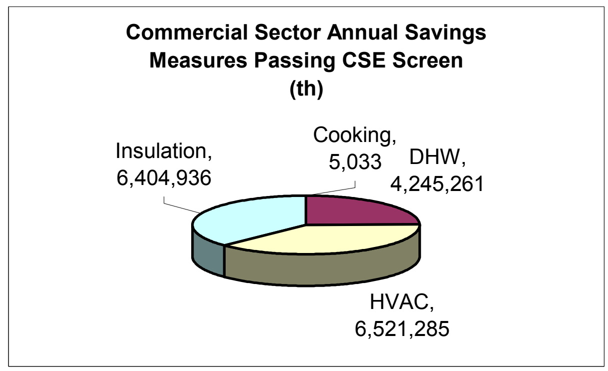


Figure 1.1 Commercial Sector Potential Program Savings

Substantial savings are available from measures which use condensing technology (either boilers or tanks) for domestic hot water. Cooking appliances used in the restaurant industry also present appealing targets for significant savings available for attractively-priced equipment investments.

Table 1.5. Summary of Commercial Results by Sector

	All Measures		Measures Passing CSE Screen	
Sector	**Average Measure CSE ($/th)**	**Annual Savings (th)**	**Average Measure CSE ($/th)**	**Annual Savings (th)**
Retrofit	0.82	24,457,716	0.20	12,254,581
Replace	0.71	7,271,263	0.36	3,292,421
New	0.74	3,663,311	0.30	1,629,513
Totals:	**----**	**35,392,290**	**----**	**17,176,515**

The results of our analysis for the commercial sector, shown by population sector, is provided in Table 1.5. The same results are shown by measure class in Table 1.6. A complete listing of the results by individual measure is shown in Section 3.1 and a detailed discussion of each measure is in Section 5.

Table 1.6. Summary of Commercial Results by Measure Class

	All Measures		Measures Passing CSE Screen	
Sector	**Average Measure CSE ($/th)**	**Annual Savings (th)**	**Average Measure CSE ($/th)**	**Annual Savings (th)**
Cooking	0.36	6,323	0.24	5,033
DHW	0.46	5,640,398	0.32	4,245,261
HVAC	0.71	13,585,977	0.26	6,521,285
Insulation	0.22	6,612,124	0.18	6,404,936
Windows	1.48	9,547,468	0.00	0
Totals:	**----**	**35,392,290**	**----**	**17,176,515**

1.3. Residential Sector Results

None of the particular measure classes in Table 1.6 dominates the list of most cost-effective measures in the residential sector for the three building types examined (single family, multi-family, and manufactured homes). Some insulation measures that use incremental costs rather than total costs (in the replacement and new sectors), have very low CSE ratings in all building types. In the multi-family sector, domestic hot water flow control easily provided the most attractive CSE ratings. Efficient furnaces and duct sealing in the single-family sector round out the list of the ten most cost-effective measures in this sector, shown in Table 1.7. Savings are reported in thousands of therms (kTh). A summary of all the measures we examined is provided in Section 3.2, and each measure is discussed in detail in Section 6.

Table 1.7. Ten Most Cost-Effective Residential Measures

Bldg Type	Measure	Sector	Cost ($/Hhld)	Measure Savings (th/Hhld/ yr)	Measure CSE ($/th)	Meas-ure Life (yrs)	Annual Program Savings (kTh)
MH	Weatherization: Floors	New	158	228	0.03	45	125
MF	DHW: Flow Control	Retrofit	17	35	0.07	8	214
SF	Weatherization: Attics	Retrofit	786	407	0.08	45	31,926
SF	HVAC: Efficient Furnace	New	200	110	0.10	25	197
MF	DHW: Pipe Insulation	Retrofit	25	20	0.10	15	122
MF	HVAC: Boiler Tune-up	Retrofit	10	20	0.11	5	1
MH	HVAC: Efficient Furnace	New	500	206	0.11	25	18
SF	Weatherization: Walls	Retrofit	984	348	0.12	45	61,421
MH	HVAC: Efficient Furnace	Replace	500	206	0.14	25	7
MH	HVAC: Duct Sealing	Retrofit	350	161	0.15	20	438
	Totals/Averages:		**3,530**	**1,795**	**N/A**	**N/A**	**94,469**

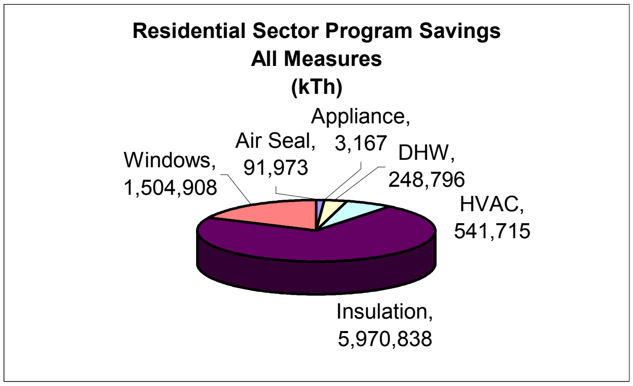
When evaluated in terms of total savings available (from measures which pass our CSE screen of $0.50/therm saved), envelope and domestic hot water measures in the single family sector clearly dominate the list. The ten measures with the greatest total program potential savings are shown in Table 1.8. No measures analyzed for the multi-family or manufactured home sectors appear in the Top 10 measures when ranked by CSE.

Table 1.8. Top Ten Residential Measures by Total Potential Savings*

Bldg Type	Measure	Sector	Cost ($/Unit)	Annual Savings (th/Unit)	Meas-ure CSE ($/th)	Measure Life (yrs)	Program Savings (kTh)
SF	Weatherization: Walls	Retrofit	984	348	0.12	45	2,763,928
SF	Weatherization: Floors	Retrofit	1,400	175	0.33	45	1,755,580
SF	Weatherization: Attics	Retrofit	786	407	0.08	45	1,436,678
SF	HVAC: Duct Seal Only	Retrofit	500	169	0.20	20	329,667
SF	HVAC: Furnace Retrofit	Retrofit	900	110	0.47	25	120,699
SF	Windows: to Class 34	New	215	31	0.35	30	51,755
SF	HVAC: Duct Insulation	Retrofit	200	35	0.38	20	45,758
SF	DHW: Eff Water Heater	Retrofit	60	20	0.30	12	32,772
SF	DHW: Combo Boiler (air)	New	1,200	207	0.39	20	11,144
SF	DHW: Combo Boiler (H_2O)	New	700	207	0.23	20	11,144
	Totals/Averages:		**6,945**	**1709**	**N/A**	**N/A**	**6,559,125**

* Measures which passed CSE screen only.

The total technical potential gas savings for all of the residential measures we considered, assuming that the entire applicable population is treated, is about 8.3 million kTh. However, that savings drops to less than 6.7 kTh when only the measures that passed our CSE screen of $0.50/therm saved are considered. Figure 1.2 illustrates the impact of each measure class on the total savings available.



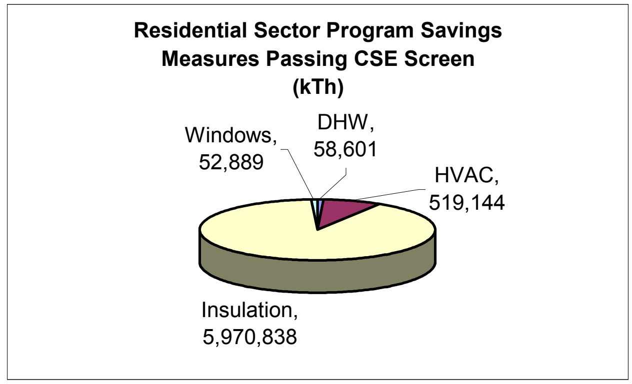


Figure 1.2 Residential Sector Potential Program Savings

The results of our analysis for the residential sector, shown by population sector, are provided in Table 1.9. The same results are shown by measure class in Table 1.10. A complete listing of the results by individual measure is shown in Section 3.2 and a detailed discussion of each measure is in Section 6.

Table 1.9. Summary of Residential Results by Sector

	All Measures		Pass CSE Screen	
Sector	Average CSE ($/th)	Program Savings (kTh)	Average CSE ($/th)	Program Savings (kTh)
Retrofit	0.32	8,234,860	0.18	6,505,635
Replace	1.03	8,745	0.31	1,353
New	0.74	117,793	0.31	94,484
Totals:	**----**	**8,361,397**	**----**	**6,601,472**

Table 1.10. Summary of Residential Results by Measure Class

	All Measures		Pass CSE Screen	
End Use	Average CSE ($/th)	Program Savings (kTh)	Average CSE ($/th)	Program Savings (kTh)
Air Seal	0.63	91,973	----	----
Appliance	1.03	3,167	----	----
DHW	0.66	248,796	0.29	58,601
HVAC	0.38	541,715	0.28	519,144
Insulation	0.17	5,970,838	0.17	5,970,838
Windows	0.94	1,504,908	0.35	52,889
Totals:	**----**	**8,361,397**	----	**6,601,472**

2. Project Overview

The goal of this project was to evaluate potential energy conservation measures to improve the efficiency of gas usage in the residential and commercial buildings and processes serviced by Northwest Natural Gas. Measures were first reviewed for technical feasibility and appropriateness to the climate and local conditions. Applicable measures were then analyzed to calculate the potential life cycle costs and benefits, and to determine the technical potential for savings. For this analysis, the technical potential is defined as the total savings that could be expected if every building that could benefit from a particular measure is actually treated.

To accomplish this, we performed the following tasks:

1. Compiled a list of potential measures for review, based on applicability to the Northwest Natural service territory.

2. Conducted a life cycle cost/benefit analysis for each measure.

3. Calculated estimates of the buildings that could benefit from each of the measures, and of the existing building stock that had already been treated through utility programs or market forces.

This analysis includes measures targeted to both new and existing stock. For existing stock, replacement opportunities were calculated separately from retrofit applications. Replacement opportunities are available when an existing building undergoes a major rehabilitation or expansion for purposes other than conserving energy. These types of projects typically must meet the current energy code; therefore, the costs and energy savings for this population are based on the increment over what would be installed in order to meet code. Retrofit opportunities are defined as projects undertaken in existing buildings for the sole purpose of reducing energy use. For this population, the total cost of the measure was used and energy savings were based on the improvement over the existing condition.

The details of the methodologies used to complete this project are discussed in Section 4. The results are presented below, divided into the commercial and residential sectors. Total program savings are presented on a life cycle basis and assume that the entire applicable population has been treated. Where more than one measure could be appropriately applied to a specific building type, the technical potential has been adjusted between measures to avoid double counting.

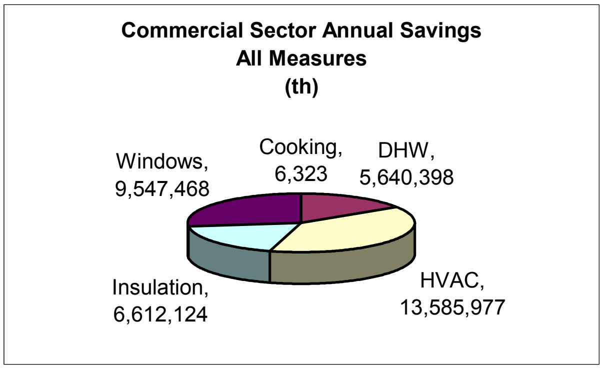
3. Summary of Results

A summary of the results of our resource assessment of potential natural gas savings in the Northwest Natural service territory are presented in the following tables.

3.1. Commercial Sector

The measures with the most attractive CSE figures were weatherization, cooking, and HVAC control measures, although the most total therm savings available from treating the entire population were in the weatherization and domestic hot water measure classes.

The potential annual gas savings for all of the commercial measures we considered, assuming that the entire applicable population is treated, is about 35 million therms. However, that savings drops to about 17 million therms when only the measures that passed our CSE screen of $0.50/therm saved are considered. Figure 3.1 illustrates the impact of each measure class on the total savings available.



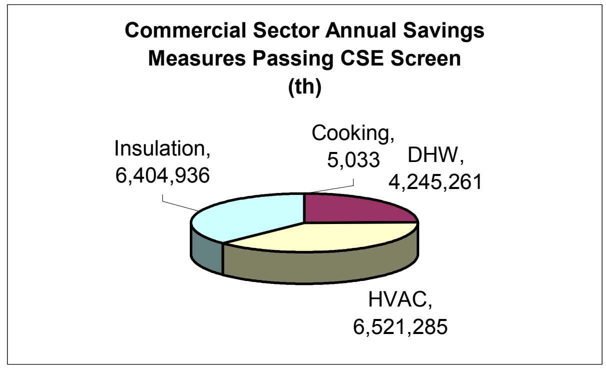


Figure 3.1 Commercial Sector Potential Program Savings

Substantial savings are available from measures which use condensing technology (either boilers or tanks) for domestic hot water. Cooking appliances used in the restaurant industry also present attractive targets for significant savings available for attractively-priced equipment investments.

Table 3.1. Summary of Commercial Results by Sector

	All Measures		Measures Passing CSE Screen	
Sector	**Measure CSE ($/th)**	**Annual Savings (th)**	**Measure CSE ($/th)**	**Annual Savings (th)**
Retrofit	0.82	24,457,716	0.20	12,254,581
Replace	0.71	7,271,263	0.36	3,292,421
New	0.74	3,663,311	0.30	1,629,513
Totals:	**----**	**35,392,290**	**----**	**17,176,515**

The results of our analysis for the commercial sector, shown by population sector, is provided in Table 3.1 and by measure class in Table 3.2.

Table 3.2. Summary of Commercial Results by Measure Class

	All Measures		Measures Passing CSE Screen	
Sector	Measure CSE ($/th)	Annual Savings (th)	Measure CSE ($/th)	Annual Savings (th)
Cooking	0.36	6,323	0.24	5,033
DHW	0.46	5,640,398	0.32	4,245,261
HVAC	0.71	13,585,977	0.26	6,521,285
Insulation	0.22	6,612,124	0.18	6,404,936
Windows	1.48	9,547,468	0.00	0
Totals:	**----**	**35,392,290**	**----**	**17,176,515**

A complete listing of the results by individual measure is shown in Table 3.3. Each of these measures is discussed in detail in Section 5.

Table 3.3. Summary of Commercial Resource Assessment Results by Measure
(Gray background indicates measures passing CSE screen)

End Use	Measure	Sector	Measure Cost ($/sf)	Measure Savings (th/sf/yr)	Measure CSE ($/th)	Measure Life (yrs)	Annual Savings (th)
Cooking	Direct Fired Convection Oven	Replace	1,338	1,152	0.08	20	85
Cooking	Direct Fired Convection Oven	New	1,338	1,173	0.08	20	46
Cooking	Infrared Fryer	Replace	1,373	1,130	0.10	15	322
Cooking	Infrared Fryer	New	1,373	1,133	0.10	15	55
Cooking	Infrared Griddle	Replace	1,048	458	0.15	20	103
Cooking	Infrared Griddle	New	1,048	463	0.15	20	17
Cooking	Direct Fired Convection Oven	Retrofit	2,988	1,143	0.18	20	686
Cooking	Infrared Fryer	Retrofit	2,538	1,130	0.19	15	1,596
Cooking	Convection Range/Oven	New	843	349	0.20	15	23
Cooking	Convection Range/Oven	Replace	843	339	0.21	15	184
Cooking	Convection Range/Oven	Retrofit	1,017	344	0.25	15	667
Cooking	Power Range Burner	Replace	870	249	0.29	15	290
Cooking	Power Range Burner	New	870	252	0.29	15	36
Cooking	Infrared Griddle	Retrofit	2,880	458	0.42	20	923
Cooking	Power Range Burner	Retrofit	2,571	249	0.87	15	1,290
DHW	DHW Boiler - Near Condensing	Replace	0.65	0.21	0.21	20	177,100
DHW	DHW Boiler - Near Condensing	New	0.45	0.14	0.22	20	315,889
DHW	Shower Heads	Retrofit	0.05	0.04	0.22	8	277,643
DHW	Condensing Tank	New	0.11	0.04	0.24	15	237,213

End Use	Measure	Sector	Measure Cost ($/sf)	Measure Savings (th/sf/yr)	Measure CSE ($/th)	Measure Life (yrs)	Annual Savings (th)
DHW	Condensing Tank	Replace	0.11	0.04	0.25	15	330,286
DHW	Combo Boiler - Near Condensing	Replace	0.18	0.04	0.31	20	48,280
DHW	DHW Boiler – Condensing	New	1.32	0.28	0.32	20	616,735
DHW	Combo Boiler - Near Condensing	New	0.18	0.04	0.32	20	78,597
DHW	DHW Boiler - Condensing	Replace	2	0.41	0.33	20	345,767
DHW	Pipe Insulation	Retrofit	0.32	0.08	0.35	15	290,128
DHW	Recirc controls	Retrofit	0.17	0.05	0.37	10	1,072,835
DHW	Combo Boiler - Condensing	Replace	0.53	0.08	0.42	20	108,191
DHW	Condensing Tank	Retrofit	0.50	0.10	0.44	15	346,597
DHW	Energy Star Tank	Retrofit	0.37	0.06	0.56	15	144,862
DHW	Combo Boiler - Condensing	New	0.61	0.07	0.61	20	140,686
DHW	DHW Boiler - Condensing	Retrofit	6.63	0.61	0.73	20	460,984
DHW	DHW Boiler - Near Condensing	Retrofit	5.24	0.40	0.88	20	303,575
DHW	Combo Boiler - Condensing	Retrofit	1.84	0.10	1.21	20	121,100
DHW	Combo Boiler - Near Condensing	Retrofit	1.40	0.07	1.32	20	85,635
DHW	DHW Boiler - Standard	Retrofit	4.57	0.18	1.68	20	138,295
HVAC	Tune-Up	Retrofit	0.01	0.02	0.11	5	159,473
HVAC	Temperature Reset	Retrofit	0.03	0.03	0.12	10	739,326
HVAC	Steam Balance	Retrofit	0.06	0.04	0.12	15	477,173
HVAC	DCV Controller & Sensor	Retrofit	0.20	0.09	0.18	15	1,832,481
HVAC	Building Warm-Up Control	Retrofit	0.05	0.03	0.21	10	543,463
HVAC	High Efficiency Unit Heater	Replace	0.29	0.06	0.34	18	976,499
HVAC	SPC Boiler - Near Condensing	New	0.16	0.03	0.38	20	380,902
HVAC	Vent Damper	Retrofit	0.06	0.02	0.38	12	106,654
HVAC	SPC Boiler - Near Condensing	Replace	0.16	0.03	0.42	20	1,305,314
HVAC	SPC Boiler - Condensing	Replace	0.57	0.06	0.65	20	1,100,499
HVAC	Condensing Furnace	New	0.45	0.05	0.69	18	352,833
HVAC	High Efficiency Unit Heater	New	0.31	0.03	0.72	18	292,854
HVAC	Power Burner	Retrofit	0.18	0.02	0.77	12	940,817
HVAC	SPC Boiler - Condensing	New	0.58	0.05	0.82	20	237,158

End Use	Measure	Sector	Measure Cost ($/sf)	Measure Savings (th/sf/yr)	Measure CSE ($/th)	Measure Life (yrs)	Annual Savings (th)
HVAC	Condensing Unit Heater	Replace	1.24	0.09	0.99	18	1,410,065
HVAC	Duct Sealing	Replace	0.50	0.04	1.01	18	345,637
HVAC	Condensing Furnace	Replace	0.77	0.04	1.29	18	599,441
HVAC	Condensing Unit Heater	New	1.31	0.06	1.52	18	585,708
HVAC	SPC Boiler - Condensing	Retrofit	1.67	0.07	1.67	20	345,851
HVAC	SPC Boiler - Near Condensing	Retrofit	1.26	0.05	1.73	20	250,569
HVAC	High Efficiency Unit Heater	Retrofit	2.15	0.06	2.46	18	603,260
Insulation	Roof Insulation - Rigid R0-11	Retrofit	0.82	0.15	0.06	30	1,070,147
Insulation	Roof Insulation - Rigid R0-22	Retrofit	1.41	0.17	0.10	30	1,215,994
Insulation	Roof Insulation - Attic R0-30	Retrofit	0.39	0.13	0.14	30	339,682
Insulation	Wall Insulation - Spray On	Retrofit	0.35	0.10	0.16	30	181,176
Insulation	Wall Insulation - Blown R11	Retrofit	0.40	0.10	0.18	30	1,266,001
Insulation	Roof Insulation - Rigid R11-22	Retrofit	0.70	0.04	0.19	30	787,186
Insulation	Roof Insulation - Blanket R0-19	Retrofit	0.65	0.14	0.21	30	325,420
Insulation	Roof Insulation - Blanket R0-30	Retrofit	0.73	0.14	0.24	30	310,118
Insulation	Roof Insulation - Attic 11-30	Retrofit	0.32	0.04	0.36	30	237,333
Insulation	Roof Insulation - Rigid R11-33	Retrofit	1.11	0.03	0.40	30	671,879
Insulation	Roof Insulation - Blanket R11-41	Retrofit	0.78	0.02	1.43	30	109,768
Insulation	Roof Insulation - Blanket R11-30	Retrofit	0.69	0.02	1.44	30	97,420
Windows	Windows - Add Low ε to Vinyl Tint	Replace	0.08	0.01	0.61	30	36,877
Windows	Windows - Add Low ε to Vinyl Tint	New	0.08	0.01	0.66	30	32,732
Windows	Windows - Add Low ε and Argon to Vinyl Tint	Replace	0.13	0.01	0.67	30	52,355
Windows	Windows - Add Low ε and Argon to Vinyl Tint	New	0.13	0.01	0.74	30	46,039
Windows	Windows - Add Argon to Vinyl Low ε	Replace	0.06	0	0.75	30	35,414

End Use	Measure	Sector	Measure Cost ($/sf)	Measure Savings (th/sf/yr)	Measure CSE ($/th)	Measure Life (yrs)	Annual Savings (th)
Windows	Windows - Add Argon to Vinyl Low ε	New	0.06	0	0.86	30	64,727
Windows	Windows - Single to Class 36	Retrofit	1.16	0.05	1.12	30	2,330,249
Windows	Windows - Non-Tinted AL Code to Class 40	Replace	0.16	0.01	1.13	30	113,982
Windows	Windows - Non-Tinted AL Code to Class 40	New	0.17	0.01	1.13	30	83,041
Windows	Windows - Single to Class 40	Retrofit	1.11	0.05	1.14	30	2,190,967
Windows	Windows - Single to Class 45	Retrofit	8.35	1.10	1.19	30	2,026,088
Windows	Windows - Tinted AL Code to Class 40	Replace	0.11	0	1.61	30	22,418
Windows	Windows - Non-Tinted AL Code to Class 36	Replace	0.4	0.01	1.85	30	174,088
Windows	Windows - Tinted AL Code to Class 45	New	0.08	0	1.86	30	3,561
Windows	Windows - Non-Tinted AL Code to Class 36	New	0.41	0.01	1.87	30	125,725
Windows	Windows - Tinted AL Code to Class 45	Replace	0.12	0	1.94	30	4,635
Windows	Windows - Tinted AL Code to Class 40	New	0.09	0	1.94	30	13,336
Windows	Windows - Non-Tinted AL Code to Class 45	New	0.11	0	2.03	30	30,855
Windows	Windows - Non-Tinted AL Code to Class 45	Replace	0.11	0	2.05	30	41,738
Windows	Windows - Double to Class 36	Retrofit	1.28	0.03	2.19	30	24,543
Windows	Windows - Double to Class 40	Retrofit	1.22	0.03	2.39	30	1,114,167
Windows	Windows - Tinted AL Code to Class 36	Replace	0.23	0	2.41	30	41,693
Windows	Windows - Tinted AL Code to Class 36	New	0.23	0	2.69	30	24,543
Windows	Windows - Double to Class 45	Retrofit	1.17	0.02	2.80	30	913,695
	Total:						**35,392,290**
	Total Passing CSE Screen:						**17,176,515**

3.2. Residential Sector

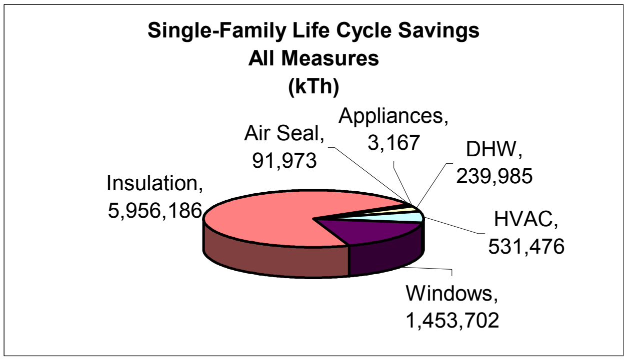
A summary of our results by population sector and building type is shown in Table 3.4. The most significant savings are available from the retrofit single-family sector. This is primarily due to the potential impact on weatherization in older uninsulated homes. Other dominant measures include windows, heating system improvements, hot water system improvements, and upgraded appliances. Each of these components is discussed in Section 6 of this report.

