Direct Use of Natural Gas:
Economic Fuel Choices from the Regional Power System and Consumer's Perspective

Council document 2012-01

Background

Is it better to use natural gas directly in water heaters and furnaces or to generate electricity for electrical space and water heating systems that provide these services? The Council has deliberated on this question since its inception. Over the years, the Council has performed several studies and issued papers addressing the issue. The topic has gone under different names; total-energy efficiency, fuel switching, direct use of gas, and others.

The natural gas companies brought suit against the Council after the First Power Plan, one among the few law suits the Council has faced. The concern was that by providing incentives for improved electricity efficiency the Council would disadvantage natural gas companies and encourage more use of electricity. Over time the concerns have morphed into arguments that direct use of natural gas is more efficient and more benign for the environment.

In 1994, the Council analyzed the economic efficiency of converting existing residential electric space and water heating systems to gas systems.[1] That study showed there were many cost-effective fuel-switching opportunities within the Region, representing a potential savings of over 730 average megawatts. However, the Council has not included programs in its power plans to encourage the direct use of natural gas. The Council has not promoted conversion of electric space and water heat equipment to natural gas equipment.

The Council's prior analysis indicated that intervention was not necessary because fuel choice markets were working well. That is, regional customers appeared to be making appropriate choices and conversions without intervention. We do not have more recent data on fuel conversion activity, but data on overall fuel shares gives some indication of consumers' choices over longer periods of time for both new construction and conversions. Consider, for example, the substantial electricity price increases in the early 1980s. The electric space heating share stopped growing in the region while the natural gas space heat share in existing homes increased from 26 to 37 percent. Although data is limited, fuel conversion of existing houses to natural gas has been an active market as well, often promoted by dual fuel utilities.

The Council's findings and policy on this issue have been very consistent. Analysis has found that direct use of natural gas is often more thermodynamically efficient than using electricity generated from natural gas. However, economic efficiency is the Council's primary measure of merit.

[1] Northwest Power Planning Council. "Direct Use of Natural Gas: Analysis and Policy Options". Issue Paper 94-41. Portland, OR. August 11, 1994.

Economic efficiency depends on the specific situation regarding natural gas and electricity prices, home size and energy use, cost of heating equipment and ductwork, and other factors. The Council has found that fuel switching is not conservation under the Northwest Power Act, which defines conservation as the “more efficient use of electricity”. Further, the Council also has determined that fuel choice markets are reasonably competitive and that those markets should be allowed to work without interference.

Thus, the current Council policy, which has been reaffirmed several times, is:

Council Policy Statement

The Council recognizes that there are applications in which it is more energy efficient to use natural gas directly than to generate electricity from natural gas and then use the electricity in the end-use application. The Council also recognizes that in many cases the direct use of natural gas can be more economically efficient. These potentially cost-effective reductions in electricity use, while not defined as conservation in the sense the Council uses the term, are nevertheless alternatives to be considered in planning for future electricity requirements.

The changing nature of energy markets, the substantial benefits that can accrue from healthy competition among natural gas, electricity and other fuels, and the desire to preserve individual energy source choices all support the Council taking a market-oriented approach to encouraging efficient fuel decisions in the region.

In light of changing technologies and energy prices and of growing climate concerns, in 2008 the Council was again asked to look at the direct use of natural gas issue. The analysis is called for in the Action Plan (ANLYS-16) of the Sixth Power Plan. This paper describes the analysis and findings and provides recommendations regarding the Council’s existing policies.

Scope and Structure of Analysis

With the financial support and cooperation of the Northwest Gas Association and Puget Sound Energy, the Council has updated its economic analyses. The Council’s Regional Technical Forum oversaw the study and its scope. The study examines fuel conversion for residential space and water heating equipment in existing homes where conversion is feasible. The Council’s goal for this analysis was to recreate its 1994 study with up-to-date information. The scope of the analysis was expanded to test the cost, risk, and carbon-emission impact of conversions. Unlike the 1994 study, the study considers conversions of electric space and water heating systems both to and from natural gas. Another major difference from the previous analysis is that all direct use of natural gas alternatives are modeled as “resources” directly in the Council’s Regional Portfolio Model (RPM). This allows the Council to directly compare the cost and risks of any conversion.

Study Objectives

This study had two specific objectives. The first was to determine which residential space and water heating systems have the lowest total resource cost (TRC) while presenting an acceptable level of risk to the region. The second objective was to determine whether the ***retail market*** will lead consumers to choose those same space-conditioning and water-heating systems. If the systems selected based on the regional cost and risk perspective are similar to those selected based on consumer economics, and they are generally being chosen by consumers then it would appear that no policy intervention is needed.

This analysis therefore examines the economics of direct use of natural gas from two perspectives -- the “regional” perspective and the “consumer” perspective. The regional perspective adopts total resource cost (TRC) economics. Selections are determined using the cost of future power supply options and wholesale prices for electricity and natural gas. Selections are made from forecasts of the market prices four times each year over the twenty-year planning horizon.[2] The effect of all the “fuel choice” decisions appears in the magnitude and timing of new generating resource additions as well as the cost associated with those additions. These costs also include possible carbon mitigation cost and the cost of incremental natural gas and electricity use. In contrast, from the consumers perspective, selection of space and water heating systems are based strictly on the retail prices for electricity and natural gas. In particular, it does not account for system level impacts such as the need to build new generation or expand gas distribution networks.

Analytical Approach

Of the 3.6 million existing households in the Pacific Northwest, about 2.6 million are eligible for converting to the alternative fuel source over the next 20 years.[3] This implies that on average about 130,000 “fuel choice” decisions will be made annually.

The first step in this analysis was to estimate the existing mix of space and water heating systems used in region by these 2.6 million households. Data from a regional customer characteristics survey[4] were used to assign existing residential dwellings to “segments groups” [5] according to characteristics associated with their energy use. These characteristics were housing type (e.g., single family vs. multifamily), size (e.g., 1050 sq. ft. vs. 2250 sq. ft.), and equipment fuel and type (e.g., gas forced-air furnace vs. electric heat pump). A total of 95 unique segment groups were identified. A complete list of these segment groups appears in Appendix A.

The next step was to estimate the energy use and the cost of replacement. The study developed estimates of the annual energy use for space heating, cooling and water heating for the five representative climates used by the Council and RTF for each space conditioning and water heating system and fuel type.[6] Appendix B provides a list of all of the space and water heating system replacement options considered for each of the 95 segment groups. Appendix C contains a summary of the energy use, and equipment, operation, and maintenance costs used in this analysis.

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[2] The frequency is determined by the architecture of the RPM.

[3] “Eligibility” was determined based on whether gas service could be provided through the extension of an existing gas main or both main and service line to the home.

[4] The 2008 American Community Survey (ACS) and the Pacific Northwest Regional Energy Survey published in 1992 (PNRES92)

[5] We use the term ***segment groups*** for consistency with the earlier Global Energy Partners (GEP) work on this study. A segment group refers to a group of households with identical attributes and circumstances relevant to the selection of replacements. We concede that the term ***segment*** would be more standard. GEP reserved the term segment, however, for a particular segment group ***and*** a particular selection of replacement appliances. Therefore, for each segment group there may be dozens of segments, each one a candidate replacement pair of space and water heating appliances. Only one pair would be chosen at a particular point in time as the least-cost replacement solution for a given segment group.

[6] The Council/RTF uses Portland, Seattle, Boise, Spokane and Kalispell as representative of the major climate types found across the region.

Appendix H lists reasons why particular space and water heating system combinations were, or were not, explicitly evaluated.

The study assumes replacements would, at a minimum, satisfy the new federal efficiency requirements. Recently adopted federal standards will require efficiency upgrades when consumers replace certain space and water heating systems. Among these space and water heating systems are natural gas furnaces, central air conditioners, heat pumps, and both gas and electric water heaters. For example, for gas water heaters with capacities above 55 gallons, the new federal standard requires a minimum Energy Factor (EF) of 0.75. For electric water heaters with capacities above 55 gallons, the new federal standard requires a minimum EF of 2.0.

