APPENDIX B

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ENERGY

Residential End Uses: Area 2: Incremental Installed Costs for Efficiency Upgrades

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EIA seeks improved estimates of the costs associated with fuel switching for certain types of residential equipment.

» Objectives for Area 2: Identify costs associated with switching fuels and equipment types for residential:
  – Space heating
  – Space cooling
  – Water heating
  – Cooking
  – Clothes dryers

» Includes costs in addition to the equipment itself, such as:
  – Ductwork
  – Piping
  – Exhaust
  – Other installation and removal costs associated with fuel switching

» Does not include costs associated with bringing natural-gas service to the home, as clarified during the project kick-off meeting

» Costs may be specific to the equipment being installed

» Use national-average costs, but identify any cases that warrant regional detail or other special consideration

We used a multi-step process to estimate fuel-switching costs.

	Step	Description
1	Generate fuel switching matrix template	Template includes baseline technologies and replacing technologies for each fuel type, and allows presentation of all possible fuel switching scenarios.
2	Prioritize fuel switching scenarios	Grade each fuel switching scenario as high, medium, or low priority based on attractiveness of technology switch according to potential for primary energy savings or reduced fuel costs.
3	Identify fuel switching activities and costs.	These activities include items such as installation of new fuel lines, new electrical wiring, and fuel tank removal.
4	Identify equipment costs of each high and medium priority fuel switching scenario.	These activities include removal of baseline equipment, purchasing price of new equipment, and installation of new equipment.
5	Aggregate fuel switching costs and equipment costs.	Combine costs from steps 3 and 4 for all high and medium priority scenarios in template.

We applied several assumptions to obtain estimates.

» Key Assumptions:

- Existing chimneys or flues, if no longer used, will not require removal
- Estimates based on switching fuels for a single equipment type (such as space heating)
  - Often, the incremental costs for switching fuels for another equipment type will be small if both existing equipment types use the same fuel and are switched to the same fuel
- Existing fuel tanks are sized to meet the requirements of the equipment type being replaced
  - For example, we assume that a propane tank supplying a stove would be much smaller than one supplying a space-heating system
- All units are assumed to have typical sizes and capacities for residential applications according to the EIA 2013 Technology Forecasts

In step 1, we created the fuel switching matrix template of baseline technologies and high efficiency technologies.

Table 1—Representative example of fuel switching template for Clothes Dryers

			Switching FROM this equipment			
			Electric		Natural Gas	LPG
			Combined Energy Factor (CEF) 3.73	Heat Pump CEF 5.43	CEF 3.3	CEF 3.3
Switching TO this equipment	Electric	CEF 3.81				
		Heat Pump CEF 5.43				
	Natural Gas	CEF 3.61				
	LPG	CEF 3.61				

All of these efficiency levels correspond to the 2015 minimum efficiency standard except for the heat pump clothes dryer, which is the only efficiency level available for this technology

All of these efficiency levels correspond to "High" efficiency units from the EIA 2013 Technology Forecast except for the heat pump clothes dryer, which is the only efficiency level available for this technology.

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In step 2, we prioritized the fuel switching scenarios to place priority on the scenarios that are most likely to be of interest.

Priority Level	Criteria	Example
High	Scenarios that are most likely to lead to significant primary energy savings and attractive economics.	Liquefied Petroleum Gas (LPG) Furnace to an Electric Heat Pump *The high efficiency heat pump will save energy, and ducts are already in place.*
Low*	Scenarios that will likely lead to increased primary energy consumption and/or increased energy costs with no commensurate non-energy benefits.	Natural Gas Furnace to LPG Condensing Furnace. *The furnace will save energy. However, the cost of fuel will increase.*
Medium	All remaining scenarios, many of which are challenging installations.	Electric Baseboard to a Condensing Furnace. *The furnace will save energy. However, the cost of retrofit construction for ducts is very difficult to estimate, and likely prohibitively expensive.*

*Because low priority scenarios are very unlikely to be of interest to a consumer, we excluded these from the rest of the analysis.

In step 3, we identified the activities and costs associated with fuel switching.

