Furnaces

Disclaimer

- In order to maximize the benefits of the National Academies' peer review of the U.S. Department of Energy (DOE) Appliance Standards Program's analytical methods, the Department is offering real world examples of its application of such methods. Specifically, DOE is posing a case study based on its supplemental notice of proposed rulemaking (SNPRM) for consumer non-weatherized gas furnaces and mobile home gas furnaces (see 81 FR 65720 (Sept. 23, 2016)). DOE has updated its analysis contained in the September 2016 SNPRM to reflect subsequent refinements to its analytical methods, including the modeling of fuel switching.
- This case study is being put forth for peer review purposes only, so as to assess the relative strengths and weakness of DOE's analytical methods, as well as areas with the potential for improvement. Consequently, the imbedded discussion, data, and any related policy statements are merely illustrative and for purposes of the peer review only.
- The case study is not to be deemed as a statement of DOE policy or position on the merits of the rulemaking that is the subject of the case study. DOE continues to review and assess its next steps on the non-weatherized gas furnaces and mobile home gas furnaces rulemaking, and it will make any subsequent announcement impacting the substance of that rulemaking through a document published in the Federal Register.

Residential Furnaces: Product Definition

DOE regulates the energy efficiency of multiple types of furnaces using the Annual Fuel Utilization Efficiency (AFUE) metric.

Included in today's review:

- **Non-Weatherized Gas Furnaces (NWGF)**: Ducted, indoor installation
- **Mobile Home Gas Furnaces (MHGF)**: Similar to NWGF but designed solely for installation in mobile homes (i.e., a space-constrained application)

Regulated but not included in today's review:

- **Weatherized Gas Furnaces:** Designed for ducted outdoor installation
- **Oil Furnaces:** Oil-fired, ducted, may be weatherized or indoor-use only
- **Boilers:** Heat water for use in hydronic or steam heating systems
- **Electric Furnaces:** Use resistive heating elements, ducted

	NWGF and MHGF
Annual Shipments (units/year 2018 per AHRI[1])	3.4 million
Total Energy Use (quads/year as of 2016)	2.2
Percentage of Total U.S. Residential Energy Use (2016)	11%
Average Product Lifetime (years)	21.5

1) The Air-Conditioning, Heating, and Refrigeration Institute represents about 300 HVAC manufacturers, covering approximately 90% of total US HVAC shipments

Current Standards

Current furnace product classes, standards, and compliance dates:

Product Class	AFUE (%)[1]	Compliance Date
(A) NWGF	80	Nov. 19, 2015
(B) MHGF	80	Nov. 19, 2015
(C) Non-weatherized oil-fired furnaces	83	May 1, 2013
(D) Mobile home oil-fired furnaces	75	Sept. 1, 1990
(E) Weatherized gas furnaces	81	Jan. 1, 2015
(F) Weatherized oil-fired furnaces	78	Jan. 1, 1992
(G) Electric furnaces	78	Jan. 1, 1992

[1] AFUE as determined in 10 CFR 430.23(n)(2) of this part.

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Residential Furnaces: Regulatory History

Date	Statutory or Regulatory Action
March 1987	NAECA set initial standards at 78% for NWGF (excluding small furnaces) and 75% AFUE for MHGF and required DOE to establish separate standards for small NWGFs (≤ 45 kBtu/h) to reduce the fuel switching impacts of the new standards.
November 1989	DOE set a 78% AFUE standard for small furnaces that went into effect on January 1, 1992. 54 FR 47916 (Nov. 17, 1989).
November 2007	DOE published a final rule amending the standards for residential furnaces to 80% AFUE for NWGF (including small NWGF) and MHGF; compliance required November 19, 2015. 72 FR 65136. Following the November 2007 final rule, the State of New York and several other parties sued DOE, asserting that the adopted standards did not reflect the maximum improvement in energy efficiency required under Energy Policy and Conservation Act (EPCA).
April 2009	The Court granted a motion by DOE for voluntary remand, which did not vacate the standards but indicated that DOE would revisit the conclusions in the November 2007 Final Rule to address regional standards and the effects of alternate standards on natural gas prices.
June 2011	DOE published a Direct Final Rule (DFR) that amended the energy conservation standards for NWGF and MHGF to 90% AFUE for the North and 80% AFUE for the Rest of the Country. 76 FR 37408 (June 27, 2011). Subsequently, the American Public Gas Association (APGA) sued to invalidate the June 2011 DFR standards as they pertain to NWGF and MHGF.