The resulting conversion cost and energy use estimates for 1,470 space and water heating systenm type pairs served as input to the RPM. The consumer life cycle cost (LCC) analysis used the same data. In both modeling processes, each of the 95 different segments is provided with between eight and 24 replacement options from which to choose. In both the RPM and the LCC simulation models, consumers can install the same type of equipment they already have or install a different technology. For example, in one identified market segment, the home has electric forced air furnace (FAF) for space heating and an electric resistance water heater. Both the RPM and LCC analyses assume that when the electric FAF fails, it could be replaced “in kind” with another electric FAF. It could also be replaced by a gas FAF or a gas/heat pump hybrid system. Likewise, when the electric resistance water heater fails it could be replaced with a new model of the same type of water heater. It could also be replaced by a gas tank water heater, a tankless gas water heater, or a heat pump water heater.

Use of the RPM provided the study with a fresh look at how the issue of risk might impact the Council's conclusions and recommendations. To understand the results of the RPM and this study, it is useful to understand a few principles of the model. In particular, the RPM evaluates resource strategies under 750 different futures. These futures differ significantly, one from the other. The scale of variation corresponds to that of "scenario" analyses that utilities perform for their integrated resource plans (IRPs). Risk is measured by the average net present value cost in the 10% (75) highest-cost futures. If decision makers select least-risk strategies, therefore, they are lending particular weight to the performance of those strategies under these high-risk futures.

The least risk strategies that emerge from Council's risk model protect ratepayers from the high cost-futures. Often, the high costs result from high wholesale prices for natural gas and electricity. Over the course of the study, it became evident that evaluating appliance life-cycle cost directly resulted in appliance choices as good as those the risk model could obtain. However, in order to mimic the results of the RPM, the simplified Fuel Choice Model needed to assume gas prices over $9.50/MMBTU and the use of the fully allocated electricity cost of a CCCT instead of the short run wholesale market price for electricity. While such natural gas prices sound high from today’s perspective, they predominate in “risky” futures. Such futures have a high carbon mitigation penalty, unfavorable regulatory treatment for environmental mitigation, or other features disadvantageous to natural gas.

As mentioned in the Objectives, the RPM captures the region’s total resource cost. Specifically, the cost of natural gas provided for direct use in space and water heating systems is added to the cost for fuel to natural-gas fired combustion turbines. Both uses of natural gas reflect the carbon penalties that arise in a future. Electricity loads met by generation reflect conversion, as does the amount of electricity energy efficiency available for economic or risk mitigation acquisition.[7] Credit for transmission and distribution equipment costs is reflected in the RPM's accounting for electricity costs. On the natural gas side of the ledger, the RTF concluded that long-term transmission cost impacts are fairly reflected in commodity cost. A characterization of the incremental distribution cost impacts was not available. It was generally held, however, that the study's explicit treatment of service extension cost captured most of the distribution system cost effects. The study did not attempt to capture gas energy efficiency programs, so no assessment is made of any conservation effect on gas use. In contrast, the study did include the option for improvements in the efficiency of electric space and water heating through the selection of higher efficiency systems, so the conservation effect of such efficiency upgrades is reflected in the results.

The Council developed a Fuel Choice Model (FCM) to prepare data for the RPM analysis. The model has various tools for exploring both input and output data. It also contains the logic to select space and water heating systems for each segment based on the direct cost estimate, as described in the previous paragraph. A version of the model is available on the Council's website at the following link. (http://www.nwcouncil.org/dropbox/DUG/FCM10.xlsm) The model contains a link to detailed documentation of the model.

Findings from the Regional Economic Perspective

Table 1 provides key information about the 95 segment groups described above. A review of this table shows that for nearly three quarters (73%) of the households it would not be economically advantageous from a regional perspective to switch space conditioning or water heating fuel source. It shows that for approximately 22 percent of the households it would be economical to convert from electric space heating or water heating to gas space or water heating. These conversions over 20 years reduce annual regional electrical loads by roughly 360 average megawatts and increase annual natural gas consumer use by about 15 trillion BTU.

Just under five percent of the region's households converted to heat pump water heaters from gas storage tank water heaters. All of the households in these market segments, however, use water heaters with capacities above 55 gallons. Table 1 shows the effect of these conversions over 20 years. Conversion to heat pump water heaters would increase regional electric loads by 24 average megawatts and decrease natural gas use by just under 2 trillion BTU annually.

A very small fraction of the region's households (less than one percent) converted from electric to gas space heating and from gas to electric water heating. These households converted from electric forced-air furnaces to gas force-air furnaces and gas tank water heaters to heat pump water heaters. The net impact over 20 years of these conversions was a three megawatt decrease in loads and about a 70 billion BTU increase in natural gas use.

Across all households, regional electric loads decrease around 340 average megawatts and natural gas use by customers increases 13 trillion BTU. However, less natural gas is used by the power generation turbines that would otherwise have served those electric space and water heating systems. After netting out the 21 trillion BTU decrease of gas use by these turbines, total regional natural gas consumption falls 8 trillion BTU per year by the end of the 20–year study.

[7] Due to the complex feedback effects inherent in conversion and EE potential, this is reflected in sensitive studies that capture the effect at either extreme of conversion.

Appendix A shows the replacement space conditioning and water heating systems selected based on both the regional and consumer economic perspective for each of the 95 market segments considered in this study.

Many policymakers are concerned about the implications of carbon dioxide emissions policies. Carbon dioxide emissions are monetized in the Council's risk model and are a significant source of cost risk. If the least-risk choices from the Council's model prevail, however, the impact on carbon dioxide emissions is negligible.

Electric space and water heating systems, of course, produce carbon dioxide through the combustion of fossil fuels required to produce the electricity that they use. The study shows that direct use of natural gas produces less carbon dioxide than do the least efficient electric space and water heating systems. This is due to the fact that the thermodynamic efficiency of even the most efficient gas-fired generation, plus losses in the transmission and distribution of electricity is below that of today's gas furnaces and water heaters.

Little CO_2 emission change can be ascribed to converting, however. The number of conversions is small. Even for a larger number of conversions, however, the result would not be dramatic. Efficient gas and electric space and water heating systems are becoming more cost-effective, reducing the gap in relative CO_2 production. For example, hot water heat pumps transport heat rather than extract heat from chemical bonds. This requires much less energy consumption. Consequently, the overall efficiency of heat pumps, including the generation of the electricity they require, is comparable to direct use of gas. The production of carbon dioxide is thus also comparable. [8]