Table 3.4. Summary of Residential Resource Assessment Results by Sector

Measure	Cost ($/Hhold)	Annual Savings (th/Hhold)	Technical Potential (HHolds)	Annual Program Savings (kTh)	Life Cycle Savings (kTh)
Single Family:					
New SF	10,295	877	81,881	4,948	109,632
Replacement SF	395	48	14,874	263	4,063
Retrofit SF	14,481	2,016	1,271,823	220,761	8,162,793
Single Family Sub-Total	25,171	2,940	1,368,578	225,973	8,276,488
Multi-Family:					
New MF	2,852	193	4,875	29	739
Replacement MF	2,769	190	7,389	225	4,507
Retrofit MF	3,672	403	43,187	1,947	53,839
Multi-Family Sub-Total	9,293	787	55,451	2,201	59,085
Manufactured Homes:					
New MH	1,223	571	2,267	189	7,422
Replacement MH	500	206	34	7	175
Retrofit MH	3,544	266	8,757	753	18,227
Manu-Homes Sub-Total	5,267	1,043	11,058	949	25,824
All Sectors:					
New, All Sectors	14,370	1,641	89,022	5,166	117,793
Replacement , All Sectors	3,664	444	22,297	495	8,745
Retrofit, All Sectors	21,697	2,685	1,323,767	223,462	8,234,860
Grand Total	**39,731**	**4,769**	**1,435,087**	**229,123**	**8,361,397**

3.2.1. Single Family

The total natural gas savings available from all measures, if performed on all applicable single family homes in the Northwest Natural service territory, would be 8.3 million kTh. Figure 3.2 illustrates the impact of the measure classes on the total therm savings available in these units. More detailed results are provided in Table 3.5.



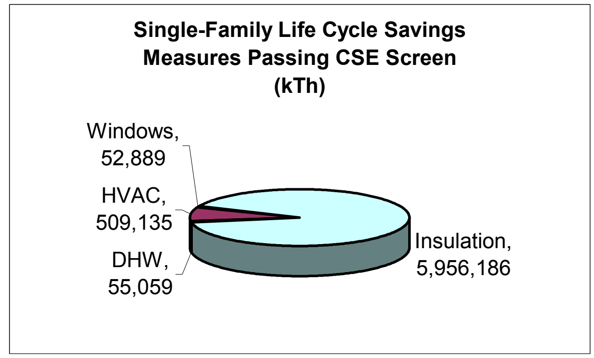


Figure 3.2. Single Family Savings Potential

As shown in Table 3.5, insulation and weatherization measures dominate the potential savings analysis. This impact is based on estimates of the number of homes built prior to 1985 that have already been weatherized. There is a great deal of uncertainty regarding the saturation of weatherization measures in existing gas-heated homes. For this analysis, we used estimates in the low range. If significantly more homes have previously been treated than was assumed in this analysis, the impact of these measures on the total available savings would be reduced.

It should also be noted that the interactions between the weatherization measures and HVAC measures have a substantial impact on the cost-effectiveness. In general, it is much less cost-effective to perform either weatherization or HVAC measures in homes that have already been treated with conservation measures from the other class. The exception to this is duct sealing, which this analysis found to be cost-effective under all conditions. These results are summarized in Table 3.5.

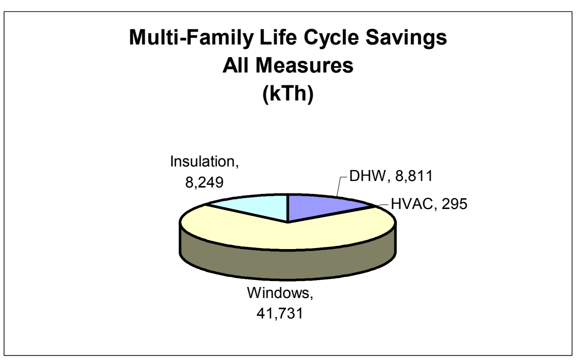
Table 3.5. Summary of Single Family Resource Assessment Results by Measure
(Gray background indicates measures passing CSE screen)

Measure	Sector	Cost ($/Unit)	Annual Savings (th/Unit)	Measure CSE ($/th)	Measure Life (yrs)	Program Savings (kTh)
Appliances: H-Axis Clothes Washers	New	180	17	1.03	13	238
DHW: Combo Boiler (water)	New	700	207	0.23	20	11,144
DHW: Combo Boiler (air)	New	1,200	207	0.39	20	11,144
HVAC: Efficient Furnace	New	200	110	0.10	25	4,935
HVAC: Duct Commissioning	New	300	45	0.45	20	8,075
HVAC: Air-to-Air Heat Exchanger	New	1,000	70	1.20	15	1,884

Measure	Sector	Cost ($/Unit)	Annual Savings (th/Unit)	Measure CSE ($/th)	Measure Life (yrs)	Program Savings (kTh)
HVAC: Gas Heat Pump	New	6,500	190	2.87	15	20,457
Windows: Upgrade to Class 34	New	215	31	0.35	30	51,755
Appliances: H-Axis Clothes Washers	Replace	180	17	1.03	13	2,929
Windows: Upgrade to Class 34	Replace	215	31	0.35	30	1,134
Air Sealing: Upgrade to 8 ACH_{50}	Retrofit	250	38	0.55	15	58,528
Air Sealing: Upgrade to 10 ACH_{50}	Retrofit	350	38	0.77	15	33,445
DHW: Hi Efficiency Water Heater	Retrofit	60	20	0.30	12	32,772
DHW: Tankless Heater (Point Source)	Retrofit	750	82	0.61	20	31,991
DHW: Tank w/ Burner & Exchanger (Polaris)	Retrofit	700	76	0.62	20	29,651
DHW: Combo Boiler (air)	Retrofit	3,850	316	0.82	20	123,284
HVAC: Duct Seal Only	Retrofit	500	169	0.20	20	329,667
HVAC: Duct Insulation	Retrofit	200	35	0.38	20	45,758
HVAC: Furnace Retrofit	Retrofit	900	110	0.47	25	120,699
Weatherization: Attics	Retrofit	786	407	0.08	45	1,436,678
Weatherization: Walls	Retrofit	984	348	0.12	45	2,763,928
Weatherization: Floors	Retrofit	1,400	175	0.33	45	1,755,580
Windows: Upgrade to Class 34	Retrofit	3,751	202	0.95	30	1,400,813
Totals/Averages:		**25,171**	**2,940**	**0.34**	**40**	**8,276,489**

3.2.2. Multi-Family

In the multi-family sector, the largest gas savings were available from windows measures; however, much of this savings is available in the retrofit sector at a fairly high cost. When full replacement costs are considered, this measure is almost triple the cost-effectiveness screen of $0.50/th. Weatherization and domestic hot water measures, especially boiler measures, are also significant sources of potential savings in this sector.



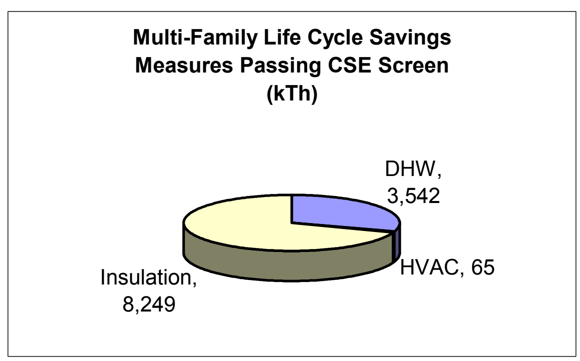


Figure 3.3. Multi-Family Savings Potential

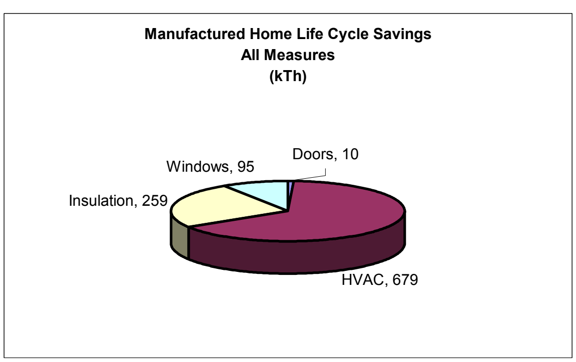
Figure 3.3 illustrates the distribution of potential gas savings across measure classes in multi-family buildings. A summary by individual measure is provided in Table 3.6.

Table 3.6. Summary of Multi-Family Resource Assessment Results by Measure
(Gray background indicates measures passing CSE screen)

Measure	Sector	Cost ($/Hhold)	Annual Savings (th)	Measure CSE ($/th)	Measure Life (yrs)	Program Savings (kTh)
DHW: Condensing Boiler	New	700	35	1.34	20	138
DHW: High Efficiency Boiler	New	569	25	1.53	20	98
HVAC: High Efficiency Boiler	New	160	30	0.36	20	10
HVAC: Condensing Boiler	New	570	60	0.64	20	20
HVAC: High Efficiency Furnace	New	770	40	1.11	25	16
Windows: U = .35	New	83	3	1.22	30	457
DHW: Condensing Boiler	Replace	700	35	1.34	20	314
DHW: High Efficiency Boiler	Replace	569	25	1.53	20	224
HVAC: High Efficiency Boiler	Replace	160	30	0.36	20	44
HVAC: Condensing Boiler	Replace	570	60	0.64	20	89
HVAC: High Efficiency Furnace	Replace	770	40	1.11	25	74
DHW: Flow Control	Retrofit	17	35	0.07	8	1,710
DHW: Pipe Insulation	Retrofit	25	20	0.10	15	1,832
DHW: Distribution Controls	Retrofit	150	8	1.57	15	733
HVAC: Boiler Tune-up	Retrofit	10	20	0.11	5	3
HVAC: Vent Damper	Retrofit	60	20	0.30	12	8
HVAC: Power Burner	Retrofit	180	20	0.90	12	8
HVAC: Zone and Loop Controls	Retrofit	630	47	1.12	15	23
Weatherization: Walls	Retrofit	392	109	0.15	45	2,993
Weatherization: Attics	Retrofit	176	22	0.33	45	1,477
Weatherization: Floors	Retrofit	307	34	0.36	45	3,778
Windows: U = .35	Retrofit	1,725	68	1.29	30	41,274
Totals/Averages:		**9,293**	**787**	**1.06**	**31**	**55,323**

3.2.3. Manufactured Homes

In the manufactured homes sector, the primary savings are available from duct sealing and from upgrading new and replacement windows. The small number of gas-heated manufactured homes sited in the Northwest Natural service territory limits the total potential savings. Figure 3.4 illustrates the savings available from each class of measures.



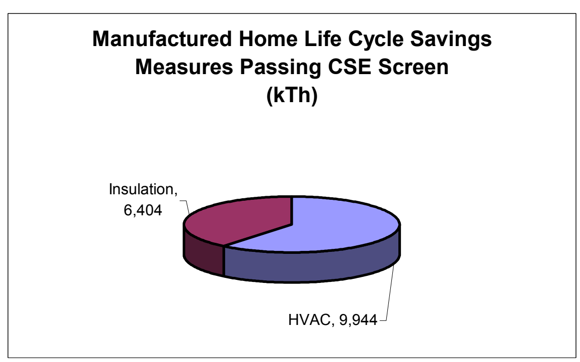


Figure 3.4. Manufactured Home Savings Potential

For this sector, the total savings potentially available from the manufactured home population is 25,824 kTh, as shown in Table 3.7. For comparison purposes, these savings total 8.3 million kTh in the single family sector and approximately 55,000 kTh in multi-family buildings.

Table 3.7. Summary of Manu Home Resource Assessment Results by Measure
(Gray background indicates measures passing CSE screen)

Measure	Sector	Cost ($/Unit)	Annual Svgs (th)	Measure CSE ($/th)	Measure Life (yrs.)	Life Cycle Savings (kTh)
HVAC: Efficient Furnace	New	500	206	0.11	25	446
HVAC: Duct Commissioning	New	350	52	0.45	20	571
Weatherization: Floors	New	158	228	0.03	45	5,637
Weatherization: Attics	New	115	20	0.23	45	495
Weatherization: Walls	New	100	11	0.37	45	272
HVAC: Efficient Furnace	Replace	500	206	0.14	25	175
Doors (U=.19)	Retrofit	280	10	1.46	30	888
HVAC: Duct Sealing	Retrofit	350	161	0.15	20	8,751
Windows (U=.34)	Retrofit	2,914	95	1.57	30	8,588
Totals/Averages:		**5,267**	**1,043**	**0 .65**	**30**	**25,824**

4. Analysis Methodology

4.1. Measure Selection and Cost-Effectiveness Screening

The first step in conducting this study was to generate a list of measures to be evaluated. Measures were included based on the following criteria:

- Reduce natural gas energy consumption without significantly reducing service or utility levels to end users;
- Currently commercially available or nearly so;
- Appropriate to the service territory, climate, and local building practice;
- For new construction or renovation, the measures are more efficient than energy code requirements;
- For which a delivery infrastructure exists or can be established.

Applicable measures were identified through regional research, a literature review, previous Ecotope projects conducted for the Energy Trust and for Washington Natural Gas (now Puget Sound Energy), Northwest Natural-provided data, and discussions with Energy Trust staff.

A cost-of-saved-energy (CSE) variable was used both to identify measures for further analysis and to rank the measures in order of cost-effectiveness. The CSE is not meant to describe the cost-effectiveness of the measures, since that is based on more detailed Energy Trust calculation methodologies and is outside the scope of this project. Instead, we used a levelized CSE of $.50 per therm saved as a rough indicator of cost-effective future gas resources. In some cases, measures of particular interest were analyzed even though the CSE was well over the $.50 per therm saved threshold (i.e., residential retrofit windows) because they may be cost effective at a later time due to natural gas price forecast increases, or because the cost of the measure may decrease over time with increased availability, or reduced equipment and delivery costs.

We assumed a 3.0% discount rate, amortized over the life of the measure. To calculate the CSE, the present worth factor of both costs and savings are calculated for the life of the measure only.

The total program savings is defined in this analysis as the total therm savings available if the entire applicable population received the measure. To establish the total program savings available from each measure, we calculated the life cycle cost and savings from each measure. In the retrofit sector, this assumes that every building for which the measure is appropriate will be treated and savings will accumulate for the life of the measure. In the new construction sector, we assume that the measure will be applied to every new building for which the measure is appropriate. For replacement/renovation measures, we assume that all of the replacement population that can receive the measure will be treated. In cases where more than one measure could be applied to a given stock, the technical potential has been adjusted to prevent double-counting or overlap. The Energy Trust goes through a more complex process to assess program cost-effectiveness. This process includes an assessment of packages of measures and a variety of programmatic costs not included in this report.

4.2. Base Case Selection

The selection of a base case to represent the condition that would be present in the absence of the measure is crucial to the development of any incremental cost or savings estimates. The base case is defined as an estimate of the existing conditions or the existing practice in the specific service territory being studied. For example, the base case for ceiling insulation in existing single family residences is an estimate of the amount of ceiling insulation that was installed at the time of construction and the saturation of ceiling insulation upgrades that have occurred through utility or market intervention. To accurately calculate the total savings that can be expected from any energy conservation program, it is crucial to understand the existing stock populating the target service territory as well as local new construction building practices.

This is important, since there are many practices in the residential and commercial building stock in Oregon that are considerably different than national standards as a result of regional efforts at developing energy efficient codes and market behavior over the last two decades. These efforts have had a substantial effect on the energy use in Oregon. Any program launched today must be conducted in the context of the impacts these measures and practices have already had.

For new construction and the replacement sector, the base case was assumed to be compliance with the prescriptive path in the Oregon Energy Code. For existing buildings, this study generally relied on published work conducted in the last decade that assessed building practices in Oregon and the rest of the Pacific Northwest. In many cases, these studies were not specifically designed to address the research questions of this analysis. However, this is considered the best information available to generate these estimates since the gas industry has not conducted any detailed assessment of their customers in the recent past. The data that does exist does not include the level of detail necessary to develop a base case for most of the measures evaluated in this study.

As a result, the development of existing conditions and practices applicable for existing and future gas customers relied heavily on the following sources:

1. Existing codes used in the Oregon building market for the last twenty years.
2. Anecdotal information collected from various practitioners in this market.
3. The Baseline Study conducted for the Northwest Energy Efficiency Alliance (Baylon, et al., 2001).
4. A large and detailed survey conducted in the Seattle area (Kennedy, et al., 1996) which documented the equipment stock and building practices in the large commercial sector.

These sources and approaches were combined to establish estimates of the current practice and current stock. These estimates were then used to generate prototypical buildings and systems for further engineering analysis, building simulations, and additional calculations. In this way, the conditions in the Oregon climate and market could be accounted for directly, and the energy impacts of the measures could be calibrated to the observed gas use developed as a part of Northwest Natural's customer characteristic studies. This process is iterative in that the total energy use of buildings in any sector can be used to adjust the simulation inputs and estimate the characteristics applicable to that market segment.

4.3. Cost Data Collection and Calculation Methodology

Accurately determining the cost to implement each measure evaluated is as important as the gas-saving potential of the measure. The sources for costs used in this study are varied but the emphasis was placed on the observed cost used in this market to install the various measures evaluated. Many of the measures included in this evaluation have been supported by electric utility programs over the last 10 years so cost estimates are readily available from utility impact evaluations that can also be used to assess gas impacts. However, for measures which have no cost data available from either electric or gas utility programs, local installers provided most of the cost estimates used in this analysis. This provides a robust set of estimates for most insulation and envelope upgrades as well as costs associated with incremental improvements in heating and hot water equipment efficiency. Whenever this sort of data was available, it was used preferentially to data collected by other utilities or in other studies.

For some efficiency measures (especially those pertaining to high efficiency appliances and other equipment) neither published data nor installer quotes were available. In these cases, we relied on national data, which was usually taken from studies and resource assessments in different localities (including the Seattle market). This data was the least reliable and usually was supplemented by inquiries to manufacturer representatives.

Unless otherwise noted, the baseline assumption for analysis in existing buildings is that the building owner would not upgrade the building with the measure in question in the absence of a utility- or Energy Trust-sponsored program. Therefore, the entire cost and savings from implementing the measure is used. The base case used to calculate both costs and savings is a weighted result for a range of prototypes intended to model the diversity of existing construction in the service territory (see Section 4.4.1 for a discussion of the prototype selection).

For new construction and the replacement market, the base case was assumed to be the Oregon Energy Code. In this case, the incremental cost and incremental savings for upgrading to the proposed measure level from an energy code basis at the time of installation is used to calculate the CSE. This methodology assumes that the owner would use standard Code-compliant options in the absence of a utility- or Energy Trust-sponsored program.

For many types of gas-fueled equipment in existing buildings, efficiency opportunities can be addressed most inexpensively when the equipment is being replaced. For these types of equipment, we developed replacement options and calculated the incremental cost and savings from upgrading the equipment at replacement. The baseline for replacement was established at the current replacement rate as reported by industry groups and manufacturers. Common practice in replacement equipment selection is influenced by the Oregon Energy

Code only in situations where the Code is applied in the field or has influenced distributor equipment offerings.

4.4. Savings Data Collection and Calculation Methodology

Several methods were employed to calculate the energy impact of the measures evaluated in this report. Savings were primarily calculated using simulations of prototypical buildings and engineering analysis. For the commercial sector, DOE-2 runs were performed for each measure against all the applicable prototype buildings. In the residential sector, Optimizer software was used to simulate the energy use interactions of each measure. Where available, we also consulted the published values from other studies and manufacturers' literature. While this method provides an estimate of savings potential, there are usually several steps needed to apply the general data to the conditions and building stock in Oregon. For this reason, the use of literature values was held to a minimum and applied largely to end uses where the efficiency and energy use did not interact with climate or existing stock.

4.4.1. Residential Prototypes and Simulations

To calculate savings for the residential sector (excluding hot water and appliance measures), Optimizer simulation software was used to assess the impact of each measure on representative prototypes. This method not only allows the impact of specific measures to be assessed, but also accounts for the interactions between measures. Particularly for HVAC and envelope measures, the order in which the measures are applied to a particular home can impact savings by a factor of 2. By simulating these effects, the savings could be weighted in order to calculate anticipated program savings from treating the entire range of existing construction in the service territory.

Single-family prototypes were selected to represent construction vintages that roughly coincide with major energy code revisions in Oregon. For the manufactured housing sector, prototypes represent MAP/SGC homes versus standard models. For the multi-family sector, a whole-building prototype representing a 16-unit building was used for each vintage band. A description of the prototypes developed for this analysis is presented in Tables 4.1 through 4.3.

