ENERGY FUTURES GROUP

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Comparative Analysis of Fuel-Switching from Oil or Propane to Gas or Advanced Electric Heat Pumps in Vermont Homes

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This report documents the results of a comparative assessment of the impacts of fuel-switching residential oil or propane space heating in Vermont to either gas heating or electric heating using cold climate ductless heat pumps. I have done the analysis from both a customer economics and a societal economics perspective. In both cases, I have used a 30 year analysis period for a fuel switch taking place in 2017, using a 3% real (i.e. after adjusting for inflation) discount rate (same as VGS in its analyses). I have also looked at the difference in impacts on carbon emissions. Note that my analysis does not address cooling. Nor does it address water heating energy use. It is likely that most homes that switch to gas for space heating will do so for water heating as well, and there are likely to be some economic benefits from such a switch. However, there are also potentially significant benefits from switching to electric heat pump water heaters as well.

What follows is a brief description of the approach and key assumptions I used, as well as the results.

Customer Economics

The analysis of the customer economics is based heavily on forecasts of future energy prices. I start with an average of the monthly energy prices for the past winter (November 2013 through March 2014) for fuel oil, propane and electricity from the Vermont Public Service Department monthly Vermont Fuel Price Report.[1] For the gas price I use the combination of fixed monthly charges plus variable charges per therm used by Vermont Gas in its analysis of the pipeline project impacts. The resulting total gas cost per therm, for the estimated average baseline heating energy consumption that I assume (90 million BTUs) is very close to the DPS reported average values. These current prices are summarized in Table 1 below. Note that they are higher for oil and (even more so) for propane than the October 2013 values used by VGS in its analysis.

Table 1: Vermont 2013-2014 Winter Fuel Prices

Fuel	Price
Oil (per gallon)	$3.88
Propane (per gallon)	$3.42
Natural Gas (per therm)	$1.56
Electricity (per kWh)	$0.15

Those starting prices were then adjusted for future years based on the U.S. Energy Information Administration's Annual Energy Outlook (AEO) 2014 price forecast for the New England

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[1] http://publicservice.vermont.gov/publications/fuel_report

residential sector through 2040.[2] Since we wanted to use a 30 year analysis period for installations that take place in 2017, we extended the AEO forecast to 2046, assuming that the annual increase from 2039 to 2040 would apply in subsequent years as well. Note that VGS used AEO 2013 forecast in the same way in their analysis (which was completed before the AEO 2014 forecast was available). A summary of the average annual rates of increase in forecast prices is shown in Table 2. Note that these are increases in *real* prices – i.e. positive values mean an increase above the average inflation rate for the economy as a whole.

Table 2: Forecast Average Annual Real Fuel Price Changes

	2014 to 2023	2024 to 2033	2034 to 2046
Oil	0.4%	0.7%	0.6%
Propane	-0.3%	1.3%	1.5%
Natural Gas	1.4%	1.7%	2.1%
Electricity	0.1%	0.8%	1.3%

As noted above, my analysis assumed that the average Vermont home that would fuel switch currently consumes approximately 90 MMBtu of fuel annually for space heating. That is a little more than VGS's assumed 100 MMBtu for both space heating and water heating (since water heating usage is typically between 15 and 20 MMBtu per year). However, the U.S. Energy Information Administration's Residential Energy Consumption Survey suggests that the average single family oil-heated home in New England consumes a little more than 80 MMBtu for space heating[3] and we would expect consumption in Vermont, where it is colder than much of the rest of New England, to be a little higher.

For homes that fuel-switch to natural gas and install a new natural gas boiler I assume that average annual heating fuel consumption does not change. That is based on the fact that a recent study of the efficiency of existing homes in Vermont found that the average existing oil boiler in the state had an efficiency of 85% and the average propane boiler had an efficiency of nearly 87%[4] - in the range of what we would expect the average new gas boiler to be. For homes that didn't install a new boiler, but instead installed a gas conversion burner on their existing boiler, I also assumed no change in efficiency. For the costs of the conversion we assume a new gas boiler cost of $4500 and an average annual rental cost of $240 – both the same as assumed by VGS. However, I also assume that, on average, the home would have had

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[2] http://www.eia.gov/oiaf/aeo/tablebrowser/#release=AEO2014ER&subject=0-AEO2014ER&table=3-AEO2014ER&region=1-1&cases=ref2014er-d102413a

[3] See table CE4.7: http://www.eia.gov/consumption/residential/data/2009/index.cfm?view=consumption#end-use

[4] NMR Group et al., "Vermont Single-Family Existing Homes Overall Report, Final", submitted to the Vermont Public Service Department, 6/13/2013.

to install a new oil or propane boiler in 10 years (assuming that the average boiler has a life of 20 years and that the average boiler is about half way through its life). Thus, homes that install a new gas boiler as part of the fuel switch receive a credit for pushing out the timeframe for the need for the next new boiler (from year 10 to year 20) and homes that install a conversion burner are only assumed to need it for 10 years. Under the customer economics analysis, none of the costs of either the pipeline extension or connecting the home to the pipeline are assumed to be borne by the new gas customers. Rather, they are assumed to be socialized across all gas customers. I have not accounted for any impact on rates that might have.