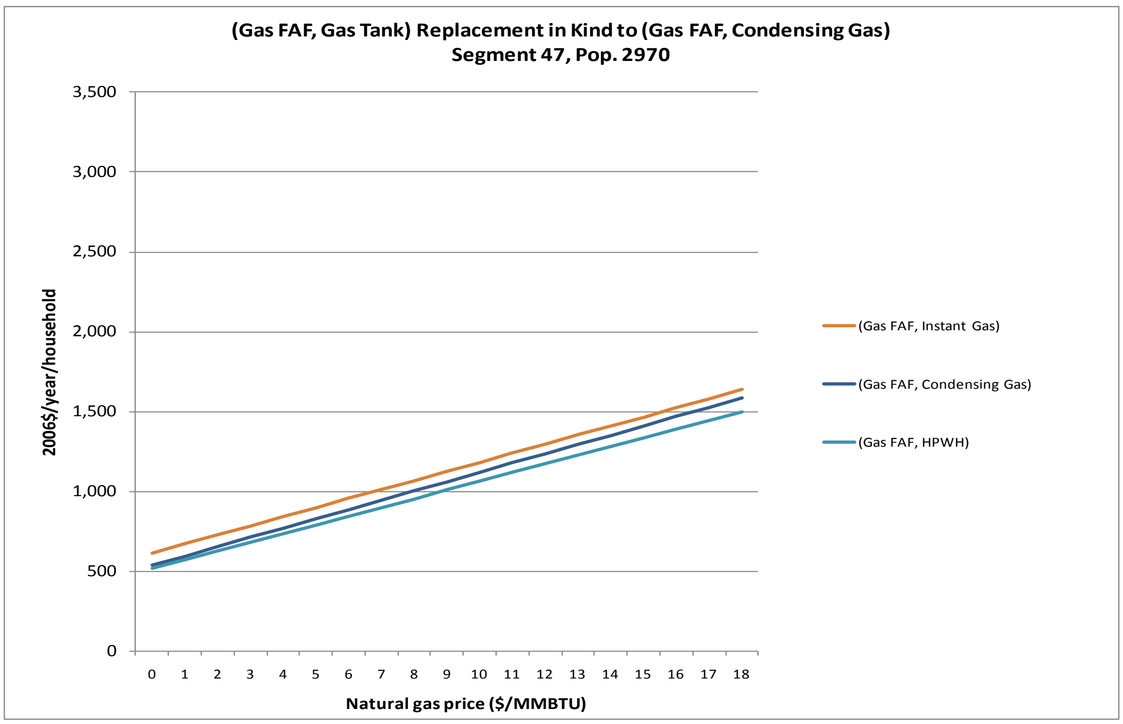
[8] Measuring efficiency at the point of use does not convey a complete picture. An electric resistance water heater converts virtually 100 percent of the electricity it consumes into heated water while typical new gas tankless water heater coverts just over 80 percent of the gas used to hot water. The current generation combined cycle combustion turbines convert just under 50 percent of the energy they consume into electricity. Roughly 10 percent of this electricity is lost as it is transferred from the point of generation to end users. Therefore, from a total system perspective the electric water heater's efficiency is only 45 percent (50% combustion efficiency x 90% transmission & distribution efficiency x 100% water heater efficiency) which is significantly below that of the gas water heater. Alternatively, heat pump water heaters have efficiency ratings that are twice those of a standard electric resistance water heater producing a total system efficiency of 90% (50% combustion efficiency x 90% transmission & distribution efficiency x 200% water heater efficiency) above that of most gas tankless water heaters.

Table 1 - Disposition of Market Segments Based on Resource Portfolio Model's Selection of Least Risk Plan										
	No. Segments Represented	No. Households /yr	20-year Total Households	Share of Total	Existing Use (MWa/yr)	Existing Use (MMBTU/yr)	Annual Change in Use (MWa/yr)	Annual Change in Use (MMBTU/yr)	Change in Use (MWa by 20th yr)	Change in Use (MMBTU by 20th yr)
Replace w/Same Fuel & Same Equipment	20	48,412	968,235	37.3%	4.92	2,500,094	-	-	-	-
w/Higher Efficiency Space Heating Equipment Only	14	1,807	36,145	1.4%	1.96	-	(1)	-	(10)	-
w/Higher Efficiency Water Heating Equipment Only	10	33,439	668,785	25.8%	21.51	-	(6)	-	(118)	-
w/Higher Efficiency Space & Water Heating Equipment	14	11,142	222,835	8.6%	15.26	-	(5)	-	(95)	-
Sub-Total	*58*	*94,800*	*1,895,999*	*73.1%*	*43.65*	*2,500,094*	*(11)*	-	*(223)*	-
Conversions from Electricity to Gas										
Space Heating only	11	1,520	30,400	1.2%	1.57	-	(1.55)	56,890	(31)	1,137,793
Water Heating only	6	21,197	423,940	16.3%	8.05	-	(8.05)	364,532	(161)	7,290,630
Space & Water Heating	6	5,745	114,900	4.4%	8.49	-	(8.29)	331,070	(166)	6,621,393
Sub-Total	*23*	*28,462*	*569,240*	*21.9%*	*18.11*	-	*(18)*	*752,491*	*(358)*	*15,049,817*
Conversions from Gas to Electricity										
Space Heating only	0	-	-	0.0%	-	-	-	-	-	-
Water Heating only	6	6,262	125,240	4.8%	0.10	98,713	1.21	(98,713)	24	(1,974,263)
Space & Water Heating	0	-	-	0.0%	-	-	-	-	-	-
Sub-Total	*6*	*6,262*	*125,240*	*4.8%*	*0.10*	*98,713*	*1*	*(98,713)*	*24*	*(1,974,263)*
Conversions from Electric Space Heating and Gas Water Heating to Gas Space Heating and Electric Water Heating	8	168	3,360	0.1%	0.16	2,648	(0.13)	3,536	(3)	70,723
Totals	*95*	*129,692*	*2,593,839*	*100%*	*58*	*2,601,455*	*(27.97)*	*657,314*	*(559)*	*13,146,277*
Changes Net of Efficiency	37	34,892	697,840	27%	18	101,361	(16.81)	657,314	(336)	13,146,277

Reduction in cost and improvements in the efficiency of heat pumps, condensing gas, and conventional space and water heaters have narrowed the economic and emission performance of these technologies. On inspection of the TRC analysis, an electric appliance may have only a small advantage over a gas appliance, or vice versa.

Figure 1 illustrates the point. The graph shows the relative economics of the three most competitive choices for a segment group that currently uses natural gas for space and water heating. The economics are expressed in real levelized annual cost per household. This particular segment group is replacing a gas forced-air furnace and gas storage tank water heater. Because the size of the tank exceeds 55 gallons, the options available for replacement are limited by federal standards to condensing gas or tankless gas water heaters and electric heat pump water heaters. Figure 1 shows only the three most competitive options out of a dozen available to this segment group. Each line corresponds to a particular pair of replacement space and water heating systems. These all retain gas forced-air furnaces for space heating. It is evident that while heat pump water heaters are the simple winner, condensing gas and instantaneous tankless gas water heaters are very close in cost. A small change in the relative purchase costs among these three could produce an different winner.

Figure 1: Gas Tank Water Heating Conversion to HPWH (Simplified)



Graphic displays of the results of the regional analysis are shown in Figures 2 and 3. Figure 2 shows space heating replacement choices. The central pie diagram shows the current mix of heating equipment and fuel. The satellite pies show how each type of heating equipment would be replaced. In general, it is most cost-effective to replace space heating equipment with the same fuel type. In only 5 percent of households is there a change in fuel source. Those changes were all from electricity to natural gas in homes without air conditioning, water heaters less than 55 gallons, and with access to natural gas already in the home or neighborhood. One clear result is that electric forced air furnaces should be replaced with different equipment, the specific replacement depending on many factors such as gas availability, relative prices, house size, and presence of air conditioning.

Figure 3 shows the results for water heating equipment choices. Here it is clear that electric resistance water heating is no longer cost-effective. The analysis shows it being replaced by either natural gas tank water heaters, if natural gas is available, or heat-pump water heaters where natural gas is not available or the water heater is greater than 55 gallons. Gas tank water heaters are replaced with the same equipment. The two small segments that will be required by federal standards to use either a condensing natural gas or heat pump water heaters because they are greater than 55 gallons are converted to heat pump water heaters.