Residential Furnaces: Regulatory History

Date	Statutory or Regulatory Action
April 2014	DOE and APGA agreed to vacate and remand the standards for NWGF and MHGF set by the 2011 DFR and that DOE would undertake another rulemaking for these products.
March 2015	DOE published a NOPR proposing amended energy conservation standards for NWGF and MHGF. Specifically, DOE proposed TSL 3 consisting of a 92% AFUE standard for all NWGF and MHGF. 80 FR 13120.
September 2015	DOE published a NODA showing the results for separate large and small furnace standards for NWGFs based on stakeholder comments. DOE analyzed 11 small furnace size scenarios ranging from ≤ 40 kBtu/h to ≤ 90 kBtu/h (in 5 kBtu/h increments) with a non-condensing furnace standard (80% AFUE) and large furnaces with a condensing standard. 80 FR 55038.
September 2016	DOE published a SNPRM proposing amended energy conservation standards for NWGF and MHGF. Specifically, DOE proposed TSL 6 consisting of a 92% AFUE standard for all MHGF and for NWGF with an input capacity greater than 55 kBtu/h. For NWGF with an input capacity less than or equal to 55 kBtu/h, DOE proposed an 80% AFUE standard. 81 FR 65720.
July 2019	In response to a stakeholder petition for rulemaking, DOE proposed to interpret EPCA to provide that adoption of energy conservation standards that would limit the market to gas furnaces that use condensing combustion technology would result in the unavailability of a performance-related feature within the meaning of 42 U.S.C. 6295(o)(4). 84 FR 33011 (July 11, 2019).

Furnaces: Market Failures

Pursuant to complying with Executive Order 12866, DOE identified market failures to justify the 2016 SNPRM of furnace energy conservation standards.

Section 1(b)(1) of Executive Order 12866, ''Regulatory Planning and Review,'' 58 FR 51735 (October 4, 1993), requires each agency to identify the problem that it intends to address, including, where applicable, the failures of private markets or public institutions that warrant new agency action, as well as to assess the significance of that problem.

DOE identified the following problems:

- There may be a lack of consumer information and/or asymmetric information about energy efficiency opportunities in the furnace market, as well as high costs of gathering information.
- There are misaligned incentives between purchasers and users of the equipment.
- There are external benefits resulting from energy efficiency that are not captured by the users of the equipment, e.g. benefits related to public health, national security, and environmental protection, such as reduced emissions of air pollutants and greenhouse gasses.

Residential Furnaces: Technology Options

The technology assessment identified the following technology options as having the potential to improve the AFUE rating of residential furnaces.

Residential Furnaces (2016 SNPRM): Technology Options	
Condensing secondary heat exchanger	Concentric venting
Increased heat exchanger surface area	Transformer improvements (standby/off mode)
Heat exchanger surface features	Switching mode power supply (standby/off mode)
Heat exchanger baffles and turbulators	Pulse combustion
Two-stage and modulating combustion	Low Nitrous-Oxides (NO_x) premix burners
Increased jacket insulation	Burner derating
Electro-mechanical flue damper	Advanced forms of insulation
Electro-mechanical burner inlet damper	Brushless permanent magnet control relay (standby/off mode)
Direct venting	

Residential Furnaces: Screening Analysis

The NWGF and MHGF Screening Analysis removed the following technologies that met one or more of the screening criteria from further consideration:

Options Screened Out	Applicable Screening Criteria
Pulse combustion	Impacts on product safety (although generally safe, similar efficiencies are achievable via induced draft, which is safer due to negative vs. positive fire-side heat exchanger [HX] pressure)
Low NOx premix burners	Technological feasibility not proven in furnaces
Burner derating	Impacts on product utility due to reduced heat output
Advanced forms of insulation	Practicability to manufacture, install, service and technological feasibility not proven in furnaces
Brushless permanent magnet control relay (standby/off mode)	Practicability to manufacture, install, and service

Furnace Engineering: Representative Classes

Choose Representative Equipment

Define Baseline Models

Analyze More Efficient Designs

Calculate MPCs

Generate Cost Curves

Product Classes Analyzed in SNPRM

- **NWGF:** Ducted, indoor installation
- **MHGF:** Similar to NWGF but designed solely for installation in mobile homes (i.e., a space-constrained application)