Table 2—Representative example of fuel switching costs for space heating

Switching TO This Fuel	Switching FROM This Fuel					
	Electricity	Natural Gas	Kerosene	LPG	Distillate	Wood
Electricity		$900.00	$1,700.00	$1,700.00	$1,700.00	$900.00
Natural Gas	$800.00		$1,600.00	$1,600.00	$1,600.00	$800.00
Kerosene						
LPG	$2,800.00	$2,800.00	$3,600.00		$3,600.00	$2,800.00
Distillate	$2,500.00	$2,500.00	$3,300.00	$3,300.00		$2,500.00
Wood	$1,500.00	$1,500.00	$1,500.00	$1,500.00	$1,500.00	

Installation Step	Cost (2014 $)
Remove LPG tank--Above Ground	$800
Wiring that can supply 240 V	$900

This is the break-down of installation steps for converting from an LPG heating system to an Electric heating system. All other fuel switching scenarios have a similar break-down.

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In step 4, we next consider old equipment removal costs, new equipment cost, and associated installation costs.

Table 3—Representative Example of switching from an LPG furnace to an Electric Heat Pump:

Removal of Existing Equipment		
Equipment	**Cost 2014 $**	**Description**
LPG Furnace 78% AFUE	$200	Labor costs of removal, including overhead and profit, trip charge, and removal/disposal fees.

Total Installed Cost of Replacement High Efficiency Equipment (includes both installation cost and equipment cost)		
Equipment	**Cost 2014 $**	**Description**
Electric Heat Pump SEER 14.5, HSPF 8.2	$3500	Install outdoor and indoor units, connect refrigerant tubing, evacuate system, charge refrigerant, startup and test run

Finally in step 5, we aggregate the fuel switching costs and equipment costs to get the total cost of the fuel switching scenario.

Table 4—Representative Example of switching from an LPG furnace to an Electric Heat Pump:

Installation Activity	Cost (2014$)
Remove LPG Tank—Above Ground	$800
Remove LPG Furnace	$200
Install wiring that can supply 240 V	$900
Purchase and Install Electric Heat Pump	$3500
Total Cost for switching from an LPG furnace to an Electric Heat Pump	**$5400**

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Completed fuel switching matrix for space heating

Table 5—Space Heating Fuel Switching Matrix

Switching TO this equipment			Switching FROM this equipment: Electric					Natural Gas			Kerosene	LPG	Distillate		Wood
			Furnace AFUE 99%	Baseboard AFUE 98%	Heat Pump SEER 13 HSPF 7.7	Ductless Mini-split SEER 13 HSPF 7.7	Ground Source Heat Pump COP 3.1 EER 13.4	Furnace 78% AFUE	Boiler 82% AFUE	Absorption Heat Pump Heating COP 1.3 Cooling COP .6	Furnace 83% AFUE	Furnace 78% AFUE	Furnace 83% AFUE	Boiler 84% AFUE	Cordwood Stove Non-Catalytic HHV 63
	Electricity	Furnace 99%AFUE						2,200	4,300		3,000	3,000	3,000	4,800	2,000
		Baseboard AFUE 98%						3,100	3,700		3,900	3,900	3,900	4,200	2,900
		Heat Pump SEER 14.5, HSPF 8.2	3,700	5,300	3,600	5,100		4,600	6,700		5,400	5,400	5,400	7,200	4,400
		Ductless Mini-split SEER 18, HSPF 9	4,000	4,100	3,900	3,900		4,900	5,500		5,700	5,700	5,700	6,000	4,700
		Ground Source Heat Pump COP 3.6, EER 17.1	18,000	19,600	17,900	19,400	17,800	18,900	21,000		19,700	19,700	19,700	21,500	18,700
	Natural Gas	Furnace 90% AFUE	3,400	5,000	3,300	4,800		2,600	4,700		4,200	4,200	4,200	6,000	3,200
		Non-Condensing Furnace 80% AFUE	2,500	4,100	2,400	3,900		1,700	3,800		3,300	3,300	3,300	5,100	2,300
		Boiler 90% AFUE	13,100	13,200	13,000	13,000		12,300	5,900		13,900	13,900	13,900	7,200	5,900
		Non-Condensing Boiler 82% AFUE	12,000	12,100	11,900	11,900		11,200	4,800		12,800	12,800	12,800	6,100	4,800
		Absorption Heat Pump Heating COP 1.3 Cooling COP .6	14,300	15,900	14,200	15,700		13,500	15,600	13,700	15,100	15,100	15,100	16,900	14,100
	Kersosene	Furnace 85% AFUE													
	LPG	Furnace 90% AFUE	5,400	7,000	5,300	6,800					6,200	2,600	6,200	8,000	5,200
		Non-Condensing Furnace 80% AFUE	4,500	6,100	4,400	5,900					5,300	1,700	5,300	7,100	4,300
	Distillate	Furnace 85% AFUE	6,700	8,300	6,600	8,100					7,500	7,500	4,200	6,000	6,500
		Boiler 86% AFUE	15,300	15,400	15,200	15,200					16,100	16,100	12,800	6,100	8,100
	Wood*	Cordwood Stove Non-Catalytic HHV 63	9,100	9,100	9,100	9,100	9,100	9,100	9,100	9,100	9,100	9,100	9,100	9,100	9,100

We made additional assumptions specific to the space heating fuel switching scenarios.