Table 4.1: Single Family Prototypes

Prototype Label	Description	Base	Represents
Pre-1975 R-0	1350 sq.ft.; < 15% glazing, R-0 attic insulation.	Attic: R-0 Wall: R-0 Floor: R-0 Window: U=1.0	1975 and earlier
Pre-1975 R-11	1350 sq.ft.; < 15% glazing, R-11 attic insulation.	Attic: R-11 Wall: R-0 Floor: R-0 Window: U=1.0	1975 and earlier

Prototype Label	Description	Base	Represents
1980	1800 sq.ft; 15% glazing.	Attic: R-19 Wall: R-11 Floor: R-0 Window: U=0.7	circa 1975-1983
1985	1800 sq.ft.; 15% glazing.	Attic: R-30 Wall: R-19 Floor: R-19 Window: U=0.7	circa 1983-1993
1995	2200 sq.ft; 15% glazing.	Attic: R-38 Wall: R-21 Floor: R-19 Window: U=0.4	circa 1993-2003 and new construction

Table 4.2: Multi-Family Prototypes

Prototype Label	Description	Base	Represents
Pre-1975 R-0	1200 sq.ft.; 15% glazing, R-0 attic insulation.	Attic: R-0 Wall: R-0 Floor: R-0 Window: U=1.0	1975 and earlier
Pre-1975 R-8	1200 sq.ft.; < 15% glazing, R-8 attic insulation.	Attic: R-8 Wall: R-0 Floor: R-0 Window: U=1.0	1975-1993
1980	1200 sq.ft; 15% glazing.	Attic: R-19 Wall: R-11 Floor: R-0 Window: U=0.7	circa 1975-1983
1985	1200 sq.ft.; 15% glazing.	Attic: R-30 Wall: R-19 Floor: R-19 Window: U=0.7	circa 1983-1993
1995	1200 sq.ft; 15% glazing.	Attic: R-38 Wall: R-21 Floor: R-19 Window: U=0.4	circa 1993-2003 and new

Table 4.3: Manufactured Home Prototypes

Prototype Label	Description	Base	Represents
SGC/MAP Existing	1568 sq.ft.; 12% glazing.	Attic: R-38 Wall: R-21 Floor: R-33 Window: U=0.38	All vintages built to SGC/MAP
Non-SGC Existing	1568 sq.ft.; 12% glazing.	Attic: R-19 Wall: R-11 Floor: R-11 Window: U=0.8	All vintages not built to SGC/MAP
SGC New	1568 sq.ft.; 12% glazing.	Attic: R-38 Wall: R-21 Floor: R-33 Window: U=0.38	New SGC-compliant

Prototype Label	Description	Base	Represents
Non-SGC New	1568 sq.ft.; 12% glazing.	Attic: R-30 Wall: R-19 Floor: R-22 Window: U=0.5	New non-SGC compliant

4.4.2. Residential Technical Potential

To calculate the technical potential (defined as the total number of homes or multi-family units available to be treated), the prototype vintage bands were weighted by population. The 2000 US Census was used to assign the population weights. The same source provided the ratios to classify the total population by county for the Northwest Natural service territory. These results were calibrated to the Northwest Natural 2000 Load Forecast (see Sector Characterization, Section 6.1).

To analyze the impact of measure interactions, each of the weatherization and fenestration measures was run against each prototype before and after a measure to upgrade the furnace efficiency was applied to that building and before and after a Performance Tested Comfort Systems (PTCS)-level duct measure was applied.

Domestic hot water and appliance savings were derived from other published sources (primarily manufacturers' data) and engineering calculations.

5. Commercial Sector Resource Assessment Results

The commercial sector is complex, having many combinations of different end uses and building types. For the most part, the end uses in gas heating are confined to four important areas.

1) Space Heating. This measure is often paired with electric cooling in some sort of forced air, unit heater or boiler system. Each of the various distribution and technology options has distinctly different conservation potential. Ventilation systems also have a large impact on space heating. For this analysis, ventilation system measures have been analyzed together with other space heating equipment because these systems are generally integrated into the HVAC system.

2) Building Envelope. Since gas space heating is dominant in the commercial sector, the ability to reduce the heat load is often one of the few measures that can achieve major impacts on overall gas use in any particular building. In general, commercial buildings include large quantities of equipment, lighting, etc., which offsets some of the space heating requirements. However, in the Oregon climate, the energy load for most commercial buildings is heating dominated. Space heating remains necessary even in relatively high-occupancy buildings such as

office spaces and department stores. As a result, the impact of envelope measures (ceiling insulation, windows, etc.) can be significant.

3) Appliances. Appliances in this sector largely appear as commercial processes. In general, process loads were excluded from this analysis. The principal exception to this is cooking appliances. Cooking represents a large end use and cooking appliances can often be made substantially more efficient using modern technologies. Another major process load in the commercial sector is laundry. Laundry is a bit more ambiguous and for purposes of our evaluation, we have reviewed gas-powered drying and found no measures which passed our CSE screen for application in this area. However, major amounts of hot water are used in laundry facilities and as a result, laundry equipment conservation measures have been included along with other domestic hot water measures.

4) Domestic Hot Water. In some building types, domestic hot water is the dominant end use. Conservation measures in this sector include the reduction of standby losses, improvements in burner efficiency and heat exchanger designs. In addition, measures were analyzed which improve the efficiency of the distribution system by managing heat loss from pipe loops supplying hot water throughout a building or managing the operation of pumps and distribution loops to minimize the overall associated standby losses.

5.1. Commercial Sector Characterization

To establish the impact of natural gas conservation on the commercial sector, a detailed description of the existing building types and end uses in the Northwest Natural service territory was required. Many measures are primarily applicable to specific building types (hot water measures have a much more substantial impact in laundries, college dormitories and other high-use building types than in warehouses, for example). Therefore, deriving the expected savings for specific building types is an essential step in preparing an accurate resource assessment.

Data characterizing the commercial sector in Northwest Natural's service territory has been developed only sporadically. The most recent significant study was conducted in 1995 (Barakat & Chamberlain). This study did provide a detailed description of the distribution end uses, building types, and gas use in the Northwest Natural sector. Northwest Natural published an Integrated Resource Plan (IRP) in 2002; however, these data are aggregated and do not provide a means to assess the conservation potential in any particular building type, end use or customer class. Therefore, we used the Northwest Natural data primarily to calibrate the results calculated from other data sources.

To construct a sector characterization for new and existing commercial buildings in Northwest Natural's service territory, we relied primarily on the Barakat study and work conducted in the same year in the Seattle area for Washington Natural Gas

(Kennedy, et al., 1995). From these sources, we constructed an estimate of building and equipment characteristics and distribution for the Oregon market.

These two studies had somewhat similar goals, although the WNG study focused more on equipment types and the distribution of the equipment efficiencies while the Northwest Natural study focused on a fairly thorough sector characterization that relied more heavily on literature values for assessing space heating efficiency, water heating efficiency, and other end uses. In the WNG study, the conservation impacts were derived from prototypes generated for that purpose and applied to each of the building types in each subsector. This matrix of simulations was extremely valuable for estimating conservation potential, and was also useful to calibrate the sector characterization information generated for both Northwest Natural and for WNG. Both WNG and Northwest Natural used extensive surveys to establish the characteristics of customer groups.

To determine the technical potential, we relied almost completely on the Northwest Natural survey sets, although the weighting schemes were sometimes problematic because the surveys include large and medium size industrial customers groups. Therefore, in some cases the building types were re-weighted to remove the industrial end uses. A set of building area and energy use index (EUI) estimates was developed using the weighting schemes derived from the Northwest Natural study,.

Table 5.1 describes the distribution of natural gas consumption across the building type categories used by Northwest Natural. These categories are based on gas consumption estimates from the 1995 Barakat study, the 1995 Washington Natural gas study, and from the 2002 IRP data. A substantial effort was made to allocate the results of these studies to match the consumption estimate in 1995. This effort made it possible to use the individual building type data and simulations from the WNG study to assess the same sectors in Oregon (even though they had not been separately identified). There is about a 10% discrepancy in overall therm usage for the entire commercial sector between the predicted energy use based on the WNG study and the Northwest Natural data. This discrepancy is likely due to differing EUI estimation in the two studies. The result of this was that EUI and simulations were used from the WNG study and that the weighting scheme was adjusted to give the correct allocation of the 2002 therms.

Table 5.1. Estimated Consumption by End Use

Subsector	1995 Estimate WNG Allocation (th)	1995 Estimate NNG Allocation (th)	2002 Estimate (th)
Education	27,687,149	28,187,245	31,238,013
Hospitals	20,320,052	22,559,931	25,001,642
Office/Trade	42,592,557	63,480,981	70,351,668
Restaurant	33,254,655	28,730,980	31,840,597
Seasonal	11,616,159	15,754,438	17,459,576
Lodging	7,296,616	9,162,697	10,154,396
Laundry	14,695,931	7,626,162	8,451,558

Subsector	1995 Estimate WNG Allocation (th)	1995 Estimate NNG Allocation (th)	2002 Estimate (th)
Other	24,591,026	31,070,700	34,433,550
Totals:	**182,054,147**	**206,573,134**	**228,931,000**

The next task of the sector characterization was to convert the energy use estimates to building area estimates. This is an important step, since the analysis tool uses a prototype building that normalizes outputs by savings per square foot or end use per square foot. Each building type has different characteristics and different energy use patterns. To make this conversion, we used data from the Northwest Power Planning Council and from the billing and simulation analysis used in the 1995 WNG survey. In the latter case, the total EUIs corresponded to the observed energy use in the different categories for the building survey. The square footage for each building type was then derived from these EUI assumptions,. Table 5.2 summarizes the EUI data by end use and building type for the commercial sector.

It is probable that there is a substantial error band associated with these sector characterization end use estimates. The derivation of these sector characterizations, while using the best and most complete information available, does require considerable assumptions for which minimal data is available. These assumptions were made in order to allow potential savings to be allocated with only the most cursory information about customer characteristics available from the utility. It is relatively common among utilities to combine information in the manner used by Northwest Natural and WNG, using material collected from surveys done by each in 1995 in order to establish building characteristics, equipment characteristics and types and other related factors that would allow an assessment of the potential impact of various measures.

Table 5.2. Allocation of Gas End Use Intensities (EUIs) by End Use (MBtu/sf)

Subsector	Heating	Water Heat	Cooking	Misc	TOTAL
Assembly	35.9	8.1	1.5	0.0	45.5
Colleges	51.1	20.0	0.5	6.0	77.6
Grocery	34.1	7.3	10.8	0.0	52.2
Hospital	46.4	12.4	6.0	2.6	67.4
Hotel	32.7	33.6	17.3	6.7	90.3
Lab	74.7	55.6	0.0	33.0	163.3
Laundry	10.0	500.0	0.0	250.0	760.0
Motel	69.7	37.3	2.4	6.9	116.3
Office - Large	26.6	5.4	0.0	0.0	32.0
Office - Small	26.6	5.4	0.0	0.0	32.0
Rest-Fast Food	33.2	50.2	425.4	0.0	508.8
Rest-Full Serve	40.5	92.4	165.9	0.0	298.8
Retail - Large	24.1	2.0	0.0	2.5	28.6
Retail - Small	24.1	2.0	0.0	2.5	28.6
Retirement	30.0	9.3	4.0	0.7	44.0
Schools - Primary	33.7	3.5	1.5	0.0	38.7
Schools - Secondary	44.0	5.2	1.4	5.2	55.8
Shop	38.6	1.7	0.0	30.0	70.3
Skilled Nursing	37.2	33.8	19.0	6.7	96.7
Warehouse (except whsl)	30.2	1.4	0.0	5.0	36.6
Other	36.5	5.1	1.5	12.0	55.1
Seasonal	30.2	1.4	0.0	5.0	36.6

Building areas are summarized in Table 5.3. These categories were developed in 1995 as part of the customer characteristics survey. We used the overall commercial energy use from the Northwest Natural forecast for allocating the end uses for each building type shown in the table. These square footage estimates are used to describe both the existing conditions and savings potential for the various building types.

Table 5.3. Square Footage Estimates by End Use (thousand square feet)

Subsector	1995	1996	1997	1998	1999	2000	2001	2002
Assembly	8,015	8,167	8,389	8,589	8,781	8,955	9,095	9,207
College	21,744	22,182	22,607	23,006	23,372	23,714	24,053	24,360
Grocery	29,403	30,051	30,726	31,337	31,921	32,485	33,013	33,491
Hospital	15,929	16,459	16,916	17,373	17,838	18,313	18,867	19,438
Hotel	10,907	11,159	11,537	11,909	12,258	12,608	12,897	13,170
Lab	17,920	18,517	19,030	19,545	20,068	20,602	21,225	21,868
Laundry	2,202	2,244	2,305	2,360	2,412	2,460	2,499	2,530
Motel	5,873	6,008	6,212	6,413	6,600	6,789	6,945	7,091
Office - Large	29,403	30,051	30,726	31,337	31,921	32,485	33,013	33,491
Office - Small	29,403	30,051	30,726	31,337	31,921	32,485	33,013	33,491
Rest-Fast Food	3,804	3,942	4,094	4,249	4,394	4,525	4,662	4,799
Rest-Full Serve	7,064	7,321	7,602	7,892	8,160	8,404	8,658	8,912
Retail - Large	40,712	41,609	42,544	43,390	44,198	44,980	45,711	46,373
Retail - Small	45,235	46,232	47,271	48,211	49,109	49,978	50,790	51,525
School - Primary	25,368	25,879	26,374	26,840	27,267	27,666	28,062	28,420
School - Secondary	25,368	25,879	26,374	26,840	27,267	27,666	28,062	28,420
Skilled Nursing	15,992	16,381	16,830	17,251	17,665	18,061	18,444	18,799
Warehouse	60,996	62,312	63,749	65,042	66,275	67,461	68,551	69,526
Other	43,414	44,238	45,441	46,524	47,563	48,506	49,264	49,874
Seasonal	14,529	14,801	15,177	15,493	15,783	16,067	16,319	16,533
Totals:	**453,281**	**463,483**	**474,632**	**484,938**	**494,773**	**504,210**	**513,141**	**521,319**

A distribution of heating equipment types by building type is presented in Table 5.4. For the most part, these allocations were made using drive-by surveys and survey responses from the WNG work. This was modified, where possible, by the information collected in the Northwest Natural survey.

Table 5.4 Gas Heat Equipment Type by End Use (%)

Building Type	Boiler	Unit Heater	Rooftop	Other Furnace	IR Heaters	Other Heat	Total
Assembly	38.8	12.7	9.7	38.9	0.0	0.0	100
College	80.0	10.0	10.0	0.0	0.0	0.0	100
Grocery	0.0	67.1	20.0	12.9	0.0	0.0	100
Hospital	80.0	10.0	10.0	0.0	0.0	0.0	100
Hotel	45.0	7.0	37.0	11.0	0.0	0.0	100
Lab	80.0	10.0	10.0	0.0	0.0	0.0	100
Laundry	16.0	52.0	24.0	8.0	0.0	0.0	100
Motel	66.0	34.0	0.0	0.0	0.0	0.0	100
Office - Large	50.0	0.0	17.0	10.5	0.0	22.5	100
Office - Small	0.0	3.7	78.0	18.4	0.0	0.0	100
Rest-Fast Food	0.0	30.6	69.4	0.0	0.0	0.0	100
Rest-Full Serve	3.3	14.0	82.8	0.0	0.0	0.0	100
Retail - Large	51.3	15.8	26.3	0.0	0.0	6.6	100
Retail - Small	1.5	47.2	30.8	12.8	0.0	8.0	100
Retirement	80.0	10.0	10.0	0.0	0.0	0.0	100
School - Primary	62.2	5.6	17.6	14.5	0.0	0.0	100
School – Secondary	62.2	5.6	17.6	14.5	0.0	0.0	100
Workshop	3.5	71.0	6.1	9.4	10.0	0.0	100
Skilled Nursing	51.3	0.0	37.1	2.8	0.0	8.8	100
Warehouse	0.7	71.5	16.6	5.1	6.1	0.0	100
Other	21.4	37.1	21.4	13.3	6.8	0.1	100

5.2. HVAC Measures

To evaluate the gas savings potential for space conditioning measures, we used the same basic sector assessments developed from survey work conducted in the Northwest Natural and WNG service territories. The latter study was used to derive the saturations of various equipment types among the prototype buildings used in this analysis. This is because the survey allowed for the probability of a particular type of equipment to be associated with floor area and building type. Even that survey was inadequate for providing the level of detail necessary and some assumptions and estimates had to be made in order to assign equipment saturations to individual building end use types, which were then averaged and applied to the remaining building types. The accuracy of the saturation estimates could be greatly improved if customer surveys are conducted to develop more specific data.

Three space conditioning equipment types were evaluated:

1. Rooftop Packaged Systems
2. Boilers
3. Air-side Heating Equipment

5.2.1. Rooftop Packaged Systems

Packaged units are designed to provide space heating, cooling and ventilation in a single piece of equipment that can be installed on numerous commercial building types. The size of these units ranges from 50 KBtuH of heating up to 1 million BtuH. The larger system is not included in this analysis because the vast majority of these systems are less than 150 KBtuH and condition a variety of building types using a single zone distribution and control and constant volume air delivery. There are three general classes of measures for this type of equipment:

1. Operations and maintenance (O&M) and commissioning in the retrofit sector.
2. Demand Control ventilation and building warm up ventilation in the retrofit sector.
3. Duct sealing in the replacement sector.

O&M Commissioning

The O&M commissioning measure allows the HVAC unit to be controlled and responsive to the space conditioning needs of the building while optimizing the energy required to meet the building's conditioning loads. In general, the packaged equipment has a variety of dampers that control heating and cooling air distribution, compressor operation, burner operation, etc. The commissioning components impact cooling and economizer operations. This can also be significant as a resource for gas conservation. The process is the result of resetting and/or repairing, the outside air damper to ensure that it is operational and does not over-supply outside air during heating cycles.

A typical packaged unit design requires a minimal amount of outside air for ventilation during heating and up to 100% outside air during cooling as part of the economizer cycle. Parts of the equipment involved in this changeover can become stuck or out of adjustment, resulting in excessive amounts of outside air. Likewise, the same problems can result in inadequate amounts of outside air. Thus, the commissioning of these units as a gas conservation measure cannot be considered reliable since the ventilation is as likely to be increased as it is to be decreased when the ventilation system is properly adjusted.

Experience with programs in the Seattle area suggest that some net gas savings might accrue to a equipment review. Since only minimal data is available on this measure we have not included it in this assessment. The measure should, however, be considered as part of a general review of packaged rooftop systems. In general, these repairs would enhance the operating effectiveness of the equipment and probably improve the saving potential of the other measures in this sector.

Control Enhancements

The second class of measures involves the addition of specific additional controls that control the heat delivery of the rooftop units. We evaluated two measures in this class; demand control ventilation (DCV) and building warm-up ventilation.

The demand control ventilation measures uses CO_2 sensors that are installed in the return air vent to determine whether the building operation requires additional ventilation air. Based on the CO_2 reading, the outside air damper can modulate open. Using this technology, the installer and operator can set the outdoor air damper at a much lower level for most of the time the building is occupied. When occupancy in a building is highly variable (such as in schools, retail, and assembly spaces) the use of a demand control ventilation system can allow the designer to reduce the default outside air intake with the confidence that when high occupancy occurs, the equipment will adjust to meet the expanded ventilation demand. Equipment has been designed to retrofit directly into the packaged rooftop system, providing a fairly direct mechanism for savings. However, not all occupancies can benefit from this kind of control. For example, office occupancies have modest ventilation requirements which do not vary substantially from one time period to another. In this end use, demand control ventilation provides little or no savings.

The second measure allows the outside air damper to be closed off when the building is in morning warm up mode after the night set back. Warm up is typically set for the hour prior to expected occupancy. Our review of buildings in the Seattle, Washington and Eugene, Oregon areas suggests that most packaged units have a control to close the damper during this period, but that it is almost never used. Thus, the savings from such a measure are limited by lack of implementation. However, implementing the existing feature of the packaged unit may prove to be extremely attractive even if an additional thermostat is necessary. The impact of the rooftop measures on gas savings is shown in Table 5.5.

Duct Sealing

For the replacement population, we examined a duct insulation and sealing measure. Hot-air distribution systems in non-residential construction are often located in areas where any heat lost through duct leakage reenters the heated space with little impact on heating energy use. These include heated plenums, interior soffits, and mechanical chases in the interior of the building.

Nevertheless, duct sealing is practical in cases where ducts are running through unheated attics and crawl spaces, although this is rare in commercial construction. We have estimated the amount of such applications in evaluating duct systems for warm air distribution. For this purpose, we have combined the effects of both duct insulation and duct sealing. The overall costs were taken from data collected in residential applications in which the duct sealing was done using Aeroseal® equipment that allows relatively inaccessible duct systems to be mechanically sealed. These measures are marginal in non-residential settings from a cost of saved energy standpoint. It is possible that some commercial systems with greater access and larger amounts of leakage would see greater benefits from this system than with typical distribution systems in typical applications. This analysis suggests that if a cost-effective duct sealing measure is to be applied in the commercial sector, some preliminary assessment or screening would be necessary before investing in the cost of retrofitting ducts to a higher leakage standard.

The analysis results for these packaged rooftop system measures are presented in Table 5.5.

Table 5.5 Package Rooftop Measures: Commercial Stock

Measure	Measure Cost ($/sf)	Measure Savings (th/sf/yr)	Measure CSE ($/th)	Measure Life (yrs)	Annual Savings (th)	Program Savings (kTh)
Building warm-up control	0.05	0.03	0.21	10	543,463	8,153
DCV Controller & Sensor	0.20	0.09	0.18	15	1,832,481	42,915
Duct sealing	0.50	0.04	1.01	18	345,637	6,998
Totals:					**2,721,581**	**58,066**

We did not proceed with an evaluation of high efficiency rooftop equipment as a potential gas savings resource. High efficiency burner and gas-fired technology was not available in most of the major product lines. Distributors maintain that the higher efficiency pulse-type burners are not in demand and are thus not offered as an option for rooftop units. Even in "high efficiency" product lines the compressor efficiency and in some cases cooling controls are emphasized with virtually no attention to the gas heating technology.

5.2.2. Boiler Measures

For commercial steam and hot water boilers, we analyzed two types of measures: equipment replacement or upgrades, and boiler controls and commissioning.