Figure 2: Space Heating Equipment Replacement Choices - Regional Perspective

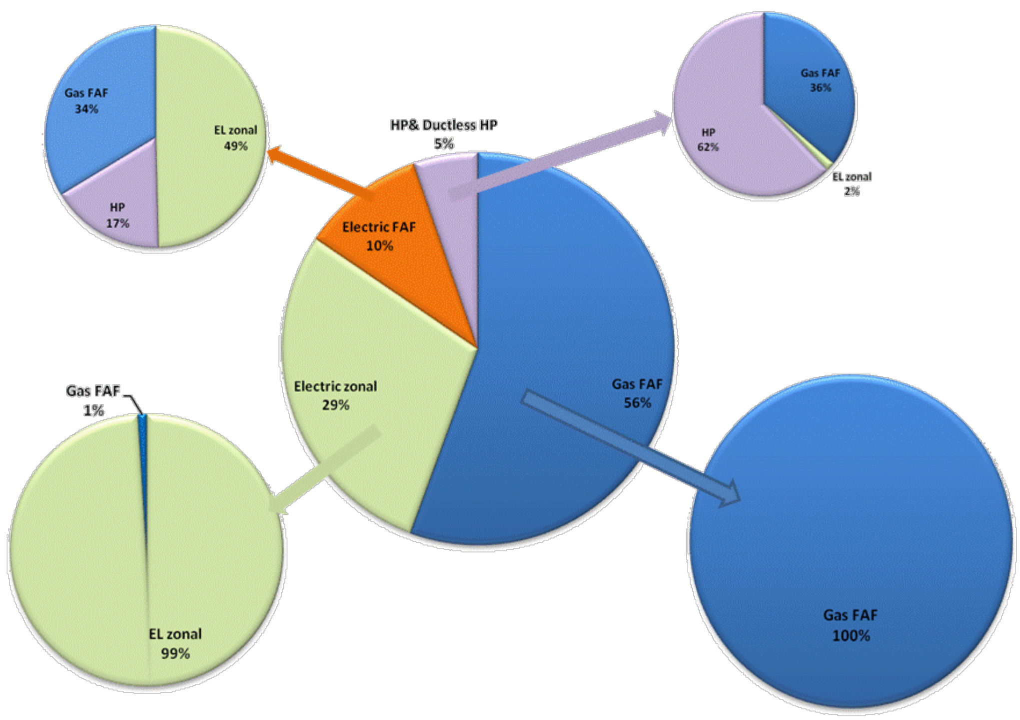
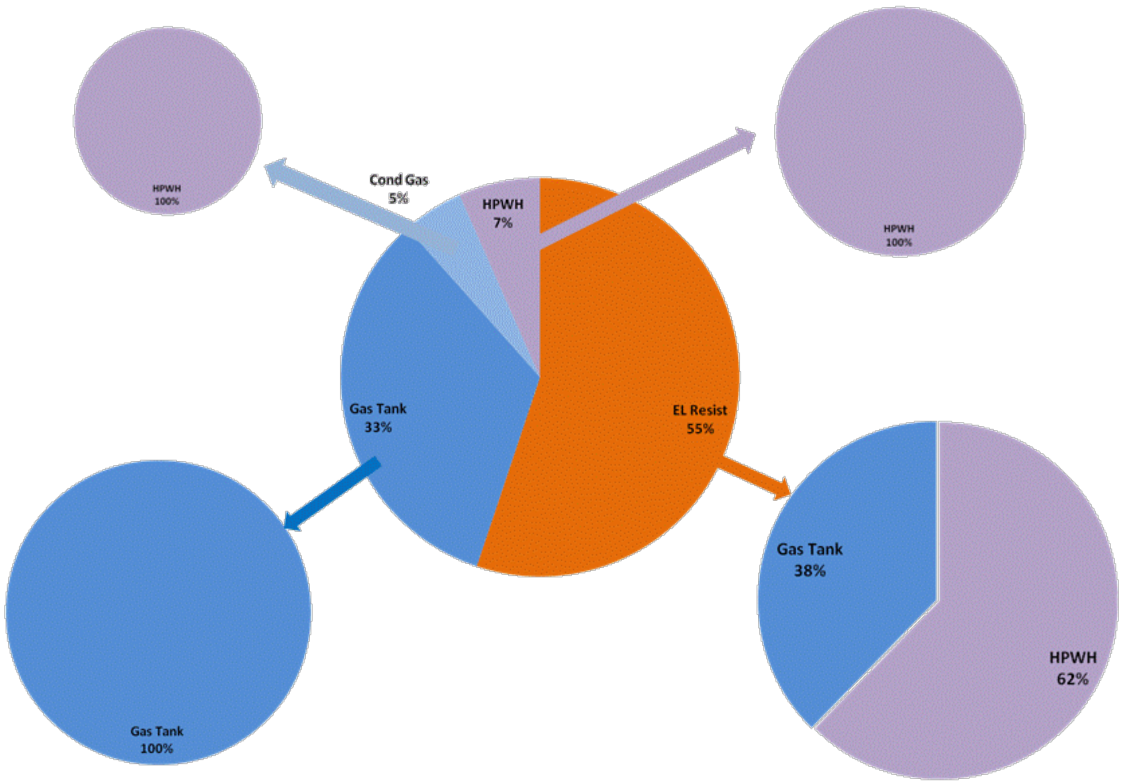


Figure 3: Water Heating Equipment Replacement Choices - Regional Perspective



Findings from the Consumer Economic Perspective

As summarized above, analysis using the Resource Portfolio Model (RPM) revealed that conversion of approximately 22 percent of existing households currently employing electricity for space and/or water heating to systems using natural gas prices could reduce total regional cost and risk. This analysis also found that conversion of a very small number (less than 1 percent) of households now using natural gas for water heating to electric water heaters would result in lower total regional cost. The objective of this phase of the Council's analysis was to assess whether consumers would generally select the space and water heating systems found to be the economic choice from the regional perspective. If this is the case and consumers appear to be selecting those systems, then there is little justification for the Council to modify its current policy on fuel choice/switching. On the other hand, if the most economic system selections from a consumer perspective do not generally mirror those found to be economically desirable from a total regional cost perspective and/or consumers do not appear to be selecting those systems, then policy intervention may be necessary.

The stakeholders agreed that two metrics should be used to represent the economic decision making criteria used by consumers when selecting a space and/or water heating system. These metrics are the "first cost" (FC) and "life cycle cost" (LCC) of the space and water heating systems. First cost (FC), as its name implies, is the initial purchase cost of space and water heating systems and the labor cost of installing them. The second metric, life cycle cost (LCC), is the discounted present value of all costs. These costs include those for purchase, installation, financing, maintenance, and operation, over the expected lives of the space and water heating systems.[9] The FC is independent of retail electricity and natural gas rates; LCC is not. Retail electric rates vary across the region by a factor of five while retail natural gas rates vary by less than two-to-one. Heating and cooling energy use are a function of the severity of the climate, which also varies significantly across the region.

In order to capture this diversity in rates and climates, the Council developed a Monte Carlo LCC model which uses a distribution of retail rates for natural gas and electricity that includes all electric and gas utilities in the region and estimates of energy use for space conditioning across five representative climate locations across the region.[10]

The LCC model was also designed capture any underlying correlation between retail gas and electric rates associated with regional geography.[11] The LCC model divides the region into five "service territories" that match climate with utilities.[12] For example, Western Oregon is represented by the Portland climate. The LCC calculation for the "Portland service territory" uses gas rates from two natural gas utilities and electric rates from twenty electric utilities that serve this general geographic area.

The LCC model performs 20,000 games, calculating a distribution of LCC for each of the 1,470 space conditioning and water heating system combinations using this distribution of natural gas and electric rates and energy use to reflect the proportion of customers facing each pair of rates within each of the five "service territories" found across the region. That is, the LCC results for each segment group from the "Portland service territory" are combined with the results from the other four "service territories" to determine the "regional average LCC" for that segment. This results in a more representative picture of diversity of net present value and costs for each space conditioning and water heating system. Figure 4 illustrates the results of the LCC model for a market segment representing just over 387,000 existing single family homes which average 1900 square feet in size, and heat with a gas furnace and have gas storage tank water heater.