- For scenarios involving distillate, LPG, and kerosene, the matrix above uses costs of removal and installation of above ground fuel tanks.
- For switching to a wood stove, we assumed that the existing heating system would remain in place as a back up to the wood stove.
  - Although central wood furnaces exist, we estimated costs for wood stoves because they are more common, and therefore a better representation of the wood heating market.
- For scenarios where the appropriate heat distribution system was not already in place, we assumed an additional cost of duct work to be $1500 and an additional cost for piping in a hydronic system to be $7000 according to internet sources.
  - These are difficult costs to obtain because they are rare installations in retrofit applications. The costs of these installations can vary significantly depending on the house characteristics.
- For scenarios in which the home is switching to an electric heating system, assume that the service panel does not require an upgrade. There will be an additional cost in situations where the retrofit requires a service panel upgrade.

Completed fuel switching matrix for water heating

Table 6—Water Heating Fuel Switching Matrix

Switching TO this equipment			Switching FROM this equipment						
			Electricity	Natural Gas		LPG		Distillate	Solar
			Storage EF .945	Storage EF .60	Tankless EF .82	Storage EF .60	Tankless EF .82	Storage EF .62	Storage Solar EF 1.8
	Electricity	Storage EF 2	1,600	1,800	1,800	2,000	2,000	2,700	
		Storage EF .92	600	800	800	1,000	1,000	1,700	
	Natural Gas	Storage EF .8	2,700	1,900	1,900	2,900	2,900	3,600	
		Non-Condensing Storage EF .65	2,400	1,600	1,600	2,600	2,600	3,300	
		Tankless EF .92	3,800	3,000	3,000	4,000	4,000	4,700	
		Non-Condensing Tankless EF .82	3,300	2,500	2,500	3,500	3,500	4,200	
	LPG	Storage EF .8	3,300			1,900	1,900	4,200	
		Non-Condensing Storage EF .65	3,000			1,600	1,600	3,900	
		Tankless EF .92	4,400			3,000	3,000	5,300	
		Non-Condensing Tankless EF .82	3,900			2,500	2,500	4,800	
	Distillate	Storage EF .68	4,700			4,900	4,900	2,300	
	Solar	Storage Solar EF 2.5	9,100	9,100	9,100	10,400	10,400	10,200	8,900

We made additional assumptions specific to the water heating fuel switching scenarios.

- Cost estimates assume that existing fuel system is for water heating only. This will not be the situation in many cases. In many cases, the water-heating and space-heating fuels will be switched together. In these cases, the incremental costs of switching the water-heating fuel will typically be small.
- For scenarios involving distillate and LPG, the matrix above uses costs of removal and installation of above ground fuel tanks. We assumed that fuel tanks for water heating would rarely be underground, unless they are for the space-heating as well.
- Solar water heaters typically have a backup water heating system. For this analysis, we made the following assumptions when switching to a solar water heating system about the back up system:
  - Switching from an electric system, assume electric backup
  - Switching from a natural gas system, assume natural gas backup
  - Switching from an LPG or distillate system, assume electric backup

Completed fuel switching matrix for cooking stoves

			Table 7—Cooking Stoves Fuel Switching Matrix				
			Switching FROM this equipment				
			Electric			Natural Gas	LPG
			Coil EF .737	Smooth EF .742	Induction EF .84	EF .399	EF .399
Switching TO this equipment	Electric	Coil EF .769	300	300		500	550
		Smooth EF .753	600	600		800	850
		Induction EF .84	800	800	800	1,000	1,050
	Natural Gas	EF .420	1,200	1,200	1,200	400	1,250
	LPG	EF .420	1,300	1,300	1,300		400

We made additional assumptions specific to the cooking stoves fuel switching scenarios.

- Cost estimates assume that existing fuel system is for cooking stoves only. This will not be the situation in many cases. In many cases, the cooking stoves and space-heating fuels will be switched together. In these cases, the incremental costs of switching the cooking fuel will typically be small.
- Big box retailers typically do not charge for removal of home appliances when they perform home delivery. Therefore, we assumed no added cost of removal of existing equipment.