Boiler Equipment

The efficiency of the boiler stock in the Northwest Natural service territory varies dramatically over the range of operating conditions in buildings. The efficiency of modern boilers (used as a base case for the new and replacement measures) is 80-90 percent. However, many existing boiler systems are over-sized or operate with poor part loads and significant distribution losses. These units can be half as efficient as new equipment. Thus, the available savings for a steam or hot water boiler heating system can be quite large. For this evaluation, we considered two types of boiler equipment efficiency improvement measures.

We did not conduct further analysis of efficiency improvements in boiler burners following a review of existing manufacturer literature. Condensing or near-condensing boilers are available that operate at much high efficiencies than standard equipment, with nominal efficiency ratings of between .9 and .95. These technologies are considerably more expensive than the high efficiency boilers, but can be attractive in most hot water boiler systems. In general, a retrofit application in which the entire boiler is replaced as part of the conservation measure does not pass our CSE screen for these units.

The results of our analysis are shown in Tables 5.6 through 5.8. For the retrofit sector, the cost used for the analysis includes the entire cost of the measure and savings are based on existing conditions. These measures are not cost effective. However, for the new and replacement measures, the cost is incremental over the cost of a code-compliant option. These measures not only provide attractive savings per dollar spent, but also provide enhanced control for better building operation and occupancy comfort.

Table 5.6 Boiler Equipment Measures in Retrofit Commercial Stock

Measure	Measure cost ($/sf)	Measure savings (th/sf/yr)	Measure CSE ($/th)	Measure Life (yrs)	Annual Savings (th)	Program Savings (kTh)
SPC Boiler - Near Condensing	1.26	0.05	1.73	20	250,569	5,348
SPC Boiler - Condensing	1.67	0.07	1.67	20	345,851	2,460
Totals:					**596,420**	**7,808**

Table 5.7 Boiler Equipment Measures in Replacement Commercial Stock

Measure	Measure cost ($/sf)	Measure savings (th/sf/yr)	Measure CSE ($/th)	Measure Life (yrs)	Annual Savings (th)	Program Savings (kTh)
SPC Boiler - Near Condensing	0.16	0.03	0.42	20	1,305,314	27,859
SPC Boiler - Condensing	0.57	0.06	0.65	20	1,100,499	23,488
Totals:					**2,405,813**	**51,347**

Table 5.8 Boiler Equipment Measures in New Commercial Stock

Measure	Measure cost ($/sf)	Measure savings (th/sf/yr)	Measure CSE ($/th)	Measure Life (yrs)	Annual Savings (th)	Program Savings (kTh)
SPC Boiler - Near Condensing	0.16	0.03	0.38	20	380,902	9,484
SPC Boiler - Condensing	0.58	0.05	0.82	20	237,158	5,905
Totals:					**618,060**	**15,389**

Boiler Controls and Commissioning

In retrofit cases where new or replacement boilers are not practical, there are several other useful measures that can be applied. These measures have to do with improving the efficiency of individual components of the boiler as part of an overall boiler tune-up.

Efficiency gains from boiler tune-ups can vary substantially, depending on the existing boiler's condition, previous maintenance, and the opportunities for installing particular performance-improving technologies. The measures we considered are listed in Table 5.9. In the field, the tune-ups can include some or all of the measures, in addition to aerating the burner, adjusting secondary air, adding flue restrictors, cleaning the fire-side heat exchanger, cleaning the water-side fire tubes, and/or installing turbulators. Not all of these measures may be applicable in a particular case, but the overall average of studies done in Minnesota and Wisconsin suggested that this package of measures can result in a 3 to 4 percent improvement in efficiency.

Table 5.9 Boiler Tune Up Measures in Retrofit Commercial Stock

Measure	Measure cost ($/sf)	Measure savings (th/sf/yr)	Measure CSE ($/th)	Measure Life (yrs)	Annual Savings (th)	Program Savings (kTh)
Temperature Reset	0.03	0.03	0.12	10	739,326	7,913
Tune-Up	0.01	0.02	0.11	5	159,473	798
Steam Balance	0.06	0.04	0.12	15	477,173	7,389
Vent Damper	0.06	0.02	0.38	12	106,654	1,371
Power Burner	0.18	0.02	0.77	12	940,817	12,191
Totals:					**2,423,443**	**29,662**

In addition to the tune-up measures, several other control and commissioning measures are considered. As with tune-ups, they could be applicable in some cases and not in others. These include the use of a vent damper to control off-cycle losses or the addition of a power burner to control the oxygen/gas mix in the firebox. Such measures do not pass our CSE screen under most circumstances.

We did not include an intermittent ignition device (IID) in the tables. This device is an electronic pilot that can replace the standing pilot in older burner equipment. The cost-effectiveness of this measure varies widely with the size of the pilot light, the duty cycle of the boiler and the general operating conditions of the hot water steam loop. While this may have an attractive CSE under some conditions in retrofits, it is always included in the higher efficiency boiler used in both the replacement and new boiler markets. Furthermore, IID may also be included part of a boiler tune-up under certain circumstances. However, the measure is not included in this analysis since the savings associated with this measure depend critically on the type of installation and burner as well as the control strategy of the boiler. In general, this measure does not pass our CSE screen.

5.2.3. Air-Side Heating Equipment

A number of types of equipment which use natural gas to heat and distribute air are used in the commercial sector. By far the most common of these is the unit heater. This heater is typically installed without ducts in the ceiling of large retail, warehouse, or other spaces. It is designed to heat air directly and blow it into the space without the use of a large distribution system.

These systems are usually relatively inefficient. In recent years, certain manufacturers have introduced condensing type unit heaters that bring the efficiency to almost 90%. As a result of codes and modern equipment standards, new equipment often exceeds 80% efficiency and many manufacturers produce a unit with approximately 84% efficiency.

For this analysis, we evaluated two different unit heater technologies: high efficiency and condensing units. The high efficiency units have efficiency ratings of up to 84%, exceeding code and code equipment standards by approximately 7%. It also exceeds the current practice unit heater use standards by more than 10%. The condensing unit heater uses a condensing burner. While it is somewhat more expensive than the high efficiency unit heater, its efficiency is improved by an additional 5-7 percent.

We have assumed that the high efficiency unit heater provides a 20% improvement over standard gravity-vented standing pilot unit heaters used in existing applications throughout the sector. The condensing burner provides an approximate 29% improvement over that same base system. The cost of the system depends critically on the condition in which the system will be installed. For the retrofit measure, we used the entire cost of installing the measure; at this cost, none of the options passed our cost-effectiveness screening threshold. The results of our analysis are shown in Table 5.10.

Table 5.10 Gas Unit Heater Measures in Retrofit Commercial Stock

Measure	Measure cost ($/sf)	Measure savings (th/sf/yr)	Measure CSE ($/th)	Measure Life (yrs)	Annual Savings (th)	Program Savings (kTh)
High Efficiency Unit Heater	2.15	0.06	2.46	18	603,260	11,617

We also examined standard high efficiency gas unit heaters as a replacement option in existing construction when the unit heaters break or are replaced for some reason other than energy efficiency. In this case, as with new construction, the cost and savings calculations are measured against a base case that minimally meets the Oregon energy code (approximately 64% efficiency rating).

For the condensing unit heater measure, the high efficiency unit served as a base case to calculate the savings in order to capture those circumstances in which the energy code requires an efficiency rating of 75%. The incremental cost is taken to be the same as in the replacement case for the condensing unit heater analysis. These results are presented in Tables 5.11 and 5.12.

Table 5.11 Gas Unit Heater Measures in Replacement Commercial Stock

Measure	Measure cost ($/sf)	Measure savings (th/sf/yr)	Measure CSE ($/th)	Measure Life (yrs)	Annual Savings (th)	Program Savings (kTh)
High Efficiency Unit Heater	0.29	0.06	0.34	18	976,499	18,804
Condensing Unit Heater	1.24	0.09	0.99	18	1,410,065	27,153
Condensing Furnace	0.77	0.04	1.29	18	599,441	11,943
Totals:					**2,986,005**	**57,899**

Table 5.12 Gas Unit Heater Measures in New Commercial Stock

Measure	Measure cost ($/sf)	Measure savings (th/sf/yr)	Measure CSE ($/th)	Measure Life (yrs)	Annual Savings (th)	Program Savings (kTh)
High Efficiency Unit Heater	0.31	0.03	.72	18	292,854	6,688
Condensing Unit Heater	1.31	0.06	1.52	18	585,708	13,376
Condensing Furnace	0.45	0.05	.69	18	352,833	8,425
Totals:					**1,231,395**	**28,488**

In this context, the incremental cost associated with condensing technology in unit heaters appears to offer a considerably lower level of cost-effectiveness than the standard high efficiency models. In general, the incremental efficiency step for the high efficiency equipment passed our CSE screen. However, the extra cost of condensing burners, at this stage, seems to offer somewhat less of an opportunity for cost-effective savings.

One caveat addresses the use of condensing high-efficiency furnaces in applications that require smaller residential-scale furnaces (up to approximately 150 KBtu). For the most part, the replacement characteristics of these furnaces are taken from the code base (AFUE=0.78) for this equipment. We have assumed that condensing equipment to be employed would have an AFUE of 0.90, even though there are somewhat higher efficiencies available in this technology.

The incremental cost associated with this furnace provides a marginally passing cost of saved energy that depends, in large part, on the efficiency of the building and distribution system. For this evaluation, we assumed a 90% efficient distribution system. This is often realistic for non-residential applications. However, in cases where substantial duct losses and distribution losses are present the cost-effectiveness of this measure increases substantially.

On the whole, this measure provides some advantages in new construction. Here, the incremental cost is taken at the low end of the cost range since it involves the application of a competitive technology. For the replacement market, the cost is taken to be about 30% higher, assuming that the replacement occurs based on some individual furnace requiring a change-out as a result of O&M considerations. This is crucial because the incremental cost assumptions for the condensing furnace determine the cost-effectiveness in both of these cases. Replacement costs of approximately $550 or above result in the technology being too expensive for consideration. For a typical single-application, residential furnace the expected incremental cost is $700-$800 and therefore does not pass the CSE screen.

5.3. Envelope Measures

Gas heating is the dominant form of space heating in the non-residential sector. Nearly 100 percent of the buildings and building types that have been constructed over the last century are heated with natural gas. The use of insulation and other heat-conserving technologies was often not available or not thought to be cost-effective when gas prices were quite low (for instance, in the middle of the twentieth century). For this reason, a substantial fraction of the commercial building stock in the Northwest Natural service territory is not insulated and provides a substantial energy savings resource pool.

The challenge of this analysis is that, because it focuses on insulation measures, the possible applications interact with one another as well as other building components, and the interaction affects the impact of more efficient heating equipment. To account for these interactions, we simulated the various envelope measures simultaneously and allowed the simulation software to select each measure in order of cost-effectiveness. This allows the savings associated with each measure in a particular simulation to be determined; however, the measures are ranked in order of cost-effectiveness and the savings associated with each measure assumes that all measures previously ranked have been applied. Therefore, the savings associated with a particular measure varies substantially depending on how these groups of measures are bundled. This results in a slightly conservative analysis, since in an uninsulated building there is no guarantee that an owner will upgrade wall or floor insulation when the ceiling insulation measure is applied. Certainly the interaction between window and insulation technologies reduces the total cost-effectiveness of insulation measures when they are applied simultaneously.

Another important interactive effect involves the variety among the buildings themselves. The level, type, and R-value of insulation appropriate to a particular building varies substantially in different building configurations. In new construction and major renovations, these levels are controlled by the energy code. But this is less common in retrofit situations. For example, a timely application of roof decking during a regularly scheduled re-roofing project can reduce the cost of the insulation by a factor of 5. The amount of insulation that may be added is, in part, a function of the geometry of the building and the roof detailing, along with the particular predilections of the building owner when the measure is installed.

Thus our analysis methodology evaluated competing measures separately, and then adjusted the technical feasibility. The technical potential for roof deck measures, for example, are divided equally among the total feasible roof area that can be treated. These will not necessarily be the most cost-effective combinations, but considerations of geometry can seriously limit certain measures while allowing certain others. We attempted to account for the total feasible area that can receive each measure. However, if the most energy effective or cost-effective measure was selected in every case, the technical potential analysis will be higher than what is presented here.

5.3.1. Insulation

There are numerous potential roof configurations in which a roof insulation measure is feasible. We evaluated three possible insulation strategies:

1. Roof Deck Insulation. Insulation is applied on the outside of the structural deck of the roof immediately below the roofing. In replacement applications, this is generally done when installing a new flat roof surface. Since this is a relatively frequent event, it is feasible to re-insulate virtually this entire sub-sector in ten to 20 years. The measure is applicable only to older buildings. Ceiling insulation was applied beginning about 1980; therefore, a substantial portion of the existing stock was insulated with this strategy during the original construction thereby, greatly reducing the applicability of the measure.

2. Blanket Insulation. This is applied to open beam/open web roofs where the structure can be insulated from below. This mechanism is usually limited to somewhat unfinished spaces such as warehouses, workshops, shops, etc. While these may be conditioned areas, they often have unfinished ceilings and thus have access to the roof structure.

3. Attic Insulation. In this case, we evaluated all insulation that could be installed within the space constraints of the area above the finished ceiling, either as a blown-in type or fiberglass batt. Attic insulation is generally the least expensive measure of the three techniques, although it has limited

applicability since it requires an open attic space. This limits its use to buildings that can be insulated above a dropped ceiling or within structural trusses over a finished ceiling.

The overall picture of the retrofit opportunities for insulation, at least in this group of selected measures, is that most insulation programs should be cost-effective in existing buildings where insulation levels are minimal. The result of such a program would be over 6 million therms of annual savings. Payback periods of less than a year based on gas savings alone are available in the most cost-effective commercial building types.

In all cases, the savings from ceiling insulation were evaluated on each individual prototype using a calculated R value for each strategy. The costs were calculated specifically for the applications to be installed in these different buildings. The cost-effectiveness of these measures varies among building types and the cost of the particular insulation upgrade also varies with the ability to use more or less expensive options. In all cases, the applicability of these insulation strategies was determined using the survey information collected in the WNG survey. These were taken as probabilities that one or another ceiling or roof configuration would be available in any given building type.

A similar process was used to assess wall insulation. The application of these measures was confined to two particular situations. The first is the small fraction of buildings with cavity walls that can receive a retrofit blow-in insulation. These tend to be small buildings or buildings with residential type occupancy in low-rise situations (e.g. motels and nursing homes). The second application is metal buildings where a layer of insulation can be sprayed on. This technology is often used for sound control but it also insulates the wall. In most metal building applications this is very cost effective even if space conditions are kept at 50°F. This measure was applied only to the "Warehouse" building type.

The summary values serve as a weighted average among all the building types that were reviewed. In most cases, this is an adequate representation of the cost-effectiveness (according to our CSE screen) of these measures in all applicable ceiling configurations. The results of our analysis of insulation measures throughout the commercial sector are summarized in Table 5.13. While the table presents all of the measures we analyzed, the total potential savings represents only the application of the measures passing our CSE screen.

Table 5.13 Insulation Measures in Retrofit Commercial Stock

Measure	Measure Cost ($/sf)	Measure Savings (th/sf/yr)	Measure CSE ($/th)	Measure Life	Annual Savings (th)	Program Savings (kTh)
Wall Insulation - Blown R11	0.40	0.10	0.18	30	1,266,001	37,980
Wall Insulation - Spray On	0.35	0.10	0.16	30	181,176	5,435
Roof Insulation -	0.82	0.15	0.06	30	1,070,147	32,104

Rigid R0-11						
Roof Insulation - Rigid R0-22	1.41	0.17	0.10	30	1,215,994	36,480
Roof Insulation - Rigid R11-22	0.70	0.04	0.19	30	787,186	23,616
Roof Insulation - Rigid R11-33	1.11	0.03	0.40	30	671,879	20,156
Roof Insulation - Blanket R0-19	0.65	0.14	0.21	30	325,420	9,763
Roof Insulation - Blanket R0-30	0.73	0.14	0.24	30	310,118	9,304
Roof Insulation - Blanket R11-30	0.69	0.02	1.44	30	97,420	2,923
Roof Insulation - Blanket R11-41	0.78	0.02	1.43	30	109,768	3,293
Roof Insulation - Attic R0-30	0.39	0.13	0.14	30	339,682	10,190
Roof Insulation - Attic 11-30	0.32	0.04	0.36	30	237,333	7,120
Totals:					**6,612,124**	**198,364**

We evaluated measures that could be applied in retrofit situations designed to achieve energy savings or as part of a regular lifecycle replacement project. Retrofit measures can be applied at any point during the life of the building. These measures are generally applicable only to buildings built prior to 1990, when insulation standards were either non-existent or un-enforced. The second category is insulation opportunities that occur during regular maintenance on the building. This is largely limited to roof configurations in which a flat roof deck is re-roofed approximately every 10 to 15 years. This presents an opportunity for installing roof deck insulation on top of the existing roof deck prior to laying down the new roof layer.

The remaining ceiling insulation measures are more typically installed as part of an energy conservation strategy rather than as part of a maintenance strategy. The blanket-type insulation is assumed to be installed in open-beamed ceilings that were previously uninsulated. It can be typically installed using staples or wires in most situations, particularly in open-beam metal buildings and warehouse configurations.

Finally, a class of measures using retrofit blown-in insulation has also been included. In this case, the level of existing insulation is not crucial to the cost-effectiveness of a blown-in measure. Upgrading to R-30 passed our CSE screen in most applications.

5.3.2. Windows

There are numerous opportunities for energy savings from windows in gas heated buildings. In many cases, the savings and cost-effectiveness are enhanced by the impact on electricity used for cooling in many commercial building types. Furthermore, prior to 1980, windows installed in any commercial building were, for the most part, single glazed, untinted and lacking low-emissivity (low-ε) coatings. While windows present one of the largest total therm targets for gas conservation, the high cost of the measures prevents them from being attractive on the basis of energy savings alone. The results of our windows analysis are shown in Tables 5.14 through 5.16. The applicability of the measures was divided into three categories:

1) Retrofit windows – This class of windows assumes that the program would approach every building with Class 70 or higher windows and purchase an entire retrofit for that building. Specific costs here include the entire cost of the window and frame. In some cases, the cost includes disassembling the curtain wall frame and replacing all the glazing. In certain cases where the base is single-glazed aluminum framed windows, this measure passes our CSE screen. However, for most building types, this measure is too expensive to be used as a retrofit measure.

Table 5.14 Windows Measures in Retrofit Commercial Stock

Measure	Measure Cost ($/sf)	Measure Savings (th)	Measure CSE ($/th)	Measure Life (yrs)	Annual Savings (th)	Program Savings* (kTh)
Sgl to Class 45	1.07	0.05	1.19	30	2,026,088	0
Sgl to Class 40	1.11	0.05	1.14	30	2,190,967	0
Sgl to Class 36	1.16	0.05	1.12	30	2,330,249	0
Dbl to Class 45	1.17	0.02	2.80	30	913,695	0
Dbl to Class 40	1.22	0.03	2.39	30	1,114,167	0
Dbl to Class 36	1.28	0.03	2.19	30	24,543	0
Totals:					**8,599,709**	**0**

*Measures which passed the cost-effectiveness screening criteria only.

2) Replacement measures – This assumes that a window is being replaced or reglazed as a result of some secondary consideration; for example, the building is being remodeled or rehabilitated or some sort of damage has occurred that requires new windows. In this case, the incremental cost of glazing the windows is already absorbed in the existing situation and only the cost of the upgrades to the glazings need be considered. This improves the cost-effectiveness somewhat, but not enough to pass our CSE screen.

Table 5.15 Windows Measures in Replacement Commercial Stock

Measure	Measure Cost ($/sf)	Measure Savings (th)	Measure CSE ($/th)	Measure Life (yrs)	Annual Savings (th)	Program Savings* (kTh)
Add Low-ε to Vinyl Tint	0.08	0.01	0.61	30	36,877	0
Add Low-ε and Argon to Vinyl Tint	0.13	0.01	0.67	30	52,355	0
Add Argon to Vinyl Low-ε	0.06	0.00	0.75	30	35,414	0
Non-Tint AL Code to U=.45	0.11	0.00	2.05	30	41,738	0

Non-Tint AL Code to U=.40	0.16	0.01	1.13	30	113,982	0
Non-Tint AL Code to U=.36	0.40	0.01	1.85	30	174,088	0
Tinted AL Code to U=.45	0.12	0.00	1.94	30	4,635	0
Tinted AL Code to U=.40	0.11	0.00	1.61	30	22,418	0
Tinted AL Code to U=.36	0.23	0.00	2.41	30	41,693	0
Totals:					**523,200**	**0**

*Measures which passed the cost-effectiveness screening criteria only.

We assumed for this analysis that the base replacement windows would have to meet the current Oregon energy code requirements (including low-ε coatings, argon fills and frame upgrades). This measure does not generally pass our CSE screen. However, in office spaces where the installation of more efficient windows has both a cooling and heating impact, this measure is attractive. This is not the case for most commercial buildings, even if a cooling load is present.

3) New Windows – This assumes that the Oregon code is being met in new construction and the incremental benefits are evaluated against this standard. As with replacement windows, these measures did not pass our CSE screen based on gas savings alone. In some cases, low emissivity coatings can be added to achieve higher performance in the aluminum frames. Because some low-ε coating or other enhancement would be required to meet the base case window, it is more difficult to achieve the higher performance specified here to reach a significant improvement over the window currently required in the Oregon code.

It is important to realize that this does not necessarily mean that the windows are not cost-effective, merely that they do not provide adequate savings based on gas heating alone. For example, when these windows are reviewed as a possible electric resource, several of these measures have very attractive CSE rates. It is also important to realize that in the case of the higher performance Class 35 and Class 40 windows, an increment of improved frame is included in the aluminum windows. This is assumed to be either an improved or more substantial thermal break, especially in curtain wall applications.

Table 5.16 Windows Measures in New Commercial Stock

Measure	Measure Cost ($/sf)	Measure Savings (th)	Measure CSE ($/th)	Measure Life (yrs)	Annual Savings (th)	Program Savings* (kTh)
Add Low-ε to Vinyl Tint	0.08	0.01	0.66	30	32,732	0
Add Low-ε and Argon to Vinyl Tint	0.13	0.01	0.74	30	46,039	0
Add Argon to Vinyl Low-ε	0.06	0.00	0.86	30	64,727	0
Non-Tint AL Code to U=.45	0.11	0.00	2.03	30	30,855	0
Non-Tint AL Code to U=.40	0.17	0.01	1.13	30	83,041	0
Non-Tint AL Code to U=.36	0.41	0.01	1.87	30	125,725	0
Tinted AL Code to U=.45	0.08	0.00	1.86	30	3,561	0
Tinted AL Code to U=.40	0.09	0.00	1.94	30	13,336	0
Tinted AL Code to U=.36	0.23	0.00	2.69	30	24,543	0

Totals:					424,559	0

*Measures which passed the cost-effectiveness screening criteria only.