The SNPRM proposed to further divide NWGFs into two product classes based on capacity:

- NWGFs with an input capacity of greater than 55 kBtu/hr
- NWGFs with an input capacity of less than or equal to 55 kBtu/hr

Comments were received suggesting DOE consider additional product classes:

- Separate product classes for non-condensing furnaces were not proposed in the SNPRM

Furnace Shipments by Input Capacity

Input Capacity Shares

Input Capacity (kBtu/h)	AHRI 2000 Gas Furnace Shipments (%)		2013 AHRI Directory Fraction of Models (%)	2022 DOE Fraction of Shipments (%)
40	9.4	2.8*	4.5	1.4
45			4.4	1.4
50		6.7*	1.8	4.2
55			1.1	2.5
60	8.6		10.9	8.2
65			0.5	0.4
70	24.8		5.5	11.3
75			6.5	13.5
80	13.7		13.6	13.7
85			0.0	0.0
90	23.2		10.2	8.6
95			1.1	0.9
100			14.9	12.5
105			1.4	1.2
110	20.4		6.5	5.6
115			0.6	0.5
120			9.0	7.7
125			1.5	1.3
130			1.1	0.9
135			2.4	2.1
140			1.5	1.3
145			0.0	0.0
150			0.6	0.5
155			0.4	0.4
160			0.1	0.1

* DOE used 1990 shipments to split the 2022 DOE fraction into “less than 50 kBtu/h” and “50 kBtu/h to less than 60 kBtu/h” bins.

Product Classes Based on Input Capacity

The 2016 SNPRM proposed to establish separate NWGF product classes based on input capacity (<55 kBTU/h vs. 55+ kBTU/h).

- The Energy Policy Act of 1992 (EPAct 1992) directed DOE to consider a separate standard level for small furnaces with an input capacity of less than 45,000 Btu/h. 42 U.S.C. 6295(f)(1)(B).
- Specifically, DOE was directed to consider a level within a specified range that would not be likely to result in a significant shift from gas to electric resistance heating.
- Furnaces with very low input capacities are common in the warmer regions of the United States where they compete with heat pumps.
- The EPAct 1992 clarified DOE's authority to use input capacity as a criteria for prescribing separate product classes for furnaces.
- DOE also notes that the EPAct 1992 directive was specifically issued in an effort to mitigate fuel switching, and that in this rulemaking, DOE also proposed to split product classes by input capacity to mitigate fuel switching.
- Hence, DOE proposed to create an additional NWGF product class based on input capacity (<55 kBTU/h vs. 55+ kBTU/h) as part of the 2016 SNPRM.

Product Class for Non-Condensing Furnaces

The 2016 SNPRM DOE did not consider non-condensing technology to be a *feature* for purposes of setting product classes for furnaces.

The 2016 SNPRM tentatively concluded that:

- The consumer utility of a furnace is that it provides heat to a dwelling, and the type of venting used for particular furnace technologies does not impact that utility.
- The venting does not provide any separate performance-related utility; therefore, DOE has no statutory basis for defining a separate class based on venting and drainage characteristics.
- The possibility that installing a non-condensing furnace may be less costly than a condensing furnace due to venting methods does not justify creating different product classes. DOE considers venting and condensate drainage costs in its cost-benefit analysis for consumers.

Product Class for Non-Condensing Furnaces

In consideration of responses to a petition submitted by the Gas Industry Petitioners, DOE has proposed an interpretation of *feature* that could lead DOE to establish separate classes for condensing and non-condensing furnaces in future rulemakings.

- On November 1, 2018, DOE published in the Federal Register a petition submitted by the Gas Industry Petitioners requesting that DOE issue an interpretive rule stating that DOE's proposed energy conservation standards for residential furnaces and commercial water heaters would result in the unavailability of "performance characteristics" within the meaning of EPCA (42 U.S.C. 6291 et seq.).
- On July 11, 2019, DOE issued a Notice of Proposed Interpretive Rule (NOPIR) to provide the public additional information about DOE's interpretation of EPCA's *features* provision in the context of condensing vs. non-condensing furnaces and water heaters, as informed by public comments (84 FR 33011).
- In light of further consideration and information presented with and in response to the petition, DOE found that difficulties posed by space constraints, installation costs, and physical changes to room layouts associated with condensing type products would have significant enough impacts on consumers to merit a different approach.