Completed fuel switching matrix for clothes dryers

Table 8—Clothes Dryers Fuel Switching Matrix						
			Switching FROM this equipment			
			Electric		Natural Gas	LPG
			CEF 3.73	Heat Pump CEF 5.43	CEF 3.3	CEF 3.3
Switching TO this equipment	Electric	CEF 3.81	600		800	850
		Heat Pump CEF 5.43	1,800	1,800	2,000	2,050
	Natural Gas	CEF 3.61	1,600	1,600	800	1,650
	LPG	CEF 3.61	1,700	1,700		800

We made additional assumptions specific to the clothes dryers fuel switching scenarios.

» Cost estimates assume that existing fuel system is for clothes dryers only. This will not be the situation in many cases. In many cases, the clothes dryer and space-heating fuels will be switched together. In these cases, the incremental costs of switching the clothes dryer fuel will typically be small.

» All estimates are for standard sized vented dryers because these are more common than vent-less compact units.

References—Published Reports

1. EERE. (2011). *Technical Support Document: Energy Efficiency Program for Consumer Products: Residential Central Air Conditioners, Heat Pumps, and Furnaces Including: Market and Technology Assessment, Shipments Analysis*
2. EERE. (2014). *Technical Support Document (NODA): Energy Efficiency Program for Consumer Products: Residential Boilers Including: Market and Technology Assessment, Shipments Analysis.*
3. EERE. (2009). *Technical Support Document: Energy Efficiency Program for Consumer Products: Residential Water Heaters, Direct Heating Equipment, and Residential Pool Heaters Including: Market and Technology Assessment, Shipments Analysis*.
4. EERE. (2012). *Technical Support Document: Energy Efficiency Program for Consumer Products: Residential Dishwashers Including: Market and Technology Assessment, Shipments Analysis.*
5. EERE (1996). *Technical Support Document for Residential Cooking Products: Volume 2: Potential Impact of alternative Efficiency Levels for Residential Cooking Products*.
6. EERE. (2011). *Technical Support Document: Energy Efficiency Program for Consumer Products: Residential Clothes Dryers and Room Air Conditioners Including: Market and Technology Assessment, Shipments Analysis.*
7. Evergreen Economics. (2012) *Northwest Ductless Heat Pump Initiative: Market Progress Evaluation Report#2.* NEEA
8. Navigant Consulting Inc. (2013). *EIA—Technology Forecast Updates—Residential and Commercial Building Technologies—Reference Case.* EIA.
9. Navigant Consulting, Inc. (n.d.). In House Expertise.

References—Internet Resources

1. Homewyse. *Cost to Install Electrical Wiring*. http://www.homewyse.com/services/cost_to_install_electrical_wiring.html
2. Homewyse. *Cost to Upgrade an Electrical Service Panel.* http://www.homewyse.com/services/cost_to_upgrade_electrical_service_panel.html
3. Houselogic. *Should You Convert from Oil to Gas Heating.* http://www.houselogic.com/home-advice/heating-cooling/should-you-convert-oil-gas-heating/
4. Green Bay Gas. *Residential Propane Service.* http://www.greenbaygas.com/residential-propane-sales.html#customer-owned-service
5. Cost Helper. *Heating Oil Tank Cost*. http://home.costhelper.com/heating-oil-tank.html
6. FIXR. *Chimney Installation Cost*. http://www.fixr.com/costs/chimney-installation
7. Thrifty Propane. *Buy a Tank*. http://www.thriftypropane.com/purchasetank.aspx
8. Appliance Magazine. *LG Heat Pump Clothes Dryer Earns Emerging Technology Award* http://www.appliancemagazine.com/news.php?article=1759314&zone=0&first=1&cid=nl.app01.20140829
9. HomeAdvisor. *How Much Does it Cost to Install Ducts & Vents?* http://www.homeadvisor.com/cost/heating-and-cooling/install-ducts-and-vents/
10. Cost Helper. *Hot Water Baseboard Heater Cost*. http://home.costhelper.com/hydronic-baseboard-heater.html

List of Acronyms

AFUE—Annual Fuel Utilization Efficiency

CEF—Combined Energy Factor

COP—Coefficient of Performance

EER—Energy Efficiency Ratio

EERE—Office of Energy Efficiency & Renewable Energy

EF—Energy Factor

HHV—Higher Heating Value

HSPF—Heating Seasonal Performance Factor

LPG—Liquefied Petroleum Gas

NEEA—Northwest Energy Efficiency Alliance

SEER—Seasonal Energy Efficiency Ratio