The overall impact of new window measures described here is approximately 425,000 therms of savings per year, applied across the commercial sector. The savings represent approximately 3% of the existing floor area and an additional 12% of new construction. However, there are many measures that would pass our CSE screen if the avoided cost criteria were somewhat higher. For example, most single glazed retrofit windows would pass our CSE screen if the criterion is raised by 30%-50%.

This would have the effect of capturing some of the non-energy benefits associated with this measure, including electricity savings and increased property values. It should be stressed that the cost effectiveness of these measures is dependent on the particular situation. Many of the window measures become cost effective if the impacts of the window retrofit include the increase in property values and the offset in O&M costs. While these advantages are not apparent in this analysis, they are factors in determining the value of an investment to gas customers.

By raising the CSE threshold to $0.75/therm saved, an additional total program savings of approximately 6 million therms is available at the current technical potential levels; about 2 million of that is from the new construction sector with the remainder coming from the replacement sector, as shown in Table 5.17. This is an extremely conservative estimate. If the CSE threshold were raised, the total available savings would be expected to approach 15 to 20 million therms.

Table 5.17 Program Savings from Windows Measures with CSE <= $0.75

Measure	Sector	Measure CSE ($/th)	Annual Savings (th)	Program Savings* (kTh)
Windows - Add Low E to Vinyl Tint	Replace	0.61	36,877	1,106
Windows - Add Low E and Argon to Vinyl Tint	Replace	0.67	52,355	1,571
Windows - Add Argon to Vinyl Low E	Replace	0.75	35,414	1,062
Windows - Add Low E to Vinyl Tint	New	0.66	32,732	982
Windows - Add Low E and Argon to Vinyl Tint	New	0.74	46,039	1,381
Totals:			**203,417**	**6,102**

*Measures which passed the **NON-STANDARD** cost-effectiveness screening criteria of **$0.75** only.

In general, the commercial sector envelopes can provide a significant amount of gas savings. Savings are dominated by insulation applied to uninsulated building components. But many opportunities exist for windows, especially as a result of renovation, remodel, and new construction.

5.4. Hot Water

Energy savings from hot water measures can come from several sources. Savings are largely determined by the end use, which dictates the need for hot water as a function of operation. As such, the load is mostly independent of both building size and climate. For this analysis, the applicability of hot water measures was based on surveys from individual building types conducted for WNG, which was then normalized to building area in those building types. This is an unsatisfactory simplification; however, in the absence of data from Northwest Natural this provided a reasonable basis for assessing the measures and applicability in the sector. The nature of the efficiency improvements in this sector is based on three classes of potential measures:

- Integrated Water Burner and Storage Tank. These measures improve the efficiency of the hot water burner and storage tank combination in cases where these are integral. These measures are meant to cover larger hot water tanks supplying a loop in an intense use such as a laundry or restaurant facility. The measure is also meant to cover smaller residential-scale tanks like those used in nursing homes, dormitory units and other residential type applications, as well as in applications with relatively modest hot water loads (such as office and retail spaces).

- Boilers. These measures are applicable in cases where boilers supply hot water either in combination with, or in addition to, space heating loops. Usually the boilers are stand-alone units associated with some amount of storage and a circulating loop that supplies hot water to a large number of points. This system is typical in the hotel and lodging end use, where many delivery end points exist that have modest hot water demands at any time. Often, these boilers are associated with the space heating of the building. For this analysis, the savings from the heating use are included in the previous section, while the hot water savings accrued from these measures are included in this section.

- Demand Control Measures. The demand control measures apply various technologies designed to limit the amount of water use at any one point. These are typically low-flow appliances, showerheads, and faucets. The measures also include pipe insulation and circulation controls that reduce the line flow.

5.4.1. Hot Water Integrated Burners and Storage Tanks

The use of tank-type water heaters is a standard method associated with almost every end use type in which only a small amount of domestic water is consumed. These are the least expensive and most straightforward applications for building service water in the commercial sector. The technologies are generally based on residential technologies with relatively modest changes for commercial applications.

Overall, 57% of the floor area associated with gas heating in the service territory uses tank technologies of various types to provide domestic water. This technology has an integral storage tank. Standby losses from that tank are typically a parasitic load on the gas water heating system. Energy readings for these systems are typically expressed as the total amount of useful heat in the water delivered to a standard usage from the tank over the total energy required to produce that amount of water. Energy code requirements for these systems vary from between about 54% and 57%, depending on the size of the water heater. While these may sound like relatively low efficiencies, they are comparable to the standby losses associated with the combination of the heat exchanger, burner and the tank jacket.

We analyzed tank upgrades to a standard EnergyStar™ high efficiency model that uses the more advanced heat-exchanger designs and burner placement to improve the overall heat transfer and reduce standby losses. In addition, higher levels of insulation on the tanks and electronic pilots improve the performance. This measure is calculated as an improvement over the code standard and represents approximately a 10% overall increase in water heater efficiency.

The condensing hot water tank measure uses condensing burner technology with an elaborate heat exchanger and flame control to reduce the temperature and condense water from the gases as part of the heat exchange. This technology is fairly standard in residential furnace and boiler technologies. It is rare in hot water heaters; only a handful of manufacturers make this technology available in hot water tank designs.

The improved efficiency of such a system is approximately 20% in overall tank efficiency for a tank compliant with the Oregon Energy Code. These tanks are considerably more expensive than standard tanks. For this analysis, we assumed a full cost of a new tank for the retrofit population. Only the incremental costs and savings of condensing technology versus current standards were used for new and replacement purposes. In the latter case, the technology appears to nearly pass our CSE screen even given the limited supply of these tanks from manufacturers. Over the long run, there would appear to be opportunities to use this in high use applications such as in laundries and restaurants. In such cases, the cost-effectiveness is about 30% better than in the average cases across the entire sector.

The results of our analysis are presented in Tables 5.18 through 5.20. The applicability of the measures has been adjusted to avoid double counting.

Table 5.18 Hot Water Tank Measures in Retrofit Commercial Stock

Measure	Measure Cost ($/sf)	Measure Savings (th/sf/yr)	Measure CSE ($/th)	Measure Life (yrs)	Annual Savings (th)	Program Savings (kTh)
EnergyStar Tank	0.37	0.06	0.56	15	144,862	7,022
Condensing Tank	0.50	0.10	0.44	15	346,597	16,476
Totals:					**491,459**	**23,498**

Table 5.19 Hot Water Tank Measures in Replacement Commercial Stock

Measure	Measure Cost ($/sf)	Measure Savings (th/sf/yr)	Measure CSE ($/th)	Measure Life (yrs)	Annual Savings (th)	Program Savings (kTh)
Condensing Tank	0.11	0.04	0.25	15	330,286	15,701

Table 5.20 Hot Water Tank Measures in New Commercial Stock

Measure	Measure Cost ($/sf)	Measure Savings (th/sf/yr)	Measure CSE ($/th)	Measure Life (yrs)	Annual Savings (th)	Program Savings (kTh)
Condensing Tank	0.11	0.04	0.24	15	237,213	8,482

5.4.2. Boilers

Boilers used for hot water in the commercial sector represent a significant end use. The measures associated with these boilers are almost exclusively based on hot water combustion efficiency improvement. We analyzed boilers used exclusively for hot water separately from combination units that supply both heating and hot water. For this analysis, the data from the heating function was calculated separately and included in the previous section on HVAC equipment. The tables in this section contain only the impacts of the hot water function.

The measures we evaluated focus on two boilers types; a near-condensing boiler that operates at a combustion efficiency of approximately 85% and a condensing boiler that operates at efficiency above 90%. Condensing boilers (typically including staging and burner modulation control) are more appropriate for larger scale applications.

Evaluation of these technologies was conducted independently for the retrofit, replacement, and new construction sectors. In the retrofit analysis, the full cost of the boiler was used. This was based on the assumption that the boiler would be changed out to replace an existing boiler that would not otherwise be replaced. The savings from this assumption are not sufficient to overcome the higher capital cost. Furthermore, the nature of such a program would certainly bring into question the role of free-ridership in changing out boilers. Free-ridership is defined as that population which takes advantage of an incentive program even though the measure would have been installed anyway in the absence of the program. For the new and replacement sectors, the analysis takes into account only the incremental cost of a given boiler at the higher efficiency. The incremental costs vary dramatically depending on boiler size and application. In general, the costs have been normalized to the total square footage of buildings in each particular end use.

Although this analysis should actually be calculated on hot water demand and normalized that way, the data for such an approach does not exist and as a result this analysis can be misleading. The most critical caveat is that buildings with intense hot water loads are averaged with buildings with very low intense hot water loads. Thus, very attractive measures have been averaged with measures that are relatively expensive because the hot water demand itself is quite low but the cost of the equipment remains fairly constant. Almost all of the measures based on incremental costs pass our cost-effectiveness screen in most applications. There are certainly applications where the improved efficiency provides insufficient benefits due to relatively low hot water demand. Office, retail, assembly, and similar end uses typically do not have the hot water loads to support even modest efficiency upgrades.

Hot Water Boilers

The summary of our analysis for boilers supplying only hot water is contained in Tables 5.21 through 5.23. These units are primarily dedicated to building types with intensive demand for hot water, such as hotels, laundry, and nursing facilities. It suggests attractive applications in new and replacement boilers in almost every category. It is important to realize that even retrofits pass our CSE screen in applications where large hot water loads are present, such as in laundry applications. An improvement of 24% is anticipated across the board in the application of improved combustion efficiency boiler technologies.

Table 5.21 Hot Water Boiler Measures in Replacement Commercial Stock

Measure	Measure Cost ($/sf)	Measure Savings (th/sf/yr)	Measure CSE ($/th)	Measure Life (yrs)	Annual Savings (th)	Program Savings (kTh)
DHW Boiler - Near Condensing	0.65	0.21	0.21	20	177,100	26,161
DHW Boiler - Condensing	2.00	0.41	0.33	20	345,767	51,076
Totals:					**522,867**	**77,237**

Table 5.22 Hot Water Boiler Measures in New Commercial Stock

Measure	Measure Cost ($/sf)	Measure Savings (th/sf/yr)	Measure CSE ($/th)	Measure Life (yrs)	Annual Savings (th)	Program Savings (kTh)
DHW Boiler - Near Condensing	0.45	0.14	0.22	20	315,889	31,471

DHW Boiler – Condensing	1.32	0.28	0.32	20	616,735	62,943
Totals:					**932,624**	**94,414**

Table 5.23 Hot Water Boiler Measures in Retrofit Commercial Stock

Measure	Measure Cost ($/sf)	Measure Savings (th/sf/yr)	Measure CSE ($/th)	Measure Life (yrs)	Annual Savings (th)	Program Savings (kTh)
DHW Boiler - Standard	4.57	0.18	1.68	20	138,295	21,147
DHW Boiler - Near Condensing	5.24	0.40	0.88	20	303,575	46,993
DHW Boiler - Condensing	6.63	0.61	0.73	20	460,984	71,665
Totals:					**902,854**	**139,805**

Combination Boilers

Combination ("combo") boilers typically have both space heating and water heating loads assigned to them. Usually, the hot water is part of a separate loop with heat exchanged into a storage tank that, in turn, circulates to the building. These burners have higher duty cycles during the heating season and much lower duty cycles during the summer season when no space heat is used.

In the combination systems some of the unevenness between end uses is smoothed out. Only in cases such as laundries is the application noticeably different from one end use to the next, and combo units are rarely used in those facilities. As a result, in cases where combo systems are used even in buildings with relatively low hot water demands, the cost-effectiveness of the high efficiency boiler applications is much improved for both replacement and newly constructed boilers. As with the hot water-only boilers, the retrofit applications are typically much too expensive and did not pass our cost-effectiveness screen. The results of this analysis are shown in Tables 5.24 through 5.26.

Table 5.24 Combo Boiler Measures in Replacement Commercial Stock

Measure	Measure Cost ($/sf)	Measure Savings (th/sf/yr)	Measure CSE ($/th)	Measure Life (yrs)	Annual Savings (th)	Program Savings (kTh)
Combo Boiler - Near Condensing	0.18	0.04	0.31	20	48,280	1,187
Combo Boiler - Condensing	0.53	0.08	0.42	20	108,191	2,590
Totals:					**156,471**	**3,777**

Table 5.25 Combo Boiler Measures in New Commercial Stock

Measure	Measure Cost ($/sf)	Measure Savings (th/sf/yr)	Measure CSE ($/th)	Measure Life (yrs)	Annual Savings (th)	Program Savings (kTh)
Combo Boiler - Near Condensing	0.18	0.04	0.32	20	78,597	2,063
Combo Boiler - Condensing	0.61	0.07	0.61	20	140,686	3,750
Totals:					**219,283**	**5,813**

Table 5.26 Combo Boiler Measures in Retrofit Commercial Stock

Measure	Measure Cost ($/sf)	Measure Savings (th/sf/yr)	Measure CSE ($/th)	Measure Life (yrs)	Annual Savings (th)	Program Savings (kTh)
Combo Boiler - Near Condensing	1.40	0.07	1.32	20	85,635	2,094
Combo Boiler - Condensing	1.84	0.10	1.21	20	121,100	3,007
Totals:					**206,735**	**5,101**

5.4.3. Demand Control Technologies

These technologies are largely based on flow control at the end use or with water-conserving appliances. In the latter category, we have not included these measures as part of the commercial hot water analysis with the exception of low-flow showerheads and sink aerators.

The difficulty when including low-flow technologies is in not being able to determine current saturation levels of the technologies. In the 1990s, most utilities in Oregon circulated low-flow showerheads to apartments in residential construction and made them available in non-residential construction. Many high-use applications (such as hotels and motels) changed out showerheads to better manage their energy bills. The degree to which this process has been completed is unknown. Furthermore, since 1996, the Oregon Energy Code has mandated low-flow showerheads in new applications, so remodels, rehabilitation and new construction projects already receive these measures. We have assumed that half of the showerheads in existing commercial buildings have already been affected by one of these programs. Nonetheless, these measures are very attractive.

The other demand control measures that were reviewed involve reduction in pipe and standby losses by various techniques. The first is the addition of pipe insulation to hot water loops. In most of the commercial sector, hot water is circulated throughout the building so that the delay time from supplying hot water to a particular use is reduced to an acceptable level. This increases standby losses by a substantial fraction, since a certain amount of hot water is constantly being circulated with heat being lost from the pipes into the surrounding space.

The addition of pipe insulation can have a major impact on this heat loss. Since pipe insulation is actually quite common, we have assumed that the actual available opportunities for implementing this application are relatively small. Overall, the analysis assumed that about 20% of the existing loops could benefit from a pipe insulation measure. This reduces the total impact of this measure. However, it is very attractive in cases where hot water loops can be identified that will benefit from additional insulation.

We also examined the use of re-circulation controls. This measure works on the premise that water that circulates through the system is controlled through a combination of pressure and temperature so that when hot water loads decline or are minimized, the loop speed is either slowed down or stopped altogether. This has applications in building types with hot water demands that can be managed by modern re-circulation control. In many applications, owners are not willing to consider the possibility of hot water being unavailable for the rare off-cycle demand. But as a control measure, it is quite attractive in the event that it can be marketed to the user.

The Oregon Energy Code has required some kind of control of hot water loops for almost ten years. However, it is not uncommon to find systems built prior to 1990 that have an uncontrolled circulation pump delivering a constant volume of water throughout the system. This measure can be applied to that fraction of buildings. As with the pipe insulation, we have anticipated that the overall impact of this measure is probably confined to about 10% of the systems available. In the event that the right combination can be identified, this measure almost always passed our CSE screen. Our analysis results are shown in Table 5.27.

Table 5.27 Hot Water Control Measures in Retrofit Commercial Stock

Measure	Measure Cost ($/sf)	Measure Savings (th/sf/yr)	Measure CSE ($/th)	Measure Life (yrs)	Annual Savings (th)	Program Savings (kTh)
Shower Heads	0.05	0.04	0.22	8	277,643	2,898
Pipe Insulation	0.32	0.08	0.35	15	290,128	39,469
Recirc controls	0.17	0.05	0.37	10	1,072,835	11,284
Totals:					**1,640,606**	**53,651**

5.5. Cooking Measures

Commercial cooking represents a substantial fraction of the gas use in the Northwest Natural service territory. Factors taken from the Northwest Natural and WNG evaluations apply to the particular building types where cooking is used. An estimate of about 17% of all gas used in the commercial sector, about 39 million therms, is consumed by various cooking end uses. Using the technologies evaluated here, an estimated ten percent of cooking energy can be saved.

This calculation is largely based on the willingness and ability of restaurants and other kitchen facilities to make major changes in their appliances over a period of time. These changes are usually brought on by the need for production and cooking efficiency and not as energy conservation strategies. When assessing the technical potential for this sector, we have substantially reduced what options are available from these measures because of free-ridership and difficulties in equipment turn over. On the other hand, cooking has been a traditional area of interest for Northwest Natural. Throughout the 1990s, the gas company offered advice to kitchen buyers and equipment specifications to encourage the use of energy efficient kitchen equipment. This process has undoubtedly resulted in some saturation of the higher efficiency equipment. We attempted to take that into account as part of assessing this sector.

Five distinct measures were examined in each of three contexts. Unlike most of the measures reviewed for the other sectors, the impact of free-ridership and retrofit cycles are considered important in assessing the overall savings that might be accumulated from each measure. The measures examined generally passed our CSE screen, and only the issue of free-ridership made the program less effective. The five measures reviewed were:

1. Direct Fired Convection Oven. These ovens cook faster than standard ovens by circulating hot air around the food. There are two types of convection ovens, direct-fire and indirect-fire. The direct-fire ovens are more efficient because the hot combustion gasses circulate directly around the food rather than transferring heat across the oven. Using an analysis constructed by CEUE 91, direct-fire technology costs slightly less than $3,000 for a new oven, representing an incremental cost of $1,300 over a conventional oven.

2. Infrared Fryer. The efficiency of a standard fryer is about 45%. Several technologies have the potential to make the fryer significantly more efficient, including infrared, pulse convection, and pulse combustion fires. Of these, only infrared is produced and sold. The infrared fryer uses electromagnetic energy from the heat source to more directly heat the desired product. In the case of fryers, this is the oil. This improves the efficiency to about 75%. However, the price is about twice that of standard deep-fat fryers. The incremental cost of an infrared fryer over a standard fryer is about $1,300 and the estimated cost of a new infrared fryer is about $2,500.

3. Kitchen Range/Oven. In this case, convection ovens are a part of a range system that is a single integrated unit. These are typically somewhat smaller ovens and have a lower cost. The cost of this unit is about $1,000 with an incremental cost of about $800 over a standard range/oven combination.

4. Infrared Griddle. This uses the same infrared technology as the fryer and is somewhat less efficient, with efficiencies ranging from about 60% to 64%.

This represents a 20% to 25% improvement over standard griddles. The infrared griddle is about $2,900; the incremental cost for the infrared griddle over the standard griddle is slightly over $1,000.

5. Power Burner. This is an alternative burner design. The efficiency of the standard automatic atmospheric range burner is estimated to be about 45%. A power burner mixes the correct amount of air and fuel and is estimated to improve burner efficiency to about 60%. The power range burner provides higher efficiency cooking and probably provides additional benefits such as greater heat control. Currently power burners are produced and marketed by a handful of manufacturers. The price for these devices is probably higher than might otherwise be the case in a more competitive environment. Cost for the power range burners is about $2,500. The incremental cost of a range containing power range burners versus a standard range is about $800.

Each of these measures was evaluated for three separate populations: the retrofit, replacement, and new construction sectors. For the new and replacement sectors, the costs and savings were evaluated against a base case of the current standard. For the retrofit sector, we assume that the existing unit would not be replaced without intervention from the Energy Trust as an energy-saving measure. For this sector, the total cost of the unit was used and savings were measured against a base case of existing installed equipment.

Even in the retrofit sector, cooking measures tend to be attractive in almost all cases. When applied as replacement for new technologies, they fell well within our cost-effectiveness screen of $0.50/therm saved. After accounting for market constraints on new kitchen equipment for all the retrofit applications, we estimate that 18-25% of the existing equipment can be retrofitted. Furthermore, about half of these retrofits should be considered free-riders.

For the replacement market, this is a more difficult question. Our estimates assume that for most of these technologies, the replacement rate is approximately 5%. About half of the units that are replaced are in the retrofit population. As a result, only a small number of units are replaced. We also assumed a similar number for new construction, although the amount of churn in the restaurant business usually results in much of the equipment being recycled into other kitchens over the life of the equipment. These are fairly conservative assumptions and are further mitigated by the large tendency for free-ridership in this sector.

The overall savings from a program of this sort might actually be two to three times the estimates. The proper incentive structure might improve replacement rates and new construction rates beyond these levels. Tables 5.28 through 5.30 summarize the results of the program with the five pieces of equipment in the retrofit, replacement and new kitchen categories. The overall savings per year are about 6 million therms. Over the life of measures and the program, almost 80 million kTh could be saved. Careful program design might be able to improve the savings numbers by a substantial fraction although the tendency for kitchens to be based on productivity and work flow, as opposed to energy conservation, might make the amount of free-ridership large. In gas cooking programs operated between 1994 and 1999, typical free-ridership rates were between 50% - 60% for cooking measures.

Table 5.28 Cooking Appliance Measures in Retrofit Commercial Stock

Measure	Measure Cost ($/Unit)	Measure Savings (th/Unit)	Measure CSE ($/th)	Measure Life (yrs)	Annual Savings (Th)	Program Savings (kTh)
Direct Fired Convection Oven	2,988	1,143	0.18	20	1,545,041	38,360
Infrared Fryer	2,538	1,130	0.19	15	2,462,279	40,970
Convection Range/Oven	1,017	344	0.25	15	277,454	5,207
Infrared Griddle	2,880	458	0.42	20	347,578	8,453
Power Range Burner	2,571	249	0.87	15	289,982	4,809
Totals:					**4,922,334**	**97,799**

Table 5.29 Cooking Appliance Measures in Replacement Commercial Stock

Measure	Measure Cost ($/Unit)	Measure Savings (th/Unit)	Measure CSE ($/th)	Measure Life (yrs)	Annual Savings (Th)	Program Savings (kTh)
Direct Fired Convection Oven	1,338	1,152	0.08	20	75,717	1,968
Infrared Fryer	1,373	1,130	0.10	15	28,304	5,463
Convection Range/Oven	843	339	0.21	15	50,771	935
Infrared Griddle	1,048	458	0.15	20	38,620	939
Power Range Burner	870	249	0.29	15	65,091	1,080
Totals:					**258,503**	**10,385**

Table 5.30 Cooking Appliance Measures in New Commercial Stock

Measure	Measure Cost ($/Unit)	Measure Savings (th/Unit)	Measure CSE ($/th)	Measure Life (yrs)	Annual Savings (Th)	Program Savings (kTh)
Direct Fired Convection Oven	1,338	1,173	0.08	20	83,901	2,028
Infrared Fryer	1,373	1,133	0.10	15	169,554	2,789
Convection Range/Oven	843	349	0.20	15	19,983	360
Infrared Griddle	1,048	463	0.15	20	17,056	398
Power Range Burner	870	252	0.29	15	25,033	412
Totals:					**315,527**	**5,987**

5.6. Commercial Sector Conclusions and Recommendations

The evaluation of energy-efficiency and conservation measures in the commercial sector suggests that a substantial opportunity exists for both the technical potential for improved efficiency in use of natural gas and for the overall program potential for delivering this conservation. As shown in the previous sections, there are opportunities for efficiency improvements to the equipment and building shell, as well as domestic hot water, cooking and related process loads.