Furnace Engineering: Baseline Models

- Choose Representative Equipment
- **Define Baseline Models**
- Analyze More Efficient Designs
- Calculate MPCs
- Generate Cost Curves

DOE identified the characteristics of furnaces at the baseline (minimum standards level) efficiency.

	NWGF	MHGF
AFUE (%)	80	80
Configuration	Upflow	Downflow
Heat Exchanger	Clamshell or tubular	Clamshell or tubular
Ignition	Hot surface igniter	Hot surface igniter
Burner	Two-stage	Single-stage
Draft Type	Induced	Induced
Blower Fan Motor	Constant-torque BPM	Improved PSC
Combustion Air Supply	Surrounding air	Direct vent (from outside)

*The 2014 furnace fans Final Rule (79 FR 38129) set standards for the electrical energy consumption of the furnace blower.

Furnace Engineering: Efficiency Levels (ELs)

- Choose Representative Equipment
- Define Baseline Models
- **Analyze More Efficient Designs**
- Calculate MPCs
- Generate Cost Curves

Gas furnaces follow similar design paths to higher efficiency.

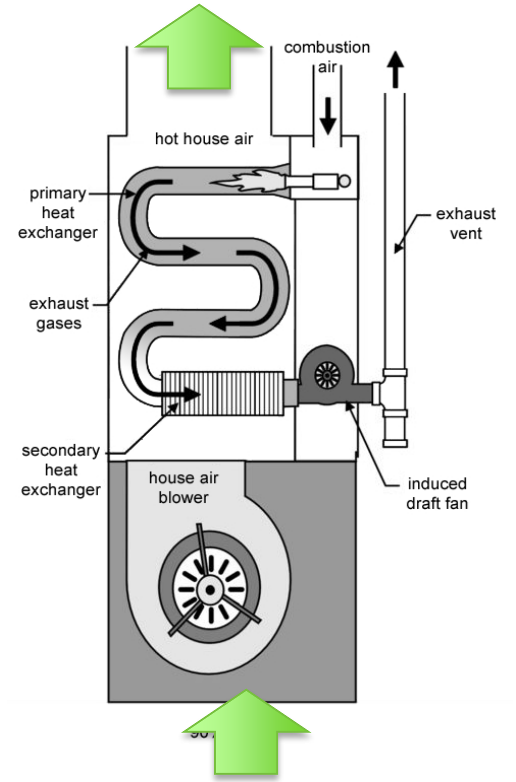
HX Choices

- All OEMs use separate HXs:
  - Primary HX extracts sensible heat (AFUE <82%)
  - Secondary HX (if fitted) extracts latent heat (AFUE 90%+), is designed to survive condensate
- **Goal:** prevent condensation in primary HX
- No partially condensing units are offered

Other Choices

- House air blower motor technologies range from permanent split capacitor to constant-airflow brushless permanent magnet motor
- Induced draft-burners may offer staging or modulation