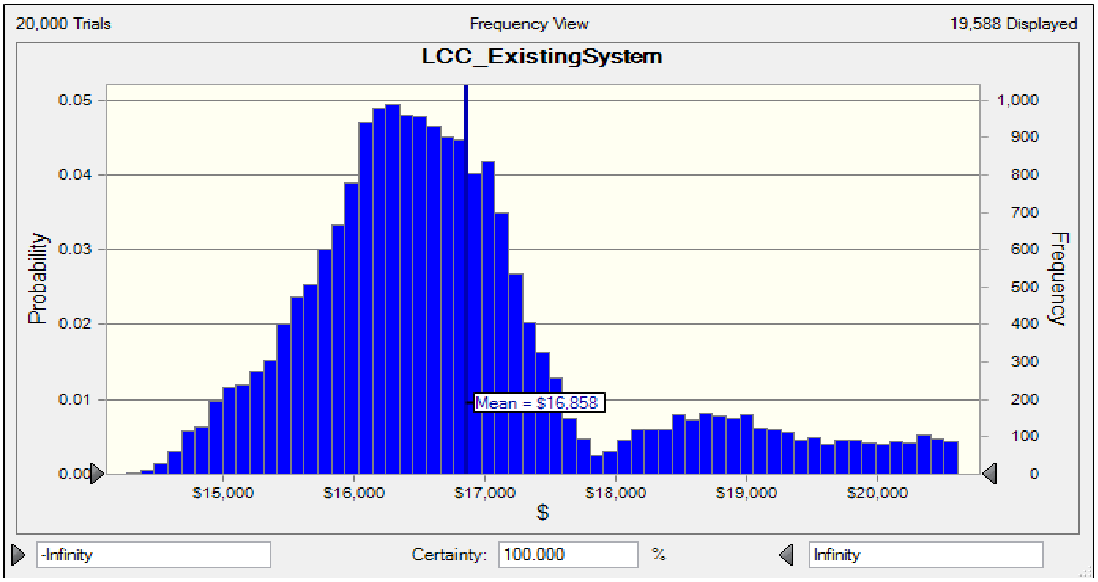
[9] In this analysis it was assumed that consumers would finance the purchase of their space conditioning and water heating system replacement at a six percent nominal interest rate for 20 years. This is simplifying assumption, since most water heater replacements are likely either paid for in cash or financed short term on credit cards. However, the discount rate in this analysis was set equal to the interest rate. As a result, the discounted present value cost of all systems is equivalent to their first cost. If a discount rate higher than the finance rate had been assumed the present value of all systems would have been below their first cost. Therefore, while the financing/discount rate assumption tends to slightly favor lower first cost systems, economic theory generally does not support the use of a discount rate below the cost of financing. The operating and maintenance and annual energy cost of all systems were treated (i.e. discounted) equivalently.

[10] The LCC model, including all of its input assumptions, can be downloaded from the Council website at: http://www.nwcouncil.org/media/7150428/retailfuelchoicemodel_pnw_v22.xlsm

[11] To reduce computational complexity, the Regional Economic analysis assumes energy use is fixed for each segment. That is, each combination of segment group and appliance choice has fixed gas and electricity use representing the estimated regionally weighted average use for that system. Since the regional economic analysis is based on wholesale gas and electricity prices and new generating facility cost it does not require "localized" energy cost.

[12] The five territories are represented by Portland, Seattle, Boise, Spokane and Kalispell.

Figure 4: Life Cycle Cost Results for Market Segment 45(Single Family, 1900 sq.ft., Gas FAF and Gas Tank DHW, Existing Gas Access)

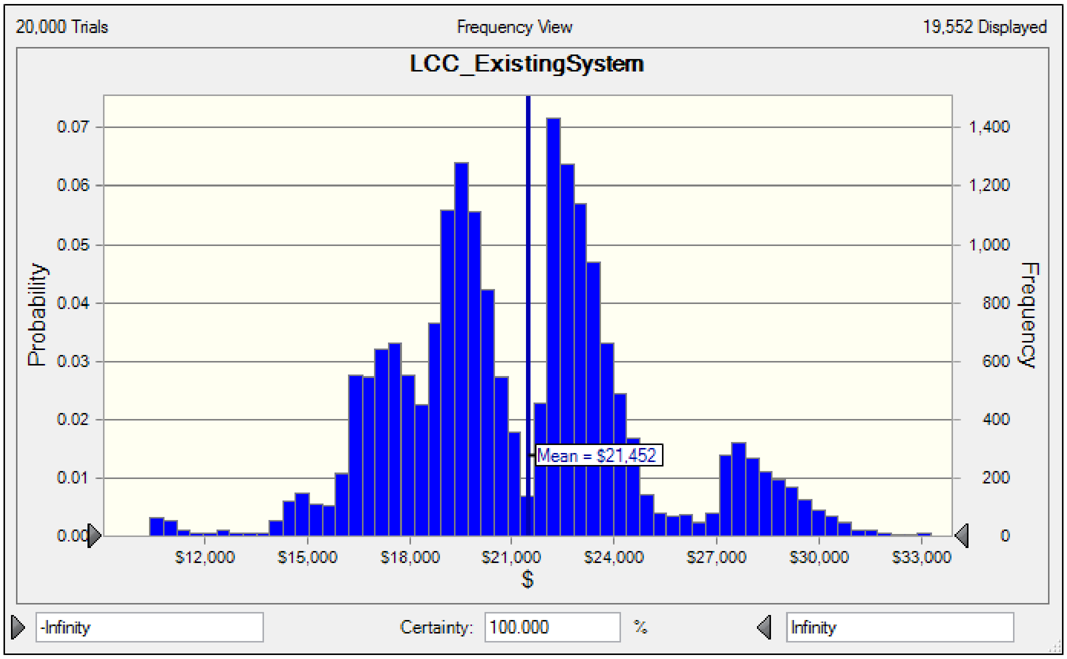


As can be seen from a review of Figure 4, the mean LCC for this space and water heating system is $16,858. However, the LCC for this space and water heating system combination could be as low as $14,000 or above $20,000 due to variations in retail gas retail rates, gas price escalation rates and climate. Despite this range, most of LCC results for this segment cluster between $15,000 and $17,500.

In contrast, Figure 5 shows four distinct "clusters" of the LCC results. Figure 5 depicts the LCC results for the 88,000 existing homes in the region that have an average size of 1900 square feet, heat with an electric forced air furnace and use an electric resistance water heater. A review of this figure shows that the LCC results for this market segment vary over a much larger range, from below $12,000 to over $33,000. Moreover, although this segment's regional mean LCC is $21,452 very few consumers are actually represented by this value. Rather, this "mean LCC" more accurately represents the average four large subgroups with LCC's centered around $17,000, $19,000, $23,000 and $28,000.

The LCC results for gas space and water heating systems and electric space and water heating systems consistently demonstrated these two distinct types of distributions. Gas system LCC results displayed a strong "central tendency" while electric systems were "multi-modal." These observations lead to the conclusion that simple averages do not capture important features of the LCC distributions. The initial LCC analysis selected space- and water-heating systems for each segment group based on the lowest regional average LCC. In order to reflect the differences in range of LCCs for gas and electric systems a second set of LCC analysis was conducted. This analysis selected the systems with lowest regional average LCC cost from among those within a single standard deviation from the mean for each segment group. This second set of results identified the space and water heating systems with lower "risk." That is, these systems exhibit less variance in LCC across the region.

Figure 5 - Life Cycle Cost Results for Market Segments 5 and 7 (Single Family, 1900 sq. ft., Electric FAF and Electric Resistance Tank DHW, No Existing Gas Access)



The consideration of risk makes the economically preferred space and water heating system selection more complex. The "unconstrained" LCC analysis favored electric space and water heating systems more frequently than the LCC analysis which was constrained by limiting the standard deviation of economically preferred systems. While the "average" LCC for these electric systems may be lower than gas systems, the variance of such systems across the region is much larger. This is consistent with the earlier observation that there is greater diversity among regional electricity rates than for retail gas prices found across the region. Moreover, it illustrates that the system with the lowest regional average LCC is not a reliable predictor of which system will be most economical for an individual consumer served by specific gas and electric utilities.

Independent of the consideration of risk is the possibility that consumers select their space and water heating systems on the basis of "first cost" or perhaps, consider both the initial cost and life cycle cost when making their decision. Figures 6 plots the first cost of six alternative space and water heating system combinations against their regional average LCC for a 1900 square foot single family home with a forced air furnace with central air conditioning and with existing gas service access.

A review of this graph reveals that gas forced air furnaces with central air conditioning and either a heat pump water heater or condensing gas water heater have very similar LCC and first costs. Figure 7 plots the first cost of six alternative space and water heating system combinations against their regional average LCC for a 1050 square foot multifamily dwelling with zonal electric space heating. For this segment group, retention of a zonal electric heating system in combination with either a heat pump water heater or gas storage tank water heater have similar LCC and first cost. Given this information one might reasonably expect consumers in these two segment groups to select one of these two system combinations based on the fact that they have both the lowest first cost and the lowest life cycle cost.