Table 5.31 shows the potential savings generated by this evaluation. It includes two separate evaluations of savings. The first ignores the cost-effectiveness of any particular measure. It assesses how much total potential might be available from standard practices that are more efficient than either the existing conditions or current codes and standards. Overall, this analysis calculated a savings of approximately 40 million therms annually at an investment cost of approximately $460 million. This represents about 16% of the total natural gas consumption for this sector. Much of this potential savings comes from measures that did not pass our CSE screen based on energy savings, especially from windows measures.

However, these measures provide non-gas savings benefits such as electric energy savings, aesthetics, customer value, etc. that may increase the overall value to both the utility and to the building occupants. Additionally, the actual investment in new windows to achieve savings might be dramatically lower than assumed here. When measures that did not pass our cost-effectiveness screen are excluded from the results, the total savings potential drops to approximately 11% and the cost drops to $168 million.

Table 5.31 Commercial Gas Savings by Measure Class

	All Measures		Cost effective	
End Use	**Annual Savings (kTh)**	**Program Cost ($)**	**Annual Savings (kTh)**	**Program Cost ($)**
Cooking	6	19,762,303	5	16,445,626
DHW	5,640	169,674,186	4,245	63,546,033
HVAC	13,586	141,606,706	6,521	25,925,626
Insulation	6,612	69,242,897	6,405	62,601,461
Windows	9,547	655,225,392	0	0
Totals:	**35,391**	**1,055,511,484**	**17,176**	**168,518,746**

For this analysis, we assumed that a program would last approximately 8 years and program costs would be spread over that period of time. These values are based on a technical potential analysis. This assumes that for the amount of money represented here, virtually all the potential savings in any particular sector or measure could be achieved during a period of 8-10 years. This, of course, is impractical. However, the program costs applied here are the full cost of the measures.

In reviewing the results of Table 5.31, it is apparent that the bulk of the savings is available from only a few classes of efficiency improvements. Approximately half of all the savings are from measures involving the upgrade of equipment efficiency to current best practices or highest standards. These measures extend through HVAC, domestic hot water and cooking end uses, and represent almost 50% of the savings identified in the table. The savings are divided about equally between improvements in building shells. These would, in turn, have a large impact on HVAC systems through the improvement in controls, operation, maintenance, etc. In the latter case, these are relatively low-cost measures that must be applied to the entire HVAC building stock in order to achieve the predicted savings.

Table 5.32 presents the same data, summarized by measure class. As shown, weatherization and equipment measures provide about the same amount of potential savings, but the cost of the envelope measures is about twice that of those related to equipment upgrades and replacements. Measures aimed at improving efficiency through commissioning and other O&M measures can provide about 16% of the total gas savings available in this sector.

Table 5.32 Commercial Gas Savings by Program Type

	All Measures		Cost effective	
End Use	**Annual Savings (kTh)**	**Program Cost ($)**	**Annual Savings (kTh)**	**Program Cost ($)**
Equipment	13,772	301,852,982	5,657	82,120,101
O&M	5,461	29,190,212	5,115	23,797,184
Weatherization	16,160	724,468,289	6,405	62,601,461
Totals:	**35,393**	**1,055,511,483**	**17,177**	**168,518,746**

From this analysis, it would appear that at least a major program component should be the development of equipment-efficiency standards along with rebates and incentives to apply the standards. This would apply to both new and existing gas-using equipment throughout the commercial sector.

Overall, it appears that substantial improvements could be made in the commercial use of gas, especially by reviewing and treating the older stock of equipment and buildings. The fact that natural gas has been very inexpensive for a long time has not provided incentive to building owners and occupants to upgrade their equipment. Even at current and projected gas prices there may not be enough incentive to convince gas consumers to implement efficiency measures. Nevertheless, a detailed review and investment in efficiency could pay dividends for both the state of Oregon and the individual gas consumers involved.

6. Residential Sector Resource Assessment Results

For the residential sector analysis, we examined six population sets: new and existing construction for the residential, multi-family and manufactured home populations. For the following discussion, measures were considered cost-effective if they passed the $.50/therm saved CSE screen described in Section 4. This is not meant to reflect the Energy Trust cost-effectiveness threshold, since they use a more detailed calculation methodology which takes into account a number of variables that are outside the scope of this project. Rather, this screen is meant to serve as the basis for recommending measures to the Energy Trust for their full cost/benefit treatment.

In the text, annual savings refer to the total reduction in therm use that can be anticipated for each unit. The total program savings is based on the technical potential and assumes that the entire eligible population is treated. Program savings are reported in thousands of therms (kTh). The formula is (Annual Savings * Measure Life * Population).

6.1. Residential Sector Characterization

To characterize the residential sector, we relied heavily on data supplied by Northwest Natural regarding customer counts, therm usage, growth rates and measure penetration. The total residential population was divided into the single family, multi-family and manufactured housing sectors using ratios from the 2000 Census, corrected where necessary using Northwest Natural population counts. For existing residential construction, the county-level gas-consuming population was extrapolated using ratios derived from the 2000 US Census applied to Northwest Natural population data. For new construction, growth rates were calculated based on Northwest Natural's Load Forecast filed in November, 2002. Conversions from electric to gas were not considered for this analysis.

Table 6.1: Northwest Natural Residential Population

	Population (N)				
	SF	Large MF (>5)	Manu Home	Other	Total
Benton	8,064	533	126	42	8,765
Clackamas	57,433	2,108	1,094	206	60,841
Clatsop	5,445	144	104	41	5,734
Columbia	7,541	88	271	80	7,980
Hood River	1,643	34	53	3	1,733
Lane	41,259	1,487	1,104	248	44,098
Lincoln	3,531	77	138	84	3,830
Linn	9,923	218	370	133	10,644
Marion	35,775	1,330	858	184	38,147
Multnomah	126,763	8,154	683	626	136,226
Polk	8,672	206	200	94	9,172
Wasco	686	13	35	11	745
Washington	79,308	5,083	739	210	85,340
Yamhill	8,454	181	265	66	8,966
Totals	**394,497**	**19,656**	**6,040**	**2,028**	**422,221**

Table 6.1 provides a summary of the population data for existing residential stock used in this analysis. Population estimates are for gas customers only. Table 6.2 summarizes the energy use for each building type.

Table 6.2: Northwest Natural Residential Energy Use

	Annual Therm Consumption			
	SF	Large MF (>5)	Manu Home	Total
Benton	6,587,961	118,548	83,210	6,789,719
Clackamas	46,922,434	468,964	724,475	48,115,873
Clatsop	4,448,402	32,012	68,663	4,549,077
Columbia	6,161,324	19,625	179,314	6,360,263
Hood River	1,341,923	7,652	34,802	1,384,377
Lane	33,708,726	330,776	731,081	34,770,583
Lincoln	2,884,827	17,074	91,718	2,993,619
Linn	8,106,968	48,508	245,409	8,400,885
Marion	29,227,767	295,966	568,739	30,092,472
Multnomah	103,565,371	1,814,209	452,815	105,832,395
Polk	7,084,616	45,776	132,535	7,262,927
Wasco	560,054	2,905	23,233	586,192
Washington	64,794,554	1,130,893	489,500	66,414,947
Yamhill	6,906,591	40,219	175,695	7,122,505
Totals	**322,301,518**	**4,373,127**	**4,001,189**	**330,675,834**

6.2. Single Family – Existing Construction

For existing single family construction, measures in the following end uses that passed the CSE screen were added to the baseline home in order of cost-effectiveness:

- Weatherization
- HVAC Systems
- Domestic Hot Water
- Windows

The major factors impacting the cost-effectiveness of these measures were the vintage of the home and the order in which the measures were performed. This was especially true for weatherization and HVAC system measures. For example, our cost-effectiveness screen was generally exceeded for a measure to install an efficient furnace in an average sized home that has previously received an insulation retrofit. Another example of a measures that exceeds the cost-effectiveness threshold is a weatherization retrofit in a home that has already received a duct sealing retrofit. Therefore, careful program design will be required to maximize the savings actually realized. For measures targeted to the retrofit sector, costs and savings are shown using the total resource cost methodology discussed in Section 4 unless otherwise noted. Costs and savings for the new construction and replacement sectors are incremental over the Oregon Energy Code.

For the most part, only measures with a cost-of-saved energy (CSE) below $.50/therm saved are included in the following tables. In some cases, more expensive measures are included as components of a package with an overall CSE below the screening threshold, or to document particular technologies of interest.

6.2.1. Weatherization Measures

Weatherization measures were considered for prototypes representing residential construction under each of the major energy code versions adopted in Oregon since 1975. Our findings indicate that the insulation levels required, under even the earliest energy code, provide enough benefit to render additional insulation measures too expensive to be good candidates for a weatherization program. However, in older stock (pre-1975), weatherization measures were both the most cost-effective and had the biggest impact on total natural gas savings (excluding windows). The total insulation package (attics, walls, and floors) provided an annual natural gas savings of 930 therms at a CSE of approximately $.17/therm saved.

The measures we analyzed and their applicability are presented in Table 6.3. For these measures, the candidate home must have no existing wall insulation, ceiling insulation of R-11 or less, and floor insulation of R-19 or less. All measures utilize blown-in or batt insulation to achieve the increased R-value. Attic insulation did not pass the CSE screen for levels above R-30; therefore, no R-38 measures were included in this table. For program purposes, we do not recommend including an R-38 attic insulation measure. Upgrading wall insulation beyond R-11 in older stock is problematic because structural framing practices common at that time would require rebuilding the entire wall to upgrade the insulation beyond that level.

Table 6.3: Weatherization: Cost-Effective Measures

Prototype	Wall	Floor	Attic
1985	R-11	R-30	R-30
1980	--	R-30	--
Pre-1975	--	--	--

The savings assume that insulation measures are applied preferentially to HVAC system measures. In practice, the Energy Trust may choose to promote efficient furnaces at times when furnaces fail. This is because the furnace contractor who visits the home may be an eager advocate of efficient furnaces, but not for insulation. Furnaces may be well-justified in larger homes with more load, or in other specific circumstances. The technical potential is adjusted to account for interactions between the weatherization measures and efficient furnace and duct measures.

6.2.2. Weatherization Results

Results for weatherization measures are shown in Table 6.4. Attic insulation provided the most significant savings with the lowest CSE, at approximately $.08/therm saved. Even if no other insulation measures were applied, an annual savings of 400 therms is available from attic insulation in older (pre-1975) building stock. Wall insulation was also very attractive, with a CSE of $.12/therm saved. Floor insulation was more expensive than the other weatherization measures, but still passed our cost-effectiveness screen at $.33/therm saved. Together, these measures provide a total program natural gas savings of almost 6 million kTh.

Table 6.4. Weatherization Measures in Retrofit Single-Family Stock

Measure	TRC Cost ($/Unit)	Annual Savings (therms)	Measure CSE ($/therm)	Measure Life (yrs.)	Technical Potential (Hhlds)	Program Savings (kTh)
Attics	786	407	0.08	45	78,443	1,436,678
Walls	984	348	0.12	45	176,496	2,763,928
Floors	1,400	175	0.33	45	222,931	1,755,580
Totals:	**3,170**	**930**	**N/A**	**N/A**	**477,870**	**5,956,186**

6.2.3. HVAC Measures

To review HVAC measures, we analyzed efficient furnaces separately from efficient duct systems. We also examined duct sealing independently from duct insulation. Simulation results indicate that the cost-effectiveness of HVAC measures was substantially impacted by the insulation levels assumed in the prototype (shown as “Wx” rows in table below) and by whether the furnace was installed before or after Performance Tested Comfort Systems (PTCS)-level duct sealing had been applied. Table 6.5 illustrates the range of savings available as these conditions are varied, assuming that the ducts are treated in accordance with the full PTCS duct sealing protocol. As can be seen, savings for homes that have been insulated are approximately half the savings available from untreated stock. Weights are based on the vintage ratios estimated for Northwest Natural’s service territory.

Table 6.5: HVAC and Weatherization Measure Interactions

Prototype	Cost	Weight	Weighted Cost	Savings	Weighted Svgs
PTCS Duct Retrofit Only (Efficiency=0.80, sealed ducts):					
75 R11	500	0.07	400	180	12
Wx	500	0.07	400	135	9
75 R0	500	0.27	399	252	68
Wx	500	0.27	399	165	44
80	500	0.18	399	137	24
85	500	0.15	399	81	12
Totals:		**1.00**	**399**		**169**
Furnace Retrofit (Efficiency=0.90, std. ducts):					
75 R11	900	0.07	899	134	9
Wx	900	0.07	899	70	5
75 R0	900	0.27	898	188	50
Wx	900	0.27	898	70	19
80	900	0.18	898	102	18
85	900	0.15	899	61	9
Totals:		**1.00**	**899**		**110**

6.2.4. HVAC Results

While performing duct sealing passed our cost-effectiveness screen in all cases, this was not the case for furnace upgrades; our CSE screen excluded this measure except in homes that have not previously received insulation upgrades. The analysis results for HVAC system measures are listed in Table 6.6. Costs are reported using the full cost methodology. Program savings have been adjusted to avoid double-counting between measures and are therefore additive.

We examined the impacts of upgrading the furnace to an AFUE rating of .9 both separately and combined with a duct sealing measure. The distribution efficiency associated with the duct sealing measure is .85. To account for interactions between measures, we assumed that 45% of homes receiving duct tests would not require any duct intervention (“dry holes”). Of the remaining homes, approximately 30% will require duct insulation while 40% will require duct sealing (these may or may not be the same homes).

The actual savings achievable in the field from duct sealing and duct insulation varies widely depending on the condition of the home to be treated. For this analysis, we assumed that duct insulation would be installed only in homes with reasonably well sealed ducts; either pre-existing or because a duct sealing retrofit was performed in conjunction with the insulation. Therefore, we assumed a distribution efficiency of .85 for the duct sealing measure and .88 for the duct insulation. The actual efficiency achieved in normal field conditions ranges from about .83 to about .86 for the duct sealing measure and from about .85 to about .9 for the duct insulation measure. The higher efficiencies indicate a level of sealing that is rarely achievable in retrofit situations.

The realized savings depend on the condition of the duct system prior to the measure installation. In addition, duct insulation became a code requirement in the first energy code implemented in Oregon in 1975. Therefore, the applicability of this measure is limited to a smaller pool of houses than the duct sealing measure. Our analysis assumptions may slightly overstate the savings from duct sealing and underestimate the savings from duct insulation; however, we believe the results most accurately estimate the actual field conditions. When these two measures are combined into a single program, the total savings accurately reflects anticipated program savings. The weighted costs associated with dry hole testing were spread across the other measures to calculate the total resource cost of the measures.

For furnace measures, we calculated the technical potential to be approximately 6,000 homes per year. This is consistent with the program achievements by Northwest Natural since 2000, although the number prior to that was less than 2,000 annually. This should not be considered free-ridership; rather, it suggests that the existing program should be maintained at its current level.

Table 6.6: HVAC Measures in Existing Single-Family Stock

Measure	TRC Cost ($/Hhld)	Annual Savings (therms)	Measure CSE ($/therm)	Measure Life (yrs.)	Technical Potential (Hhlds)	Program Savings (kTh)
Duct Seal Only	500	169	0.20	20	97,535	329,667
Furnace Retrofit	900	110	0.47	25	43,891	120,699
Duct Insulation	200	35	0.38	20	65,369	45,758
Totals:	**----**	**314**	**N/A**	**N/A**	**206,795**	**496,124**

6.2.5. Domestic Hot Water (DHW) Measures

In existing single family construction, the most attractive measure impacting domestic hot water is to upgrade the existing water heater with an energy efficient version with an Efficiency Factor (EF) of .61. This measure provides a CSE of $.50/therm saved. However, the measure with the most potential for total therm savings is a Polaris®-type combination water heater and furnace unit. This combination minimizes standby losses on the hot water side, and maximizes the furnace efficiency through a design which utilizes an efficient modulating burner and a heat exchanger, along with a well-insulated tank with a minimally-sized air intake and other innovative features. In retrofit situations, the existing duct system can be used. The analysis results in Table 6.8 include the cost of sealing the ducts as part of the combo unit installation.

Assuming that 10% of the homes for which this would be a suitable measure are actually converted, the total life cycle gas savings would be more than 29,500 kTh. The major drawback to this measure is that homeowners rarely consider replacing either the furnace or the hot water heater until the unit fails, so the opportunity to replace both units at once must be considered a market transformation effort. The significant savings associated with the hot water tank provide an attractive payback, however; providing an opportunity to market this option to homeowners seeking the benefits of a more efficient furnace under the existing Northwest Natural program. Table 6.7 shows the savings associated with the hot water versus the furnace systems for the combo unit. Savings were weighted to reflect the significance of each stratum to the total. (See prototype discussion in Section 4.4.1).

Table 6.7. Combo Polaris®-Type Unit: Hot Water v. Furnace Savings

Prototype	Furnace (th/yr)		Domestic Hot Water (th/yr)		Total (th/yr)	
	Savings	Weighted	Savings	Weighted	Savings	Weighted
75 R11	271	18	82	5	353	24
Wx	157	11	82	5	239	16
75 R0	362	97	82	22	444	119
Wx	195	52	82	22	277	74
80	207	36	82	14	289	51
85	124	19	82	13	206	32
Totals:		**234**		**82**		**316**

The other two measures we examined were the Polaris®-type hot water unit (without a furnace function) and point-source "instahot"-type units. Both technologies rely on reduced standby losses to produce gas savings, have similar measure lives and first costs, and provide similar savings. For this analysis, we assumed an applicability factor of 10% for each of the two measures.

6.2.6. Domestic Hot Water Results

The analysis results for domestic hot water measures are shown in Table 6.8. Costs are incremental over a base unit with an EF of .55. The technical potential for program savings was adjusted to avoid double-counting among measures and are additive.

Table 6.8: Domestic Hot Water Measures in Existing Single-Family Stock

Measure	Incr Cost ($/Unit)	Annual Svgs (th)	Measure CSE ($/th)	Measure Life (yrs.)	Technical Potential (Hhlds)	Program Savings (kTh)
High Efficiency Water Heater (EF=.61)	60	20	0.30	12	136,549	32,772
Tank w/ Burner & Exchanger (Polaris®-type) (EF=.84)	700	76	0.62	20	19,507	29,651
Tankless Heater (Point Source) (EF=.88)	750	82	0.61	20	19,507	31,991
Combo Boiler (air) (EF=.84/AFUE=.94)	3,850	316	0.82	20	19,507	123,284
Totals:	**---**	**494**	**N/A**	**N/A**	**195,070**	**217,698**

6.2.7. Window Measures

A window measure to upgrade existing stock (approximately U=1.0) to U=.34 just passed our CSE screen at $.47/therm saved using a total resource cost. We also applied the same measure (on an incremental basis) to a base case of U=.40 to reflect the replacement market. However, it must be noted that this measure presents unique analysis difficulties. Both the costs and savings associated with this measure are highly variable when applied to single-family homes, primarily because there are two manufacturing techniques used to achieve Class 34 windows. Both costs and savings vary significantly between the two procedures. These two methods are:

1. Apply an additional low-ε coating to a Class 40 base. This has the effect of decreasing the shading coefficient, which has a small negative impact on gas heat. The cost of this technique is approximately $.32 per square foot of glass.

2. Add an argon fill to a Class 40 base. This technique has no impact on the shading coefficient. However, it costs about $1.00 per square foot of glass.

For this analysis, we assumed that half of the homes would receive windows treated with an additional low-ε coating and the remainder would receive windows with argon.

6.2.8. Window Results

The results of our Class 34 window analysis are provided in Table 6.9. The costs presented use the TRC method described in Section 4.

Table 6.9: Window Measures in Existing Single-Family Stock

Measure	Cost ($/Hhld)	Annual Svgs (th)	Measure CSE ($/th)	Measure Life (yrs.)	Technical Potential (Hhlds)	Program Savings (kTh)
Class 34-TRC	3,751	202	0.95	30	231,157	1,400,813
Class 34-Incr	215	31	0.35	30	1,219/yr	1,134
Totals:	**3,966**	**233**	**--**	**N/A**	**--**	**1,401,947**

6.2.9. Air Sealing Measures and Results

Air sealing was reviewed as a stand-alone measure. The assumption is that a blower door screening would be done and the home would have a base of 12 air changes per hour at 50 Pascals (ACH_{50}). There are two measures considered here. The first measure includes weatherstripping around doors and windows, caulking at window and door frames, and outlet gaskets. The second measure seeks to further reduce air leakage to 8 ACH_{50}, we assumed the use of a blower door to identify leaks, then above measures applied in all needed (and accessible) locations. The results of our analysis, which indicate that this is not a cost-effective measure, are shown in Table 6.10. It should be pointed out that while the measure as analyzed is not cost effective for the average home, if the home has a base case infiltration rate high than 12 ACH_{50} then at least the combination of the two measures is cost effective. The program to do air sealing would, however, have to be designed to screen for these cases.

Table 6.10: Air Measures in Existing Single-Family Stock

Measure	TRC Cost ($/Hhld)	Annual Svgs (th)	Measure CSE ($/th)	Measure Life (yrs.)	Technical Potential (Hhlds)	Program Savings (kTh)
Air Sealing to 10 ACH_{50}	350	38	0.77	15	58,521	33,445
Air Sealing to 8 ACH_{50}	250	38	0.55	15	102,411	58,528
Totals:	**600**	**76**	**N/A**	**N/A**	**160,932**	**91,973**

6.2.10. Appliance Measures and Results

The appliance measures we analyzed are efficient washers and efficient gas dryers. The washers we analyzed are E-Star models with front loading capability, horizontal axis rotation, and high speed spin cycles. Dryers were dropped from further analysis because the cost of efficient models falls within the same range as inefficient models. Therefore, the actual incremental cost is zero. Also, dryer efficiency is achieved through providing less energy-intensive cycle options for the consumer's use (i.e., permanent press cool down cycle, moisture-sensing cycle). Therefore, savings calculations must make assumptions about consumer usage patterns that reduce the confidence interval to unacceptable levels. The results of our analysis are shown in Table 6.11.