Typical 90%+ AFUE furnace showing air flow in unit



Source: Access Heating and Air Conditioning

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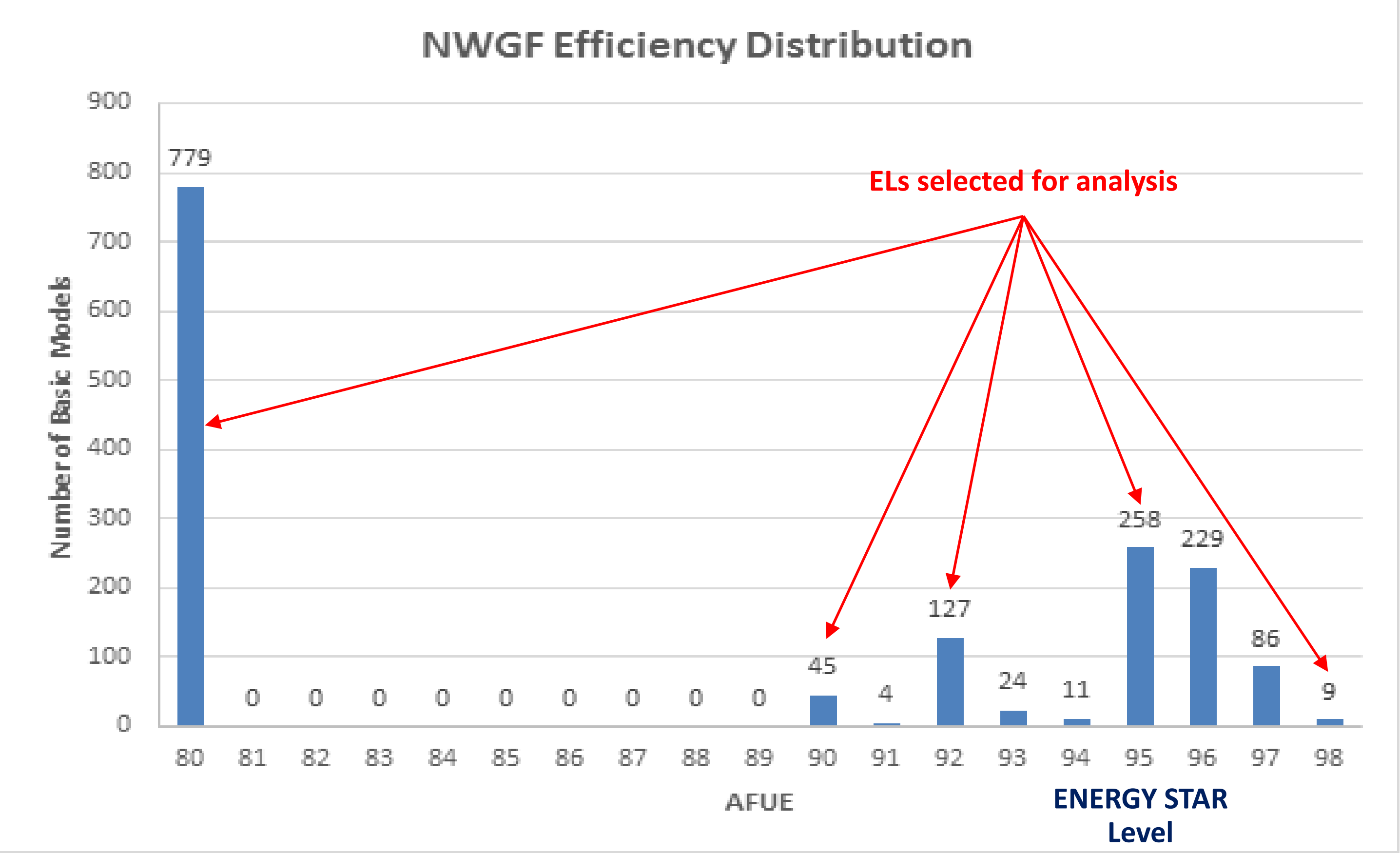
Furnace Engineering: ELs

- Choose Representative Equipment
- Define Baseline Models
- **Analyze More Efficient Designs**
- Calculate MPCs
- Generate Cost Curves

DOE identified the ELs for analysis based on market information, product literature, and feedback from manufacturers.



Furnace Engineering: Design Path

Choose Representative Equipment

Define Baseline Models

Analyze More Efficient Designs

Calculate MPCs

Generate Cost Curves

DOE conducted teardowns and received manufacturer feedback to determine the technologies to reach ELs.

Product Class	EL	AFUE (%)	Typical Technology Associated with Level	Reason for Selection
Non-Weathered Gas	1	80	Non-condensing HX, two-stage, constant-torque BPM blower motor	Baseline
	2	90	80 + secondary condensing HX	Lowest condensing level
	3	92	90 + increased secondary HX area	Common condensing level
	4	95	92+ increased secondary HX area	Most common condensing level
	5	98	95 + increased secondary HX area + modulating combustion + constant-airflow BPM blower motor	Max-tech
Mobile Home Gas	1	80	Non-condensing HX, single-stage, PSC blower motor	Baseline
	2	92	80 + secondary condensing HX	Lowest condensing level
	3	95	92+ increased secondary HX area	Most common condensing level
	4	96	95 + increased secondary HX area	Max-tech

Furnace Engineering: Teardown Analysis

Choose Representative Equipment

Define Baseline Models

Analyze More Efficient Designs

Calculate MPCs

Generate Cost Curves

DOE estimated incremental manufacturer production cost (MPC) for ELs/design options based on furnace teardowns.