For the analysis of fuel-switching to a cold climate ductless heat pump, I assumed that the installation would be a multi-head (e.g. 3-head) system. The cold climate versions of those systems are expected to hit the market in late 2014. A recently completed Northeast Energy Efficiency Partnerships field study of cold climate heat pumps in central New Hampshire suggests that the fuel oil or propane savings from single-head systems averaged the equivalent of roughly 40 MMBtu (assuming an average annual COP of 2.8, a little lower than the Vermont PSD assumption of 3.0 as shown on its monthly Vermont Fuel Price Reports)[5] – or about 45% of the 90 MMBtu we have assumed for the average home. Based on professional judgment and conversations with Mitsubishi staff, I assume that a 3-head system would meet about 80% of the heating needs of a home; the remainder would still be met with fuel oil or propane. Again based on conversations with Mitsubishi staff, I assume that the cost of a three-head system would be about $6000 – or roughly double the current cost of a single-head system (costs do not increase linearly with number of heads). Alternatively, the same portion of heating load could be met at approximately the same level of efficiency with three single-head units of the type that are on the market today, but at a cost of about $3000 more per home. Because a heat pump is assumed to have a life of only 15 years, the analysis includes an additional cost to replace the unit once during the 30 year analysis period.

The net effect of this analysis is that both a full fuel switch to gas and a partial fuel switch to a cold climate ductless heat pump should be very attractive to consumers. Per BTU of oil or propane displaced, the net present value (NPV) of the net benefits to customers of a ductless heat pump are slightly higher than for the gas fuel switch. However, because the gas fuel switch displaces all the previously used oil or propane (rather than just the majority of it with the heat pump), its total net benefits to customers are a little larger given the fuel price and other assumptions noted above. These results are summarized in Table 3 below.

Table 3: Customer Economics of Fuel Switch from Oil/Propane (2014 dollars)

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[5] The study found that the average metered heat pump consumed 3421 kWh per year on a weather-normalized basis (see: http://www.neep.org/Assets/uploads/files/emv/emv-library/NEEP%20DHP%20Report%20Final%205-28-14%20and%20Appendices.pdf). Using the same study's average seasonal heat pump COP of 2.8 and an average fossil fuel heating system seasonal efficiency of 80% (consistent with an average boiler efficiency rating of 85%, adjusted down five percentage points for distribution system losses), that equates to 41 MMBtu/year.

Starting Fuel	30 Year NPV		NPV per MMBtu Displaced	
	Switch to Gas	Switch to Electric	Natural Gas	Heat Pump
Oil	$15,527	$12,641	$173	$176
Propane	$34,923	$28,159	$388	$391

Societal Economics

For the assessment of societal economics, I used Efficiency Vermont's cost-effectiveness screening tool, which includes forecast avoided costs (not the same as retail rates/prices used in the customer economics analysis described above) and a carbon dioxide emissions externality cost of $100/ton. The avoided costs are based on the 2013 regional avoided cost study (which includes Vermont-specific values).[6] Note that the screening tool also typically uses a 10% risk discount on costs and a 15% non-energy benefits adder. However, those values are meant to reflect additional benefits of efficiency measures which are arguably not present in the same way or magnitude for pure fuel-switching projects. Thus, I have eliminated those adjustments in our analysis.

Almost all of the other assumptions in our analysis – including the costs of gas conversion burners or new boilers, the costs of a ductless heat pump, the magnitude of the oil/propane savings from both a full gas fuel switch and a partial heat pump fuel switch, etc. – are the same as in the customer economics assessment. The only notable difference (other than the use of societal avoided costs rather than customer energy costs) is that the societal economics includes a $1600 cost for connecting the home to the gas distribution system. I have not added any additional costs associated with the pipeline and distribution system build-out. That potentially makes my analysis of the societal economics of the gas fuel switch look better than it actually would be. With that important caveat, the results of my societal economics assessment are presented in Table 4 below.

Table 4: Societal Economics of Fuel Switch from Oil/Propane (2012 dollars)

Starting Fuel	30 Year NPV		NPV per MMBtu Displaced	
	Switch to Gas	Switch to Electric	Natural Gas	Heat Pump
Oil	$24,579	$24,891	$273	$341
Propane	$21,786	$22,629	$242	$310

A couple of aspects of the results of the societal screening, in comparison to the customer economics assessment, merit discussion.