Table 6.11: Appliance Measures in Existing Single-Family Stock

Measure	Cost ($/Unit)	Annual Svgs (th)	Measure CSE ($/th)	Measure Life (yrs.)	Technical Potential (Hhlds)	Program Savings (kTh)
H Axis Washer - Replace	180	17	1.03	13	13,655	2,929

6.3. Single Family – New Construction

The Oregon residential energy code is one of the most stringent in the region, which limits the opportunities for Trust intervention in new construction in this sector. For this group, some HVAC system measures and appliance measures passed the $.50/therm saved CSE screen. We also calculated a measure to upgrade Class 40 windows to Class 34, which provided more than 1,380,000 in total program gas savings at a CSE of $.35/therm saved.

6.3.1. HVAC Measures

The most cost-effective HVAC measure for new construction was the installation of an efficient furnace, with a CSE of $0.10/therm saved. This measure alone could provide almost 5,000 kTh in savings through the life of the program. Another attractive measure is the Polaris®-type combination hot water / furnace unit (as described in section 6.2.5), with a CSE of approximately $.39/therm saved for a unit with a standard ducted air distribution system. For new construction, this unit can utilize either an air or a water distribution loop. For our analysis, we assumed that half of the units installed would use a standard duct system for heat distribution while the remainder would use a water loop system with radiators. The cost of the distribution system was not included since that would be part of the home design. The costs and savings are incremental over a code-level furnace and hot water heater.

Aside from the combo unit, the only HVAC measure we analyzed for the single-family new construction sector that passed our cost-effectiveness screen is duct commissioning. The CSE for this measure is $.45/therm saved; with a total program savings of 8,000 kTh.

We also reviewed a number of less common equipment options; however, none passed our CSE screen. We analyzed an air-to-air heat exchanger measure, in which savings accrue to the gas furnace system. This measure was more expensive than anticipated, with a CSE of $1.20/therm saved. Our initial estimates for the other equipment options, including gas heat pumps and a measure combining solar preheat with an efficient gas furnace, indicate that these measures cost well over $1 per therm saved. Therefore, further analysis was not conducted on these measures.

6.3.2. HVAC Results

Analysis results for new single-family HVAC measures are shown in Table 6.12. Costs and savings are incremental over a code base. Savings have been adjusted to prevent measure overlap and are additive at the program level.

Table 6.12: HVAC Measures in New Single-Family Stock

Measure	Cost ($/Unit)	Annual Svgs (th)	Measure CSE ($/th)	Measure Life (yrs.)	Technical Potential (Hhlds)	Program Savings (kTh)
Combo Boiler (air)	1,200	207	0.39	20	2,692	11,144
Combo Boiler (water)	700	207	0.23	20	2,692	11,144
Heat Exchanger	1,000	70	1.20	15	1,794	1,884
Duct Commissioning	300	45	0.45	20	8,972	8,075
Efficient Furnace	200	110	0.10	25	1,794	4,935
Gas Heat Pump	6,500	190	2.87	15	7,178	20,457
Totals:	**---**	**829**	**N/A**	**19**	**25,122**	**57,639**

6.3.3. Window Measures

To evaluate Class 34 windows for the new single-family sector, we generated incremental costs and savings over a Class 40 base. On that basis, windows provide an attractive program option with a CSE of $.35/therm saved. As discussed in Section 6.2.7, there are two technologies that are primarily used by window manufacturers to achieve a window with a U-value of .34. For this analysis, we assumed that half of the installed windows would use the low-ε coating method and the remainder would use the argon method.

6.3.4. Window Results

The results of our Class 34 window analysis are provided in Table 6.13. The costs and savings are incremental over a Code base (U=.4).

Table 6.13: Window Measures in New Single-Family Stock

Measure	Incr Cost ($/Unit)	Annual Svgs (th)	Measure CSE ($/th)	Measure Life (yrs.)	Technical Potential (Hhlds)	Program Savings (kTh)
Class 34	215	31	0.35	30	55,650	51,755

6.3.5. Appliance Measures and Results

The appliance measures we analyzed are efficient washers and efficient gas dryers. The washers we analyzed are E-Star models with front loading capability, horizontal axis rotation, and high speed spin cycles. Dryers were dropped from further analysis because the cost of efficient models falls within the same range as inefficient models. Therefore, the actual incremental cost is zero. Also, dryer efficiency is achieved through providing less energy-intensive cycle options for the consumer's use (i.e., permanent press cool down cycle, moisture-sensing cycle). Therefore, savings calculations must make assumptions about consumer usage patterns that reduce the confidence interval to unacceptable levels. The results of our analysis are shown in Table 6.14.

Table 6.14: Appliance Measures in New Single-Family Stock

Measure	Cost ($/Unit)	Annual Svgs (th)	Measure CSE ($/th)	Measure Life (yrs.)	Technical Potential (Hhlds)	Program Savings (kTh)
H Axis Washer -New	180	17	1.03	13	1,108	238

6.3.6. Single Family: Conclusions and Program Recommendations

Window measures are the most attractive program option for single-family new construction, providing almost 52,000 kTh in life cycle natural gas savings. Window upgrades are also attractive in the existing home market, both in retrofit and replacement situations.

In the gas-heated stock, much less effort has been expended by utilities on weatherization programs than comparable electrical utilities have conducted, resulting in very low saturation levels for most measures. However, efficient furnaces have been installed at a rate of about 6,000 per year by Northwest Natural since 2000. The level prior to that was about 2,000 per year. About a third of these units have been conversions and the rest are new construction and replacement units.

When utilizing the results of this study for program design, care must be taken to consider the interaction of various types of measures when calculating anticipated savings. This is particularly true for the interaction between retrofit measures involving the envelope and those involving the heating system. Because both measure classes substantially reduce the overall building energy use, the order in which the measures are applied to a particular house have a substantial impact on the savings that can be anticipated for that measure. For example, if a pre-1975 home is weatherized with a wall, floor and attic insulation package, the savings that can be anticipated from a furnace upgrade are reduced to 70 therms per year from the 188 therms per year that could be anticipated if that same house had not received an insulation retrofit. Table 6.15 illustrates the changes in overall building heat loss rate (UA) as these two measure classes interact. As shown, the available energy savings substantially decrease as energy code base insulation levels rise.

Thus, one of the largest uncertainties in this analysis regards the level of insulation in the base case. This resource assessment estimates that the majority of older homes have R-0 in the attic. If this proves not to be the case, available gas savings will be somewhat less.

Table 6.15: HVAC and Weatherization Measure Impacts on Building UA

		Base		Efficient Ducts/Furnace with base insulation		Efficient Ducts/Furnace with cost-effective insulation pkg.	
Prototype	**Description**	**Bldg. UA**	**Therms**	**Bldg. UA**	**Therms**	**Bldg. UA**	**Therms**
75 R-0	1350 sf; R-0 attic	1032.8	1574	1070.3	1249	502.6	417
75 R-11	1351 sf; R-11 attic	833.1	1180	833.1	894	502.6	417
80	1800 sf	705.2	898	705.2	681	571.6	491
85	1800 sf	510.9	538	510.9	407	--	--
95 (new)	2200 sf	466.2	449	416.7	275	--	--
Weighted Averages:		**731.2**	**972.3**	**726.7**	**731.5**	**517.5**	**433.0**

This impact is not linear; measures applied first have a disproportionately higher impact than those that follow. Figure 6.1 illustrates the impact of insulation levels on the savings available from the same HVAC measures.

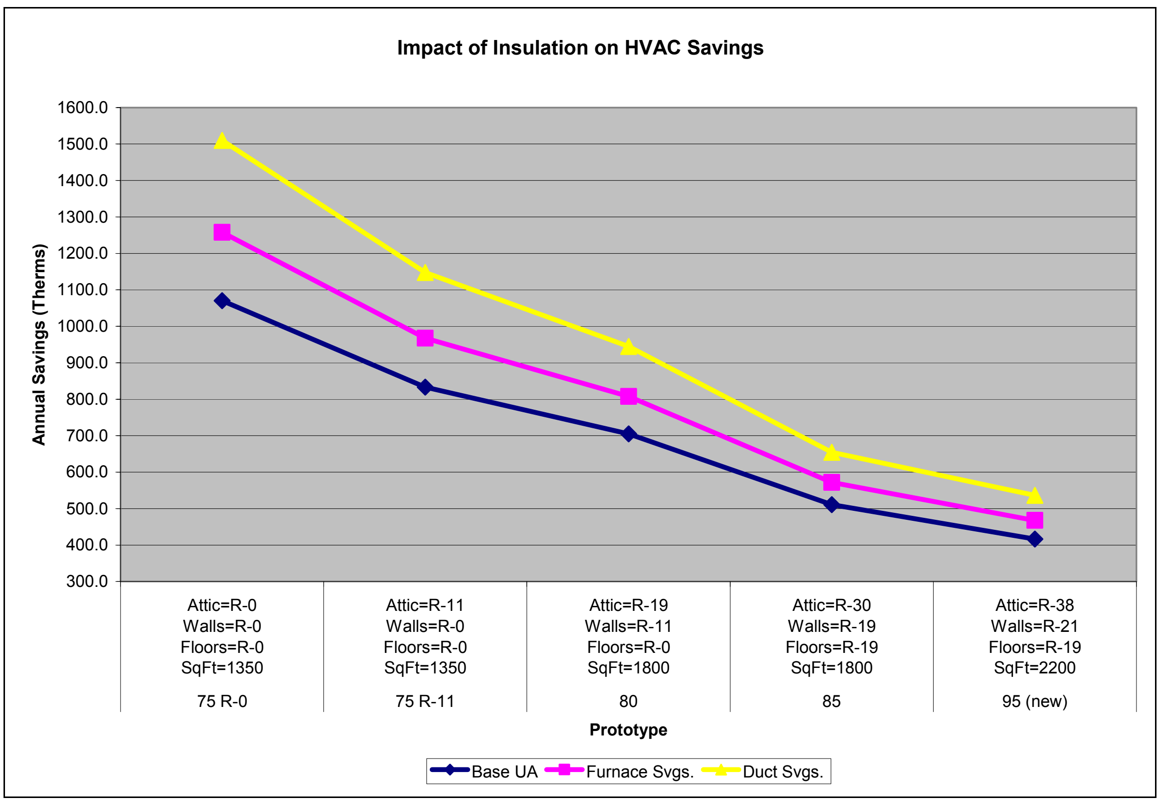


Figure 6.1. Measure Impacts on Existing Single-Family Home Therm Usage.

Duct sealing also passed our cost-effectiveness screen in all existing vintage bands. Insulation remains the most attractive measure for older building stock with R-0 components. Furnaces have a large impact in uninsulated homes, but do not always pass our screen in more efficient housing stock. Therefore, insulation and duct retrofit measures fit together well into one program, as do furnaces and ducts. Including both furnace and weatherization measures in one program, however, can increase the administrative overhead of the program while actually minimizing the realized savings.

Newer technologies have substantially improved the efficiency of domestic hot water systems. Replacing standard hot water tanks with more efficient models can provide about 41,000 kTh of saved natural gas in total life cycle savings at a CSE of $0.50/therm saved. Saturation of this technology remains low in the existing sector. Extremely efficient water heater options include units with modulating burners and heat exchangers (Polaris®-type) and point-source tankless units ("instahots"). Both of these technologies are cost-effective and provide substantial savings. The Polaris®-type units can save about 76 therms per year, and the point source units save about 82 therms annually.

An emerging technology that warrants special mention is the Polaris®-type combo water heater/furnace. This technology is 20 years old, but new materials and technologies such as modulating burners have greatly increased the reliability and longevity of the equipment and its efficiency. The combo unit provides substantial savings in both the domestic hot water and furnace systems, particularly in retrofit situations. In new construction, this technology may be successful with lower levels of intervention in the marketplace. For the existing housing sector, however, the Energy Trust can have a significant impact on increasing the market penetration of this equipment by offsetting the cost of replacing the hot water tank to a homeowner in the market for a new furnace system.

6.4. Multi Family – Existing and New Construction

The multi-family sector provides a unique analysis situation. For building-wide measures (such as central heating and hot water systems), this sector was analyzed using costs and savings developed for relevant building types in the commercial sector. For measures impacting individual units (such as weatherization and windows) and small buildings with unit heating, a residential-type analysis methodology was adopted. For retrofit construction, we assumed the total cost of the measure, while in new and replacement construction, we calculated costs and savings on an incremental basis over the energy code. Savings for most measures were calculated using simulations based on a whole building prototype with 16 1200-sf units (see Section 4.4.1).

Similar to the manufactured housing sector, the major difficulty in generating natural gas savings through conservation programs aimed at multi-family buildings is the limited applicability. Only approximately 22,000 units are supplied by gas in the Northwest Natural service territory. Of these, only about 5,000 have central heating systems. In addition, about 10,000 of these units have gas hot water service with electric heat. Therefore, even cost-effective measures with a large impact on the energy use of individual buildings are unlikely to generate substantial program savings.

For the retrofit sector, the measures which passed our CSE screen that have the most impact on total savings involve controls -- hot water distribution and flow controls, and HVAC zone and loop controls for centrally-heated buildings offer total life cycle savings of about 4,200 kTh. The replacement of existing windows with Class 34 units provides the most gas savings (more than 41,000 kTh). However, this measure is expensive when only energy benefits are considered at $1.90/therm saved when the TRC cost of approximately $8.25 per square foot of glass is used.

6.4.1. Weatherization Measures

To evaluate weatherization measures in this sector, we separately examined wall, attic and floor insulation against a whole building prototype. As in the single-family sector, these measures are only applicable to older, unweatherized stock. (typically built prior to 1975). Taken as a whole, the CSE for a program including all three measures is $.28/therm saved and the total program savings is approximately 8,200 kTh.

6.4.2. Weatherization Results

The results of our analysis of weatherization measures are presented in Table 6.16 (for each unit within the building). The costs and savings shown are calculated compared to the existing conditions; the savings are additive.

Table 6.16: Weatherization Measures in Existing Multi-Family Stock

Measure	Cost ($/Unit)	Annual Savings (th)	Measure CSE ($/th)	Measure Life (yrs.)	Technical Potential (Hhlds)	Program Savings (kTh)
Attics	176	22	0.33	45	1,527	1,477
Floors	307	34	0.36	45	2,443	3,778
Walls	392	109	0.15	45	611	2,993
Totals:	**875**	**165**	**N/A**	**45**	**4,581**	**8,248**

6.4.3. New and Existing Multi-Family HVAC Measures

Boiler upgrades to high efficiency ("near condensing") or condensing models were both attractive options when analyzed for the replacement market. The high efficiency boilers achieve combustion efficiencies in excess of 80% through the use of power or induced draft burners and heat exchange processes. Condensing flue or pulse technology can achieve seasonal efficiencies up to 94%. These boilers are steel or cast aluminum with ceramic burners and microprocessor controls that maximize combustion efficiencies. They exhaust at a temperature low enough to condense the latent heat out of the exhaust into the heat exchanger, thereby increasing the efficiency by approximately 5 to 10 percent.

In this case, the question is the cost/benefit impact of upgrading the replacement boiler with a model that is more efficient than the energy code requires. Boilers are typically only replaced at breakdown rather than as part of a retrofit undertaken specifically for energy savings. Therefore, incremental costs over a code base were used. Condensing models are about 45% more expensive per therm saved, with a CSE of about $.29 versus $.16 for a near-condensing boiler, but save about twice as much natural gas overall (440 MMBtu versus 220 MMBtu by year 2011). Upgrading central furnaces to more efficient models was an expensive option, at a CSE of $.80/therm saved.

Central heating system controls provide an attractive program measure. Modest savings are available from upgrading the efficiency of the existing unit through the addition of a power burner and vent damper in conjunction with a standard tune-up. This measure assumes the tune up is performed in accordance with Minneapolis Energy Office protocol. This work can include de-rating the burner, adjusting the secondary air, adding flue restrictors, cleaning the fire-side of the heat exchanger, cleaning the water side, or installing turbulators. Other modifications may include up-rating the burner to reduce oxygen or de-rating the burner to reduce stack temperature. In gas systems, excess air and stack temperatures are often within reasonable ranges, so the technical potential for this measure is limited. Combining this measure with the vent damper and power burner measures increases both applicability and cost effectiveness, and was assumed for this analysis. Together, these three measures provide about 19 kTh of life cycle gas savings at a weighted combined CSE of $.31/therm saved.

Separately, we examined a measure to optimize zone and loop controls. This measure includes any combination of temperature reset, optimized circulation controls, valve and steam trap maintenance, and unit thermostats that are deemed necessary for the specific system by the field technician. Based on the commercial sector results, we were optimistic that this measure would be cost-effective. However, the CSE is $1.12/therm saved, which is substantially higher than the screen of $.50/therm we are using for this analysis. Savings were not significant at 2.3 kTh for the total program if all potential candidates are treated. This measure could be cost-effective in certain conditions, but this is not a generally applicable measure. Heat pump loops with large area of building and a diverse load (such as mixed use commercial buildings) are the only practical candidates.

6.4.4. New and Existing Multi-Family HVAC Results

The results of our multi-family analysis are shown below in Tables 6.17a through 6.17c. The equipment measures for existing construction are targeted to a replacement market and were calculated using incremental cost and savings over an energy code base, while the control measures are based on a retrofit population and costs were generated considering full cost and savings. The technical potential within each table has been adjusted to avoid double-counting between measures; therefore, savings are additive.

Table 6.17a: HVAC Equipment Measures in Existing Multi-Family Stock

Measure	Incr Cost ($/Unit)	Annual Savings (th)	Measure CSE ($/th)	Measure Life (yrs.)	Technical Potential (Hhlds)	Program Savings (kTh)
Condensing Boiler	570	60	0.64	20	74	89
High Efficiency Boiler	160	30	0.36	20	74	44
High Efficiency Furnace	770	40	1.11	25	74	74
Totals:	**1,500**	**130**	**N/A**	**N/A**	**222**	**207**

Table 6.17b: HVAC Control Measures in Existing Multi-Family Stock

Measure	TRC Cost ($/Unit)	Annual Savings (th)	Measure CSE ($/th)	Measure Life (yrs.)	Technical Potential (Hhlds)	Program Savings (kTh)
Boiler Tune-up	10	20	0.11	5	33	3
Power Burner	180	20	0.90	12	33	8
Vent Damper	60	20	0.30	12	33	8
Sub-Total	**250**	**60**	**N/A**	**N/A**	**99**	**19**
Zone / Loop Controls	630	47	1.12	15	33	23
Totals:	**880**	**107**	**N/A**	**N/A**	**132**	**42**

Table 6.17c: HVAC Equipment Measures in New Multi-Family Stock

Measure	Incr Cost ($/Unit)	Annual Savings (th)	Measure CSE ($/th)	Measure Life (yrs.)	Technical Potential (Hhlds)	Program Savings (kTh)
Condensing Boiler	570	60	0.64	20	16	20
High Efficiency Boiler	160	30	0.36	20	16	10
High Efficiency Furnace	770	40	1.11	25	16	16
Totals:	**1500**	**130**	**N/A**	**N/A**	**48**	**46**

6.4.5. New and Existing Multi-Family Domestic Hot Water Measures

Most hot water system replacement measures in the multi-family sector did not pass the CSE screen of $.50/therm saved. Condensing boilers used for hot water had a CSE of $.61/therm saved, while near-condensing high efficiency boilers had a CSE of $.69/therm saved. Therefore, no equipment measures are recommended for this group.

We evaluated several hot water control measures for the retrofit multi-family sector. A measure to limit distribution by installing an electronic controller to turn off the boiler and circulation pump was not attractive at a CSE of $1.57/therm saved. However, water pipe insulation was attractive at a CSE of $.10/therm saved and provided a total program gas savings of more than 1,800 kTh. About the same total gas savings (1,700 kTh) can be achieved through a flow control program. For this analysis, we assumed that flow would be reduced from 3.4 gallons per minute (GPM) to 2.0 GPM through some combination of shower heads (75%) and faucet aerators/flow restrictors (25%). We assumed that flow regulators would be installed wherever appropriate and that approximately 20% of the market had already been treated. The CSE for this measure is an attractive $.07/therm saved.

6.4.6. New and Existing Multi-Family Domestic Hot Water Results

The results of our analysis for hot water measures in the multi-family sector are presented in Tables 6.18a and 6.18b. Costs and savings are additive for the group of commissioning measures.

Table 6.18a. Hot Water Measures in Existing Multi-Family Stock

Measure	Cost ($/Hhld)	Annual Svgs (th)	Measure CSE ($/th)	Measure Life (yrs.)	Technical Potential (Hhlds)	Program Savings (kTh)
Distribution Controls	150	8	1.57	15	6,106	733
Flow Control	17	35	0.07	8	6,106	1,710
Pipe Insulation	25	20	0.10	15	6,106	1,832
Condensing Boiler	700	35	1.34	20	448	314
High Efficiency Boiler	569	25	1.53	20	448	224
Totals:	**1,461**	**123**	**N/A**	**N/A**	**1,118**	**4,813**

Table 6.18b. Hot Water Measures in New Multi-Family Stock

Measure	Cost ($/Hhld)	Annual Svgs (th)	Measure CSE ($/th)	Measure Life (yrs.)	Technical Potential (Hhlds)	Program Savings (kTh)
Condensing Boiler	700	35	1.34	20	197	138
High Efficiency Boiler	569	25	1.53	20	197	98
Totals:	**1,269**	**60**	**N/A**	**N/A**	**394**	**236**

6.4.7. Window Measures and Results

We analyzed upgrading windows for the existing stock (from Class 70 or Class 100 to Class 34) using the same technological assumptions as discussed in Section 6.2.7. As with the other sectors, this measure was expensive at a CSE of $1.29. Market research conducted by the Alliance indicates that windows are rarely replaced in this sector in the absence of some incentive program, therefore this measure was considered a retrofit measure primarily undertaken for energy savings. The total gas savings available are substantial if the costs are shared between the building owner and the Energy Trust. Table 6.19 provides the results of our window analysis for this sector.

To be effective, a program design for windows in this sector should be aimed only at influencing the selection of Class 34 windows versus the standard Class 40 option. This assumes that the homeowner is willing to pay for the additional benefits of new windows, including increased home value and more comfortable quarters. To aid the Energy Trust in determining the feasibility of conducting a program in the multi-family sector for this measure, we calculated the maximum amount the Energy Trust could spend to achieve the CSE screening goal of $.50/therm saved. The break-even point is $1.25 per square foot of glass. These results are for the Trust's information only and are not included in any of the tables in this report to avoid skewing additive savings columns.