- Select products from multiple manufacturers at each EL.
- Use teardown process to estimate MPCs for selected products.
- MPCs are compared to the baseline MPC for each manufacturer individually and baseline cost subtracted to determine manufacturer-specific incremental costs above baseline.
- To the extent possible, DOE validates components costs and total MPC with manufacturers.

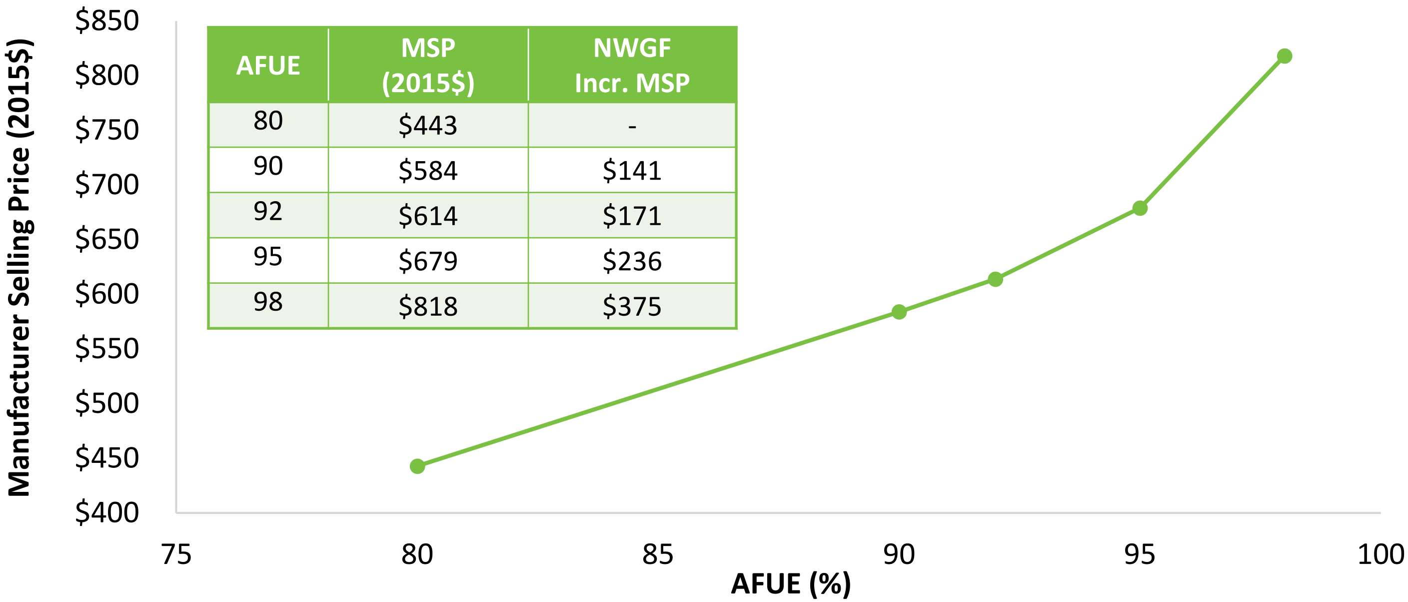
Number of Units Torn Down by Rated AFUE							
AFUE	80	90	91	92	93	95	98
# of Units	8	5	1	6	1	8	2

Furnace Engineering: Price-Efficiency Relationship

- Choose Representative Equipment
- Define Baseline Models
- Analyze More Efficient Designs
- Calculate MPCs
- **Generate Cost Curves**

DOE developed a *typical design path* that orders design options by cost and efficiency improvement.

- Incremental MPCs above baseline were subsequently aggregated together to form a cost-efficiency curve.
- As feasible, DOE compares cost-efficiency curves to existing market efficiency and price data or stakeholder-provided data.
- To convert MPC to manufacturer sales price (MSP), DOE applies a manufacturer markup (derived from SEC 10-K reports) and adds in shipping costs.



AFUE	MSP (2015$)	NWGF Incr. MSP
80	$443	-
90	$584	$141
92	$614	$171
95	$679	$236
98	$818	$375

Furnace Engineering: Scaling Results

- Choose Representative Equipment Classes
- Define Baseline Models
- Analyze More Efficient Designs
- Calculate MPCs
- **Generate Cost Curves**

DOE extended teardown results to additional capacities.