Figure 6 - Life Cycle Cost vs. First Cost of Alternative Space and Water Heating Systems for a 1900 sq. ft. Single Family Home with Forced Air Furnace and Central Air Conditioning and Existing Gas Service Access

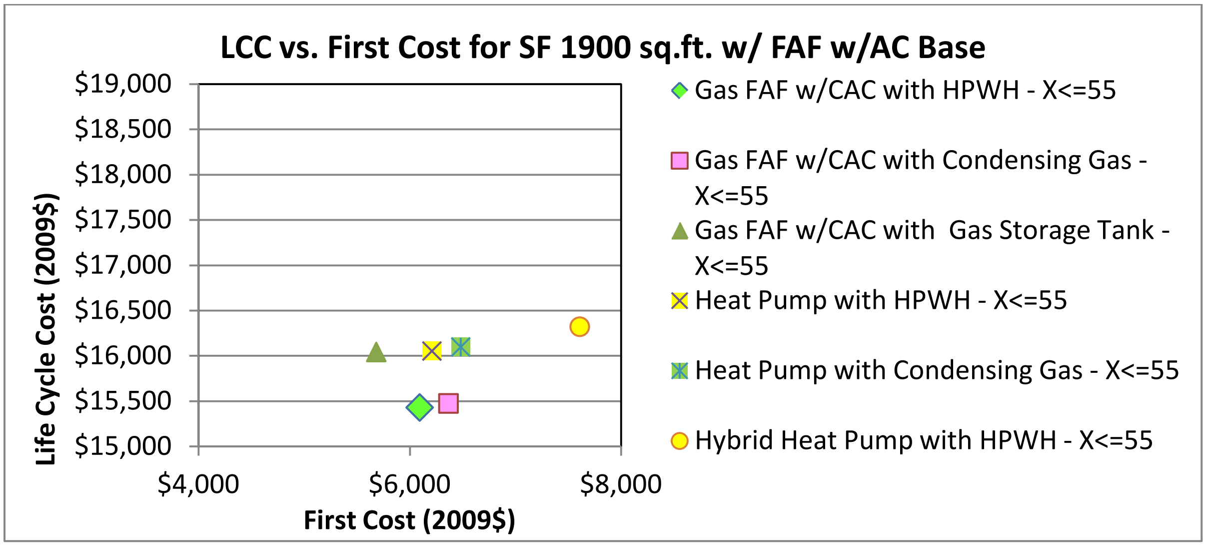
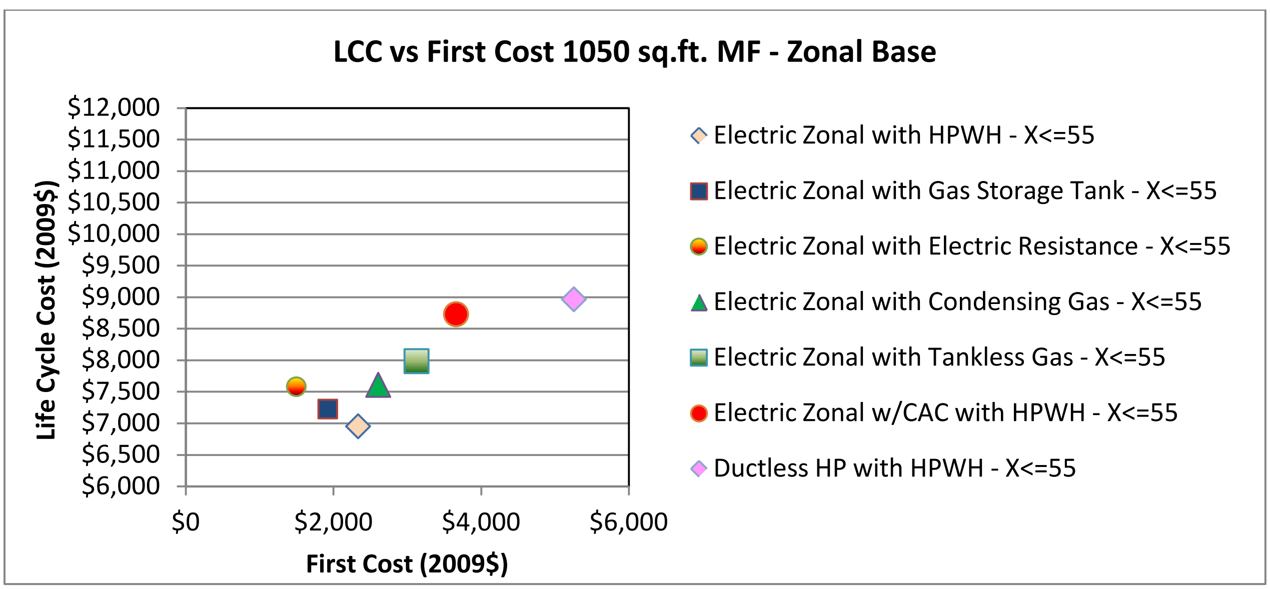


Figure 7 - Life Cycle Cost vs. First Cost of Alternative Space and Water Heating Systems for a 1050 sq. ft. Multifamily Dwelling with Zonal Electric Heating Regardless of Gas Access



Appendix D contains a detailed summary of the first cost and average regional LCC results for all space and water heating system combinations considered in this analysis under both the unconstrained and constrained conditions for each of the six housing types (i.e., two multifamily and four single family homes) used in this analysis.

Impact of Gas Service Extension Cost

The Regional Economic analysis model and the LCC models use identical input assumptions for the first cost and annual operation and maintenance cost of all space and water heating systems. However, the Regional Economic analysis model incorporates estimates of the cost of extending gas service (lines and mains) to homes for those market segments that do not have existing gas service. From a regional perspective, these costs are incurred when a gas line or main is installed to service a home. However, the allocation of gas extension cost to individual consumers who are adding gas service is less clear. The share of gas line extension costs paid by individual consumers varies considerably due to differences distance from a gas main, local soil conditions, access, anticipated gas consumption of the home and other conditions. It also varies across the region due to differences in regulatory policy regarding how such cost allocated across existing and new gas customers.

In order to test the sensitivity of the LCC results to assumption regarding how the cost of new gas service is recovered, two scenarios were analyzed. In Scenario A, the cost of gas service extension to a home without existing gas service was assumed to be recovered entirely from the consumer in that home. In Scenario B, the cost of gas service extension to a home without existing gas service was assumed to be recovered across all gas customers through gas retail rates. These two scenarios bracket the range of cost that might be incurred by an individual consumer adding gas service.

As might be expected, the addition of gas service extension cost to the cost of installing a gas space and/or water heating system significantly alters its LCC. Figure 8 shows the existing market share of gas and electric space heating systems and the market share of these systems in the year 2030 assuming that all consumers select those systems with the lowest regional average LCC under both scenarios. This figure also shows the market share of gas and electric space heating systems by year 2030 assuming consumers selected their space heating systems based on a regional economic perspective (labeled RPM). A review of Figure 8 reveals that under Scenario A the market share of gas forced air furnaces in 2030 remains basically unchanged from existing conditions. In contrast, under Scenario B the market share of gas forced air furnaces increases from around 55 percent today to just over 70 percent by 2030. These two results bracket the 60 percent market share for gas forced air furnaces in 2030 that was produced using the regional economic perspective (RPM).

It is also notable that both the Regional Economic analysis and the consumer LCC analysis indicate that conversion of existing electric forced air furnaces to either natural gas or higher efficiency electric systems reduces both regional and consumer costs. The Regional Economic analysis found that conversion to electric zonal systems was the economically preferred option while the LCC perspective selected heat pumps or ductless heat pumps under Scenario A and gas furnaces and heat pumps/ductless heat pumps under Scenario B. The difference between the Regional Economic analysis and the consumer LCC is a result of restricting the conversion of homes with central forced air systems to systems which also have central forced air (i.e., not zonal or ductless heat pumps) in the LCC analysis. Had this constraint not been in place the LCC results would be similar to the RPM results.