Table 6.19. Window Measures in Existing Multi-Family Stock

Measure	Cost ($/Unit)	Annual Svgs (th)	Measure CSE ($/th)	Measure Life (yrs.)	Technical Potential (Hhlds)	Program Savings (kTh)
Windows: U = .34	1,725	68.25	1.29	30	20,158	41,274

For the new multi-family measure, we analyzed upgrading Class 40 windows (energy code base) to Class 34. This measure is not attractive at $1.22/therm saved, but the entire sector is quite small (about 500 units annually). Even with a 90% applicability rate, the total program gas savings is only about 450 kTh. The results of our window analysis are presented in Table 6.20.

Table 6.20. Window Measures in New Multi-Family Stock

Measure	Cost ($/Unit)	Annual Svgs (th)	Measure CSE ($/th)	Measure Life (yrs.)	Technical Potential (Hhlds)	Program Savings (kTh)
Windows (U=.34)	83	3.44	1.22	30	4,432	457

6.4.8. Multi-Family: Conclusions and Program Recommendations

There are a number of measures available for the existing multi-family stock that passed our CSE screen, including HVAC, hot water and weatherization measures. However, the small population for the HVAC and hot water measures significantly limits the total gas savings that can be anticipated from a program targeted to this group. Weatherization and hot water control remain the most cost-effective and easily implemented program options.

For the new construction sector, boiler upgrades are attractive, but provide less than 30 kTh of program gas savings with 100% participation. The technical potential (16 boilers) for the sector may be too small to support a program with significant overhead expenses and cannot yield significant gas savings for the Trust.

6.5. Manufactured Homes – Existing and New Construction

The most important factor to consider when planning for reductions in gas usage in the manufactured home sector is the extremely limited technical potential. There are only approximately 6,000 manufactured homes using natural gas in the service territory, with less than 140 new homes sited each year. Of these, about half were built to Manufactured Housing Acquisition Program (MAP) or Super Good Cents (SGC) standards and are therefore not good candidates for any gas conservation programs, including window upgrades (base is U=.38). Construction practices in the manufactured home sector also inhibit insulation upgrades. However, some weatherization in the new construction sector and HVAC measures did pass our CSE screen of $.50/therm saved.

For the retrofit sector, costs and savings are calculated compared to the existing dwelling. New and replacement measures are calculated using incremental costs and savings over an Oregon energy code base case.

6.5.1. HVAC Measures and Results

For existing construction, only two measures passed our CSE screen. Furnace upgrades to an AFUE (Average Fuel Use Efficiency is a standard rating for residential combustion efficiency meant to capture the seasonal performance of heating equipment) of .80. Since manufactured homes are regulated under a separate federal standard they are permitted to install furnaces as low as .75 AFUE and prior to 1994 the standard was as low as .72. These upgrades at the time of replacement have a CSE of $.18/therm saved and duct sealing targeted to the retrofit sector has a CSE of $.15/therm saved. It should be pointed out that gas heating in the Oregon manufactured home sector is extremely rare account for less than 5% of the manufactured homes sited and much less that 1% of the gas heated home targeted by this assessment.

The technical potential for upgrading furnaces at replacement is extremely limited (approximately 7 homes annually), so the total program savings is slightly more than 125 kTh. The PTCS duct sealing measure is targeted to the retrofit sector and has a technical potential of about 340 homes per year. With a CSE of $.15/therm saved, the total program gas savings could be anticipated from this measure is about 8,750 kTh. Table 6.21 presents these results. The technical potential for these two measures are not comparable; therefore, the savings are additive.

Table 6.21. HVAC Measures in Existing Manufactured Home Stock

Measure	Cost ($/Unit)	Cost Basis	Annual Svgs (th)	Measure CSE ($/th)	Measure Life (yrs.)	Technical Potential (Hhlds)	Program Savings (kTh)
Duct Sealing	350	TRC	161	0.15	20	2,718	8,751
Efficient Furnace	500	Incr	206	0.14	25	34	175
Totals:	**850**		**367**	**N/A**	**N/A**	**2,752**	**8,926**

For new construction, furnace upgrades to an AFUE of .9 from a code base have a CSE of $.14/therm saved. A duct commissioning measure (similar to the duct sealing measure aimed at retrofit construction) has a CSE of $.045/therm saved.

As in the existing manufactured housing sector, the technical potential limits the total gas savings that can be anticipated from a program based on furnace and duct measures in new homes even though the cost/benefit analysis is favorable for any particular home. Administrative costs and program overhead for a program as limited as the gas-served manufactured home market may negate the attractiveness of the CSE screening analysis. The results of our analysis for these two measures are shown in Table 6.22. Costs and savings shown are incremental over an Oregon Energy Code base. Savings are additive.

Table 6.22. HVAC Measures in New Manufactured Home Stock

Measure	Cost ($/Unit)	Annual Svgs (th)	Measure CSE ($/th)	Measure Life (yrs.)	Technical Potential (Hhlds)	Program Savings (kTh)
Duct Commissioning	350	52	0.45	20	549	571
Efficient Furnace	500	260	0.11	25	69	446
Totals:	**850**	**312**	**N/A**	**N/A**	**618**	**1,017**

6.5.2. Window Measures and Results

As discussed in Section 6.2.7, we evaluated a measure to upgrade windows in existing manufactured homes to Class 34 assuming that equal numbers of homes were treated with the low-ε and argon fill technologies. The results of this analysis are presented in Table 6.23. The CSE for this measure did not meet our cost-effectiveness screen at $1.57/therm saved, but windows represent the sector's most significant total program savings available at approximately 8,500 kTh. Therefore, as in the multi-family sector, we calculated the incremental cost required to achieve a CSE of $.50, which is approximately $5 per square foot of glass. This estimate is not included in the tables in this report so that the total savings numbers are not distorted.

Table 6.23. Window Measures in Existing Manufactured Home Stock

Measure	TRC Cost ($/Unit)	Annual Svgs (th)	Measure CSE ($/th)	Measure Life (yrs.)	Technical Potential (Hhlds)	Program Savings kTh(kTh)
Class 34	2,914	95	1.57	30	3,020	8,588
Doors (U=.19)	280	10	1.46	30	3,020	888
Totals:	**3,194**	**105**	**N/A**	**N/A**	**6,040**	**9,476**

6.5.3. Weatherization Measures

In manufactured homes that are not built to SGC standards, opportunities exist to upgrade the insulation levels to SGC levels at an attractive cost of saved energy. For this set of measures, the insulation levels in the attic would be raised from R-30 to R-38, in the walls from R-19 to R-21, and floor insulation would increase from R-22 to R-33.

6.5.4. Weatherization Results

Insulating floors in new manufactured homes passed our CSE screen at $.03/therm saved and provided the bulk of insulation-derived savings at 228 therms annually. Costs and savings are incremental over an Oregon Energy Code base, and are additive. The results of our analysis for these measures are shown in Table 6.24.

Table 6.24. Weatherization Measures in New Manufactured Home Stock

Measure	Cost ($/Unit)	Annual Svgs (th)	Measure CSE ($/th)	Measure Life (yrs.)	Technical Potential (Hhlds)	Program Savings (kTh)
Attics	115	20	0.23	45	549	495
Walls	100	11	0.37	45	549	272
Floors	158	228	0.03	45	549	5,637
Totals:	**373**	**259**	**N/A**	**45**	**1,647**	**6,404**

6.5.5. Manufactured Homes – Conclusions and Program Recommendations

From a cost/benefit perspective, the manufactured housing sector offers some opportunities for Energy Trust intervention to increase the gas use efficiency of these homes. However, the very small number of units served with natural gas in the Trust's service territory greatly limits the energy savings that can be anticipated. If all measures which passed our CSE screen were applied to every home that qualifies, the total program gas savings would be about 25,650 kTh. Therefore, we recommend that a program targeted at this stock be included with single-family homes or given a lower priority than programs aimed at the single- and multi-family markets.

7. References

Publications:

Analysis Group, Inc. *1993. First Year Load Impacts of Southern California Gas Company's Commercial Demand-Side Management Programs (Program Years 1990, 1991, and 1992).* Prepared for Southern California Gas Company. Los Angeles, CA.

Baylon, David & Jonathan Heller. *Super Good Cents Heat Loss Reference, Volume I: Heat Loss Assumptions and Calculations*. 1988. For the Bonneville Power Administration, Portland, OR.

Baylon, David & Jonathan Heller. *Super Good Cents Heat Loss Reference, Volume II: Heat Loss Coefficient Tables*. 1988. For the Bonneville Power Administration, Portland, OR.

Bohac, D., R. Landry, R. Voegtline, T. Dunsworth and M. Hewett. 1989. *Field Measurement of Multifamily Boiler Losses*. Minneapolis Energy Office, MEO/TR89-7-MF, Minneapolis, MN.

California Conservation Inventory Group (CCIG). 1996. *Database for Energy Efficient Resources (DEER).* Prepared for California Energy Commission (CEC), P300-94-005. Sacramento, CA.

Consortium for Energy Efficiency, *Opportunities for Partnerships Between Electric, Gas, Water and Waste-Water Utilities*. 2002. Boston, MA.

Davis, Bob & David Baylon. *Energy Efficient Manufactured Homes: Technical Reference*. 1996. For the Bonneville Power Administration, Portland, OR.

Ewing, G., D. Neumeyer, S. Pigg and J. Schlegel. 1988. *Effectiveness of Boiler Control Retrofits on Small Multifamily Buildings in Wisconsin*. Proceedings of the 1988 ACEEE Summer Study. American Council for an Energy Efficient Economy. Washington, DC.

Four Winds Alliance and D&R International. *Opportunities for New Appliance Market Transformation Programs in the Pacific Northwest*. 2000. For the Northwest Energy Efficiency Alliance. Portland, OR.

Hewett, M. 1990. *Do Vent Dampers Work in Multifamily Buildings?* Home Energy, vol. 7, no.2. Berkeley, CA.

Hewett, M., T. Dunsworth, H. Emslander and M. Koehler. 1988. *Measured Energy Savings from Vent Dampers in Low Rise Apartment Buildings*. Minneapolis Energy Office, MEO/TR88-2-MF. Minneapolis, MN.

Kennedy, M. 1991. *Cafe Flora Energy Conservation Study for the Energy Smart Design Program*. Prepared for Seattle City Light, Energy Smart Design. Seattle, WA.

Kennedy, M., Jim Hanford, Aaron Houseknecht, David Baylon. 1995. *Demand Side Energy Savings in WNB Firm Commercial Sector*. Washington Natural Gas. Seattle, WA.

Koomey, J., C. Dunham and J. Lutz. 1994. *The Effect of Efficiency Standards on Water Use and Water Heating Energy Use in the U.S.: A Detailed End-Use Treatment*. Proceedings of the 1994 ACEEE Summer Study. American Council for an Energy Efficient Economy. Washington, DC.

Krause, W. E., M. Hewett and M.S. Lobenstein. 1992. *Commercial Gas Space Heating Equipment: Opportunities to Increase Energy Efficiency*. Center for Energy and the Urban Environment, CEUE/TR91-3-CM. Minneapolis, MN.

Lobenstein, M.S. 1993. *Controlling Recirculation Loop Heat Losses*. Home Energy, vol. 10, no. 1. Berkeley, CA.

Lobenstein, M.S. and M. Hewett. 1991. *Commercial Gas Cooking Equipment: Opportunities to Increase Energy Efficiency*. Center for Energy and the Urban Environment for Minnegasco, Inc., CEUE/TR91-1-CM. Minneapolis, MN.

Lobenstein, M.S., D. Bohac, T. Staller, M. Hancock and T. Dunsworth. 1992. *Measured Savings from Integral Flue Dampers and Thermal Vent Dampers on Domestic Hot Water Heaters in Multifamily Buildings*. Minnesota Center for Energy and Environment for Energy Resource Center, CEE/TR92-2-MF. Minneapolis, MN.

Minneapolis Energy Office (MEO). 1988. *Determining Applicability of Front-End Modular Boilers: Modeling Retrofit Performance; Assessing Project Management*. MEO/TR88-8-MF. Minneapolis, MN.

Northwest Natural Gas Company. 1992. Foodservice Gas Equipment Catalog, 1992 – 1993 Edition. 23rd Edition. Northwest Natural Gas, Portland, OR.

Nugent, Brian. 1994. 1995 Refrigeration & Food Service Retrofit Express Program; PG&E Advice Filing 1867-G/1481-E. Pacific Gas & Electric. San Francisco, CA.

Office of Energy Efficiency and Renewable Energy (US Department of Energy). *Consumer Energy Information: EREC Reference Briefs.* 2002. Merrifield, VA.

Southern California Gas Company. 1994. Advice Filing No. 226X. Los Angeles, CA.

United Industries Corporation. 1988. *DOE-2 Commercial Building Prototype Review and Revision: Conservation Analysis Summary*. Prepared for Bonneville Power Administration, UIC Report # 8815. Bellevue, WA.

Web Sites:

National Fenestration Rating Council (NFRC). www.nfrc.org.
Northwest Energy Efficiency Alliance. www.nwalliance.org.
Energy Efficiency and Renewable Energy. www.eere.energy.gov.

Appendix A: Initial Commercial Measure List

Identifier	Measure	Description	/New Replace / Retrofit
Commercial Sector			
Space Heat Equipment			
201	Condensing Furnace	Condensing/pulse residential-type furnaces.	New / Rep
202	Gas Heat Pump	Replaces furnaces & furnace + AC.	New / Rep
203	High Efficiency Unit Heater	Includes power vent with IID	New / Rep
204	Infrared Heater		New / Rep
205	High Efficiency Replacement Burner		Retr
206	Intermittent Ignition Device		Retr
207	High Efficiency Boiler		New / Rep
208	Condensing Boiler		New / Rep
209	Vent Damper	For atmospheric boilers	Retr
210	Oxygen Trim		Retr
211	Modulating Boilers		Retr
212	High Performance Tune Up	Boiler only	Retr
213	Automatic Blowdown		
214	Power Burner		New / Retr
Space Heat Distribution			
	Demand Control Ventilation	CO-sensor controlled ventilation in systems designed for periodic crowds.	New / Retr

Identifier	Measure	Description	/New Replace / Retrofit
Commercial Sector			
216	Building Warmup Ventilation Control	Timed economizer control shuts off fresh air in unoccupied warm up period.	New / Retr
217	Steam Balancing		Retr
218	Steam-to-Hot Water Conversion		New / Rep
219	Steam Trap Maintenance		Retr
220	Pipe Insulation		All
221	Supply Air Temperature Reset		Retr
Space Heat Controls			
222	Zoning and Loop Controls	Includes thermostatic radiator valves on SZHW or TPS, balancing MZHW, zone valve maintenance.	
223	Make Up Air Controls Reset		Retr
224	Air Destratification Controller	Control add on for unit heaters; allows fan to run without burner for mixing.	
225	Timeclock		Retr
226	Setback Thermostat (2 stage)		All
227	EMCS		All
Heat Recovery			
228	HVAC heat recovery		New / Retr
229	Kitchen heat recovery (hood, oven, range).	Heat recovery to space heat or hot water load	All
230	Washer drain heat recovery	Heat recovery from dishwashers and clothes washers	All
231	Refrigeration heat recovery	Chiller/refrigeration heat recovery	All
232	Boiler flue gas heat recovery	For older, large boilers w/process or hot water load	All
233	Dryer flue gas heat recovery	Large dryers only	All
Hot Water Equipment			

Identifier	Measure	Description	/New Replace / Retrofit
Commercial Sector			
234	High Efficiency Boiler	Alone or part of space heating boiler.	New / Rep
235	Condensing Boiler	Alone or part of space heating boiler.	New / Rep
236	High Efficiency Res Water Heater	EF 0.60	New / Rep / Retr
237	Condensing Comm Water Heater	Stand-alone unit	New / Rep / Retr
238	Sidearm Boiler	Separate to allow primary boiler shutdown in warm weather	
239	Vent Damper		
240	Solar Water Heater		
241	Gas Boost Water Heater	Increase temp to 180 deg.	
Hot Water Distribution and Controls			
242	Pipe Insulation		Retr
243	DHW Circulation Controls	Timeclocks on pump & setpoint; demand control on setpoint.	Retr
244	Lower Temperature Setpoint		Retr
Envelope			
245	Windows-Class35 (New)	From Class50	New
246	Windows-Class35 (Replace)	From Class100 (prox)	Rep
247	Insulation-Roof	Attic blown-in, or batt in open joist. Deck insul at re-roof or ceiling modification	
248	Insulation-Wall	Cavity fill, furred interior, and interior blown-on cellulose.	
249	Air curtain		
250	Greenhouse plastic layers	Add plastic glazing layer.	
Appliances - Laundry			
251	High Efficiency Dryer	Includes auto termination and exhaust recycle.	New / Rep

Identifier	Measure	Description	/New Replace / Retrofit
Commercial Sector			
252	Extractor Washer	Removes moisture through high speed spin.	New / Rep
253	Horizontal Axis Washer		New / Rep
254	Ironers		New / Rep
Appliances - Cooking			
255	Chinese range		
256	Direct-fired convection oven		
257	Convection range/oven		
258	Convection oven/steamer		
259	Convection oven vent damper		
260	Power range burner		
261	Jet impingement burner		
262	Infrared fryer		
263	Infrared griddle		
264	Clamshell griddle		
265	Infrared warewashers		
266	Infrared dishwashers		
267	Infrared broiler		
268	Infrared water heat booster		
269	Intermittent ignition device (IID)		
270	Kitchen steam conversion		
271	Cheesemelters		
272	Pasta cookers		
273	Hot Food Tables		
274	Steam Tables		
275	Warewashers		
O&M			
276	Retrocommissioning		
277	Furnace Tune Up		
278	Venting repair/replacement		
Swimming Pools			
279	Swimming Pool Covers		New / Rep / Retr

Identifier	Measure	Description	/New Replace / Retrofit
Commercial Sector			
280	High Efficiency Pool Heater		New / Rep / Retr
281	Solar Pool Heater		New / Rep / Retr
Process			
282	NONE-NW classifies all processing as industrial.		

Appendix B: Initial Residential Measure List

Identifier	Measure	Description	/New Replace Retrofit /
Residential Sector			
Space Heat Equipment			
101	High efficiency furnace	AFUE .75 to .9	Retr
102	High efficiency furnace	AFUE .8 to .9	New / Repl
103	Furnace tune-up	Heat exch cleaning, burner adjustment	Retr
104	Gas heat pump		
105	Boiler combo w/DHW		
106	Residential boiler	Circulating hot water heat	
107	Radiant floor		new
108	Programmable thermostat		Retr
109	Two-pipe HVAC		
Space Heat Distribution			
110	Duct testing & diagnostics		Retr
111	Duct sealing / repair		Retr
112	Duct insulation		Retr
Hot Water			
113	High efficiency tank	AFUE .55 to .61	
114	Efficient tank, burner / exchanger	AFUE .55 to .84	
115	Solar tank (preheat)		
116	Solar w / direct-fire demand		
117	Wastewater heat recovery		
118	Demand water (central)		
119	Demand water (distributed)		
Envelope			
120	Insulation - ceiling (from ~R-0)	R-19	Retr
121	Insulation - ceiling (from ~R-19)	R-38	Retr
122	Insulation - floor	R-19	Retr
123	Insulation - wall	R-11 (blown in)	Retr

Identifier	Measure	Description	/New Replace Retrofit /
Residential Sector			
124	Windows replacement	~ U = 1.0 to U = .5	Retr
125	Windows improvement	U = .5 to U = .4	Retr/Rep
126	Windows - high efficiency	U = .4 to U = .35	New/Rep
127	Doors - superinsulated		Retr
128	Air sealing / HR ventilation		All
Appliances			
129	Horizontal axis clothes washer		
130	High spin speed clothes washer		
131	Efficient clothes dryer		
132	Efficient dishwasher		
133	Efficient gas range	controls & venting	
Other			
134	Residential fuel cells (1-3 kW)	More a demand reduction measure than a gas savings	New / Repl

Appendix C: Initial Multi-Family Measure List

Identifier	Measure	Description	/New Replace / Retrofit
Multi-Family Sector			
Space Heat Equipment			
001	Condensing Furnace	Condensing/pulse residential-type furnaces.	New / Rep
002	High Efficiency Replacement Burner		Retr
003	Intermittent Ignition Device		Retr
004	High Efficiency Boiler		New / Rep
005	Condensing Boiler		New / Rep
006	Vent Damper	For atmospheric boilers	Retr
007	Modulating Boilers		Retr
008	High Performance Tune Up	Boiler only	Retr
Space Heat Distribution			
009	Steam Balancing		Retr
010	Steam-to-Hot Water Conversion		New / Rep
011	Steam Trap Maintenance		Retr
012	Pipe Insulation		All
013	Supply Air Temperature Reset		Retr
Space Heat Controls			
014	Zoning and Loop Controls	Includes thermostatic radiator valves, zone valve maintenance.	
015	Make Up Air Controls Reset		Retr
016	Setback Thermostat (2 stage)		All
017	EMCS		All
Hot Water Equipment			
018	High Efficiency Boiler	Alone or part of space heating boiler.	New / Rep

Identifier	Measure	Description	/New Replace / Retrofit
Multi-Family Sector			
019	Condensing Boiler	Alone or part of space heating boiler.	New / Rep
020	High Efficiency Res Water Heater	EF 0.60	New / Rep / Retr
021	Condensing Comm Water Heater	Stand-alone unit	New / Rep / Retr
022	Sidearm Boiler	Separate to allow primary boiler shutdown in warm weather	
023	Solar Water Heater		
Hot Water Distribution and Controls			
024	Pipe Insulation		Retr
025	DHW Circulation Controls	Timeclocks on pump & setpoint; demand control on setpoint.	Retr
026	Lower Temperature Setpoint		Retr
Envelope			
027	Windows-Class35 (New)	From Class50	New
028	Windows-Class35 (Replace)	From Class100 (prox)	Rep
029	Insulation-Ceiling	R-38	Retr
030	Insulation-Wall	R-11	Retr
031	Insulation-Floor	R-19	Retr
032	Entry doors (New)	U = .54 to U = .19	New
033	Entry doors (Retrofit)		Retr
Appliances			
034	Horizontal axis clothes washer		New / Rep
035	High spin speed clothes washer		New / Rep
036	Efficient clothes dryer		New / Rep
Swimming Pools			
037	Swimming Pool Covers		New / Rep / Retr
038	High Efficiency Pool Heater		New / Rep / Retr

Identifier	Measure	Description	/New Replace / Retrofit
Multi-Family Sector			
039	Solar Pool Heater		New / Rep / Retr