For NWGF:

- Teardown analysis focused on models at a representative input capacity of 80 kBtu/h.
- Teardowns were also performed at capacities above and below the representative capacity to determine how components and costs typically scale.
- DOE estimated MPC for products with input capacities above and below the representative capacity.

For MHGF:

- Teardown analysis focused on NWGF but included six MHGF units.
- MHGF teardowns compared to NWGF teardowns from same manufacturer at same input/efficiency to isolate differences in MHGF as compared to NWGF.
- MPC of MHGF estimated based on design differences with NWGF.

Furnace Engineering: MSPs

- Choose Representative Equipment Classes
- Define Baseline Models
- Analyze More Efficient Designs
- Calculate MPCs
- **Generate Cost Curves**

DOE’s estimates of MSPs by AFUE efficiency level and capacities:

NWGF Manufacturer Sales Price*

AFUE	MSP [$]			
	60 kBtu/h	80 kBtu/h	100 kBtu/h	120 kBtu/h
80	427	443	469	502
90	554	584	636	690
92	580	614	674	723
95	643	679	746	798
98*	785	818	875	933

*NWGF with a constant torque BMP indoor blower motor and two-stage combustion

MHGF Manufacturer Sales Price*

AFUE	MSP [$]
80	386
92	494
95	556
96	589

*MHGF (80 kBtu/h capacity) with improved PSC indoor blower motor

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Markups

Baseline Markups

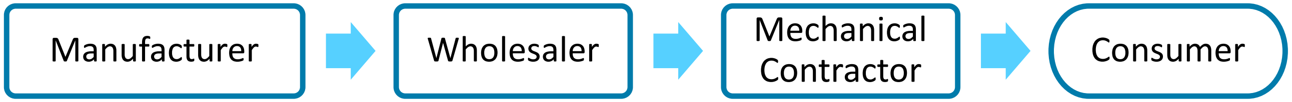
- Relate the MSP of baseline equipment to the consumer purchase price.
- DOE applied baseline markups to the MSP of the baseline level.

Incremental Markups

- Relate the increase in MSP of more efficient products to the increase in consumer purchase price.
- Cover only expenses that vary with MSP (e.g., operating expenses and profit).
  - Fixed costs such as overhead and labor do not scale with increased efficiency.
- DOE applied the incremental markups to the incremental difference in MSP at each level above the baseline.
- DOE's use of incremental markups is based on the premise that:
  1. Some costs will scale with the increase in product cost while other costs remain constant after standards.
  2. Firms face a relatively competitive market.
  3. Firms are not likely to sustain higher profits in the medium/long run as a windfall resulting from standards, as would be implied by a fixed markup scenario when product costs increase and demand is relatively inelastic.

Markups

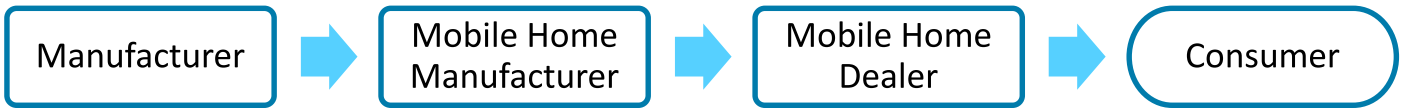
Replacements



New Construction

NWGFs:

MHGFs:



Note: The national account channel for NWGFs purchased for commercial installations includes manufacturer, wholesaler, and consumer.

Input Variable	Data Source
Manufacturer	SEC 10-K reports (see engineering)
Wholesaler	Firm income statements from the Heating, Air-conditioning & Refrigeration Distributors International (HARDI) 2012 Profit Report
Mechanical Contractor	Air Conditioning Contractors of America (ACCA) 2005 Financial Analysis report; US Census Bureau, 2012 Plumbing and HVAC Contractors sector
General Contractor	US Census Bureau, 2012 Commercial Building Construction sector
Mobile Home Manufacturer	US Census Bureau, 2012 Manufactured Home (Mobile Home) Manufacturing and All Other Specialty Trade Contractors sectors
Mobile Home Dealer	US Census Bureau, 2012 All Other Specialty Trade Contractors sector; information from mobile home dealer websites and other sources
Sales Tax	2016 Sales Tax Clearinghouse Data

Markups: Unpublished Changes

In the unpublished analysis, DOE revised its contractor markups estimates to better align with RS Means and Craftsman Cost Books approaches and other sources.