Figure 8 - Comparison of Existing Space Conditioning System Market Share with Market Shares in 2030 for System Selected based on Regional Economic and Consumer Economic Perspective

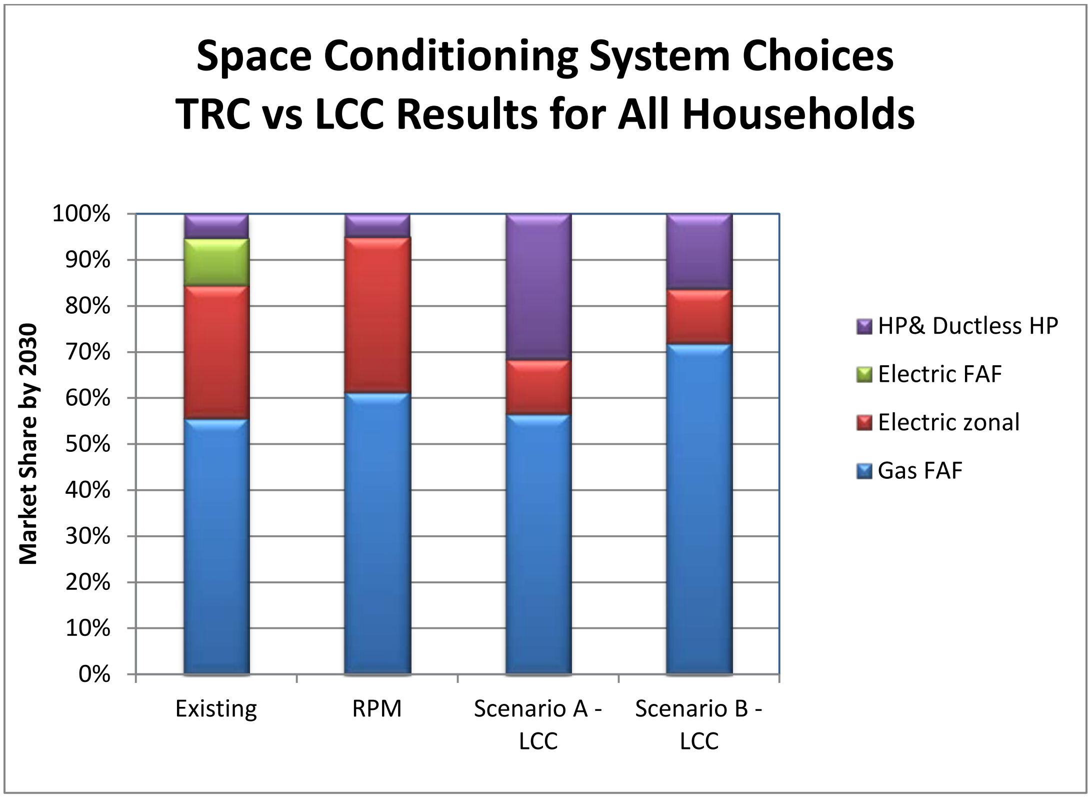
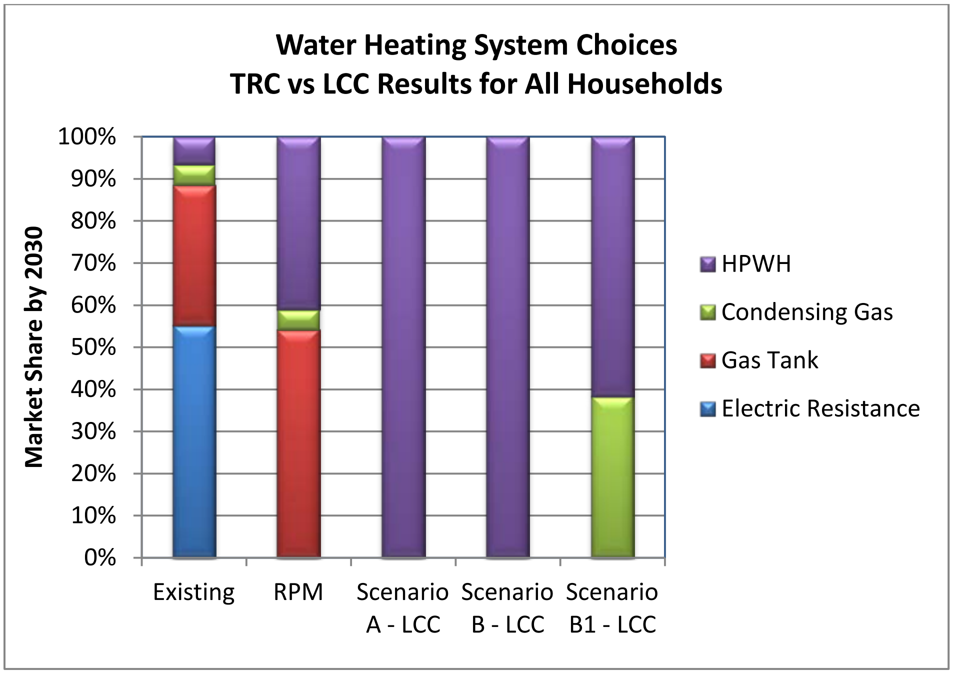


Figure 9 compares the Regional Economic and consumer LCC choices for water heating systems. The water heating equipment choices differ considerably between the two perspectives. The Regional Economic study selected gas tanks; the LCC model chooses a heat pump water heater (HPWH), even under Scenario B, which assumes that the cost of gas access is recovered in retail rates and not wholly from the individual customer. The conversion of all of the region's water heaters to heat pump water heaters over the next two decades is clearly unrealistic. As was shown in Figure 6, inspection of the LCC results revealed that condensing gas water heaters and heat pump water heaters are economically indistinguishable by this model. Given the uncertainties in all of the inputs to the LCC model, small differences in LCC between these two systems should not be viewed as significant. A modification of Scenario B (B1) was made to determine the share of market segments that would adopt a condensing gas water heater if it had a LCC within one percent of the LCC of heat pump water heaters. Under this scenario, nearly 40 percent of water heater replacements would install condensing gas water heaters rather than a heat pump waters.

Figure 9 Comparison of Existing Water Heating System Market Share with Market Shares in 2030 for System Selected based on Regional Economic and Consumer Economic Perspective



What this additional sensitivity analysis reveals is that the economics of these choices are close, similar to the case for the Regional Economic study. In nearly all of these market segments, the "next lowest" LCC cost option for water heating is generally a condensing gas water heater. Typically, only a few hundred dollars out of a total LCC of $6,000 - $15,000 separates these two options. Either heat pump water heaters or condensing gas water heaters will be required to be installed for all tanks above 55 gallons in capacity beginning in 2015. Both of these technologies currently have very small market shares in the region. Therefore, it is too soon to predict which technology will be preferred by the marketplace, especially given their roughly equivalent LCC.

Overall Findings and Recommendations

This review finds that from a regional perspective the vast majority (73%) of households should not convert existing space conditioning or water heating systems. This is particularly true for space heating where 95 percent of households should remain with their current heating fuel. From the Regional Economic perspective, the cost of extending natural gas service to households without service is an economic impediment for electricity customers to change fuels. Similarly, the cost to produce the electricity required to meet the additional demand of the electrical appliance renders conversion from a gas appliance uneconomic for many households. These consumers will nevertheless find significant opportunities for energy efficiency improvements irrespective of their fuel use.

This study finds that about 23% of households would reduce total regional cost by converting either a space heating appliance or a water heating appliance. Most of these opportunities occur for water heating, which accounts for 80 percent of the conversions. These households would see water-heating conversion as attractive from the consumer perspective, at least "on average" across the region. The economic advantages of converting from electric to natural gas water heating, while clear for these households from the regional perspective where gas is available, is more ambiguous from the perspective of individual consumers. Gas (condensing gas water heaters) and electric (heat pump water heaters) technologies are roughly equivalent economically. Therefore, it appears premature to "pick a winner" in the water heating technology race.