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[6] http://publicservice.vermont.gov/sites/psd/files/Topics/Energy_Efficiency/AESC%20Report%20-%20With%20Appendices%20Attached.pdf

First, unlike the under the customer economics assessment, the societal analysis suggests that it is more cost-effective to switch from oil than from propane. This appears to be a function of the different fuel costs in the two assessments. As noted above, for the customer economics assessment we used current average Vermont fuel prices and modified them over the next several decades based on the AEO 2014 forecast. The Efficiency Vermont screening tool used for the societal economics assessment uses forecast fuel prices from the regional avoided cost study. For fuel oil, the two sets of forecast prices are very similar. However, the propane fuel costs used in the customer economics assessment are considerably higher (35-40% higher on an NPV basis for our analysis period of 2017 to 2046) than those in the Efficiency Vermont screening tool. That is largely a function of the fact that the customer economics assessment uses actual propane costs from the most recent winter, which were about 40% higher than the 2013 avoided cost study forecast; the escalation rates for future (post-2014) propane prices are similar in both analyses.

Second, though the fuel oil prices used in both the customer economics and societal economics analyses are roughly similar, the fuel switch from oil to gas has greater net benefits under the societal assessment. This appears to be because the avoided gas costs in the societal screening tool are about 20% lower than the gas costs used in the customer economics assessment. The societal avoided costs are actually quite similar to the variable portion of the customer costs. However, the customer costs also include non-trivial fixed monthly charges. Some portion of those fixed monthly charges – e.g. for meter reading, billing and customer service – are societal costs. However, the scope of this analysis was too limited to allow quantification of those costs, so they are not included in the results provided above (making the gas fuel-switch appear slightly more attractive societally than it should).

Finally, the heat pump fuel switch looks better under the societal economics assessment. Under the customer economics assessment, the NPV of net benefits was 19% lower for the heat pump fuel switch than for the gas fuel switch. Under the societal assessment, the net benefits of the heat pump fuel switch are 1-4% greater than the net benefits of a gas fuel switch. A major factor in these differences is that the societal cost of increased electricity consumption for space heating are 40-50% lower than the retail electric rates used for the customer economics assessment.

Carbon Emissions Impacts

In addition to the economic analysis, I also did a quick comparative assessment of the impact of fuel switching to gas or heat pump heating on carbon emissions. For that assessment I used the same carbon dioxide emission rates for oil, propane and natural gas that are used in the Efficiency Vermont screening tool. Note that those rates only account for emissions associated with the actual burning of the fuel. For electricity, I used the Vermont-specific marginal emission rates at the generator that were estimated in the regional 2013 avoided costs study and increased them by marginal winter line loss rates. Table 5 provides a summary of the resulting emission rate assumptions.

Table 5: Carbon Dioxide Emission Rate Assumptions for Different Fuels

Fuel	Starting Assumption	Tons per MMBtu Input	Average Heating System Efficiency	Tons per MMBtu Output
Oil	73.15 kg/MMBtu	0.080	80%	0.101
Propane	63.07 kg/MMBtu	0.069	80%	0.087
Natural Gas	53.06 kg/MMBtu	0.058	80%	0.073
Electricity	1117 lb/MWh	0.164	280%	0.058

As Table 5 shows, the emissions rate per MMBtu of fuel consumed is highest for electricity. However, one must also adjust these rates to reflect the average seasonal efficiency of the heating systems that would be installed with each fuel to obtain rates per unit of heat produced. The most efficient heating system for oil, propane and natural gas are all less than 100%. In contrast, the average COP for the heat pumps analyzed in this assessment is 2.8, or essentially 280% efficient. As a result, the carbon dioxide emissions per unit of heat produced is actually lowest for heat pumps (about 20% lower than for natural gas). Thus, as shown in Table 6, I estimate the reduction in carbon emissions from the partial fuel-switch to electricity to be greater than the carbon emission reductions from a full fuel switch to natural gas.

Table 6: Carbon Emission Reductions from Fuel Switching to Gas or Heat Pump

Baseline Fuel	New Heating Fuel	
	Natural Gas	Electric Heat Pump
Oil	27%	34%
Propane	16%	26%

Conclusions

The results presented above lead to some interesting high level conclusions:

- There is a significant difference between customer economics and societal economics when analyzing the relative cost-effectiveness of fuel switching to gas vs. fuel switching to ductless heat pumps. In general, public policy decisions should be made on societal economics.
- Under societal economics, the cost-effectiveness of fuel-switching to a ductless heat pump appears to be at least comparable to the cost-effectiveness of fuel-switching to natural gas. And that is before accounting for any portion of the cost of building

pipeline and other infrastructure (other than the service line to the house which we have included in our analysis) associated with getting gas to new residential customers.

- Fuel-switching to cold climate ductless heat pumps appears to lead to fewer greenhouse gas emissions under current marginal emission rates for electricity. It is difficult to forecast how marginal electric emission rates will change in the future. However, if there is eventually serious effort to address climate change, they could conceivably improve. My analysis assumes no such improvement.
- The analysis of the relative benefits of gas and heat pump fuel switches are sensitive to a variety of assumptions, particularly future fuel prices and the portion of the home that can be heated by a three-head ductless heat pump.