Gas forced air furnaces with central air conditioning appear more attractive from both a regional and consumer perspective where gas service is already available. However, from a regional perspective the additional cost of extending gas service results in heat pumps being the economically preferred space conditioning system, while consumers might select the gas forced air furnace with air conditioning when the cost of extending gas service is recovered across all gas sales. Moreover, as in prior Council analysis, this study again found that from a consumer perspective the economic selection of residential space conditioning and water heating systems is highly dependent upon the gas and electric rates of individual consumers. Electric rates, and to some extent gas rates, vary widely across the region. The optimal choice therefore depends on the utility and the climate.

Although this analysis has identified situations where it would be regionally cost-effective to convert fuels, the overall effects on electricity use, natural gas use, and carbon emissions would be negligible. Across all households, regional electric loads decrease around 340 average megawatts or about 1.5 percent of forecast 2030 loads. While natural gas use by customers increases 13 trillion BTU, less natural gas would be used by the power generation turbines that would otherwise have served those electric space and water heating systems. After netting out the 21 trillion BTU decrease of gas use by these turbines, total regional natural gas consumption would be 8 trillion BTU per year, or about 1 percent, less by the end of the 20–year study.

The study does not directly address the issue of whether incentives for improved efficiency of electricity use are affecting consumers' equipment replacement choices, because there is little reliable data on replacement choices at the regional level. Existing fuel shares align well with the results of this analysis indicating that markets have not been seriously distorted by efficiency incentives to date. However, changing market dynamics and asymmetric equipment incentives offered across fuels may impact the conversion market. These potential impacts warrant continued monitoring by the Council and other stakeholders.

With the exception of work underway to evaluate the impact of equipment incentives on the marketplace, the foregoing analysis suggests that policy intervention is not currently necessary to ensure that selection of space and water heating systems found to be least cost/risk from the regional perspective are chosen by consumers. There is general alignment between the systems that are economically preferred from a regional perspective and those that are most economical from the "average" regional consumer's perspective. Further, the fuel conversions that are found to be cost-effective in the analysis would have only very small effects on energy use and carbon emissions. Therefore, the staff recommends that the Council retain its existing policy regarding the direct use of natural gas, including continued monitoring of equipment replacement decisions to ensure that electricity efficiency incentives are not contributing to less efficient fuel choices.

APPENDICES

Appendices A, B, C, E, F, and G are all contained in one Excel workbook. The workbook is available on the Council's website at the following link:
http://www.nwcouncil.org/media/7150427/dugappendicesa_g-exceptd_110411.xlsx
The appendices are separate tabs in the workbook with the appropriate labels. Their contents are described below:

Appendix A - Existing Residential Segment Groups and Economically Preferred Replacement Segments from the Regional and Consumer Perspectives

Appendix B - Conversion Options Considered for Each Residential Segment Group

Appendix C - Space Conditioning and Water Heating Energy Use and System Cost Assumptions

Appendix E - Summary of Distributions for Retail Electricity and Natural Gas Rate and Escalation Rates Used in LCC Analysis

Appendix F - Disposition of Existing Residential Segment Groups Based on Regional Economic Perspective

Appendix G - Projected 2030 Market Share for Space and Water Heating Systems Based on Regional and Consumer Perspective

Appendix D - Life Cycle Cost Results by Dwelling Type for Constrained and Unconstrained Cases. The appendix is available on the Council's website at the following link:
http://www.nwcouncil.org/media/7150429/dugappendixd_lccsystemsummaries_110411.xlsx

Appendix H - Study Constraints on Replacement of Space and Water Heating Systems. Appendix H is included in this document.

Appendix H – Study Constraints on Replacement Space and Water Heating Systems

This analysis did not explore all possible technological options for space and water heating system replacement. It placed constraints on the selection of replacement space and water heating systems. These constraints and the reasoning behind them are detailed below.

1. Exclude from consideration all **gas hydronic space heating**, both as existing and as a retrofit technology. Reason: This segment is very small and the economic hurdle for adopting a different heating appliance is too high.
2. Limit zonal electric system replacement options to **ductless heat pumps** instead of conventional a heat pump as a retrofit space heater. Other central forced air heating systems are available as replacement options for zonal electric. Reason: Ductless heat pumps do not require the expense of installing ductwork, but it was not viewed as providing equivalent consumer utility in situations where a heat pump or furnace with central air conditioning system are already present.
3. Limit selection of water heaters to **high-efficiency condensing gas, tankless gas,** and **heat pump water heaters** (**HWPH)** equipment options as replacement for water heaters with capacity over 55 gallons. Reason: The efficiency levels required by the 2015 federal standards preclude the use of lower efficiency electric resistance and non-condensing gas storage tank water heaters.
4. Assume **high-efficiency condensing gas, tankless gas and heat pump water heaters** are available for selection irrespective of tank size. Reason: While federal standards will limit the selection of replacement water heaters to **high-efficiency condensing gas, tankless gas,** and **heat pump water heaters** (**HWPH)** for tank capacities over 55 gallons, these technologies are available for use by consumers with smaller tank sizes.
5. Exclude hot water heaters over 55 gallons from multi-family households. Reason: Multi-family housing is smaller and has occupants than single-family homes.
6. Only households with existing gas service or the potential for economic gas service as the potential population for consideration in this study. Reason: Households without potential for economic gas service (i.e., no natural gas service available via a main extension) only have the option of upgrading the efficiency of the electric space and water heating systems.
7. Exclude existing **zonal space heating** conversions to **electric FAF**. Reason: Replacement of an electric FAF with a zonal electric space heating increases cost and annual energy use, hence it would never be selected as a more economic option.
8. Assume segment groups without air conditioning and without a heat pump for space conditioning will not add air conditioning in conversion. Segment groups with air conditioning or heat pumps will always replace the air conditioners in kind or choose heat pumps for space conditioning. Consequently, segment groups without existing heat pumps can ignore cost, efficiency, and power usage assumptions for air conditioning. Reason: The cost and energy consumption of the AC will be a wash. We assume only one kind of AC appliance. Existing heat pumps, on the other hand, introduce a connection between heating and cooling cost and service.

9. Assign no credit for or value to the cooling service of heat pumps, if they are chosen for a segment that does not have an existing heat pump.[13] Include, however, the energy requirements associated with the cooling load in the economic assessment. Reason: While we recognize the inconsistency and bias against conversion to heat pumps, we believe the information necessary to properly discount the heat pump cost and energy does not exist. The RTF, moreover, has indicated they would prefer not to assign a value to the cooling service.
10. Exclude **gas/HP hybrid** as an explicit retrofit appliance. Reason: Initially, we excluded this option because we did not have adequate cost or performance data. For the final analysis, this system was included in the consumer LCC analysis. Based on the economic and efficiency data provided by stakeholders this system was not found to be economically competitive with alternative systems. Given the general alignment between the LCC and RPM findings it is highly unlikely that these systems would be selected as an economically preferred option by the RPM.

The possible value for each field that describes a segment appears below.

	Existing SH	Existing WH	Retro SH	Retro WH	Water heater size	Household	Basement	Gas Availability	Air conditioning
number	4	2	5	5	2	2	2	3	2
	FAF Electric	Electric Resistance	FAF Electric	Electric Resistance	X<=55	SF	Yes	M	Yes
	Heat Pump	Gas Tank	Heat Pump	HPWH	X>55	MF	No	E	No
	Zonal Electric		Ductless HP	Gas Tank				Existing	
	Gas FAF		Zonal Electric	Instant Gas					
			Gas FAF	Condensing Gas					

Figure 4: Possible Values for Each Field Describing a Segment

With the constraints enumerated above, the number of segments is reduced to 1,470 from 9,600.

Source: q:\MS\Plan 6\Studies\Model Development\Direct Use of Gas\101004 Study\Developing new segment groups\Development of segments 110112.docx)

[13] After the study, it was observed that if we wished to know how heat pump replacement faired if the cooling service were considered, we can look at those segments ***with*** existing AC. For all segments without existing heat pump, there are two segment segments that are identical except for existing AC. Of course, if a segment has an existing heat pump space heater, the issue is moot. The replacement must have AC.