- Sensitivity analysis with alternative estimates of incremental markups:
  - **Reference Scenario:** 1.21 (Replacement) or 1.15 (New Construction)
  - **High Scenario:** Assume same as baseline markup = 1.40 (Replacement) or 1.33 (New Construction)
  - **Low Scenario:** Assume same as RS Means = 1.10 (both Replacement and New Construction)

Market Participant	SNPRM				Unpublished Analysis			
	Replacement		New Construction		Replacement		New Construction	
	Baseline	Incr.	Baseline	Incr.	Baseline	Incr.	Baseline	Incr.
Manufacturer	1.34		1.34		1.34		1.34	
Wholesaler	1.36	1.10	1.36	1.10	1.36	1.10	1.36	1.10
Mechanical Contractor	1.56	1.24	1.47	1.17	1.40	1.21	1.33	1.15
General Contractor	-		1.36	1.12	-		1.36	1.12
Sales Tax	1.07		-		1.07		-	
Overall Markup	**2.84**	**1.84**	**3.65**	**1.95**	**2.56**	**1.80**	**3.29**	**1.90**

Markups: Unpublished Changes

- Contractor Labor costs include fringe benefits (similar to both Craftsman and RS Means), before overhead and profit. Fringe benefits were not included in SNPRM calculations.
- Cost of Equipment Sales (excluded costs from Contractor Markup calculation):
  - Total payroll, construction workers wages + **Added** Fringe costs (34% of total sales)
  - Cost of materials, components, and supplies (48%)
  - Cost of construction work subcontracted out to others (14%)
  - **Added** Rental costs of machinery and equipment (1%)
  - **Added** Purchased professional and technical services (1%)
  - **Added** Refuse removal services (0.1%)
  - Cost of selected power, fuels, and lubricants (3%)
- Contractors have a different way of dealing with material markups: some have a very high markup (1.50 or above), and some do not have any or minimal markup since they have minimal effort (1.10 or below) or consumer purchases through retail store (including online).

Product Price Trend

- DOE applied a price trend (also referred to as learning or experience curves) to furnace prices to determine product prices in future years.
- Analysis is based on producer price index (PPI) data for "warm air furnaces" to estimate price as a function of cumulative shipments.

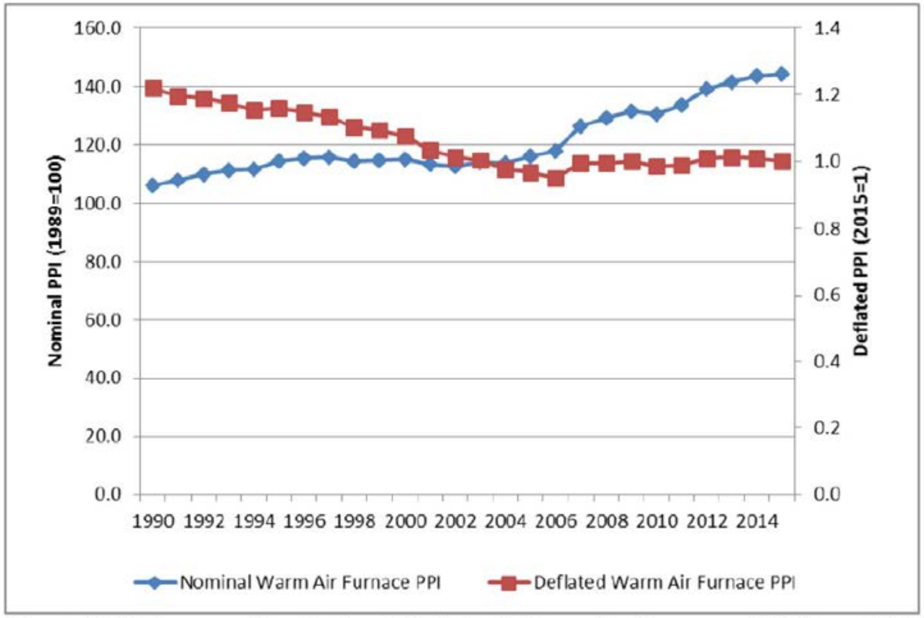


Figure 8C.3.1 **Nominal and Deflated Warm Air Furnaces PPI from 1990 to 2015**

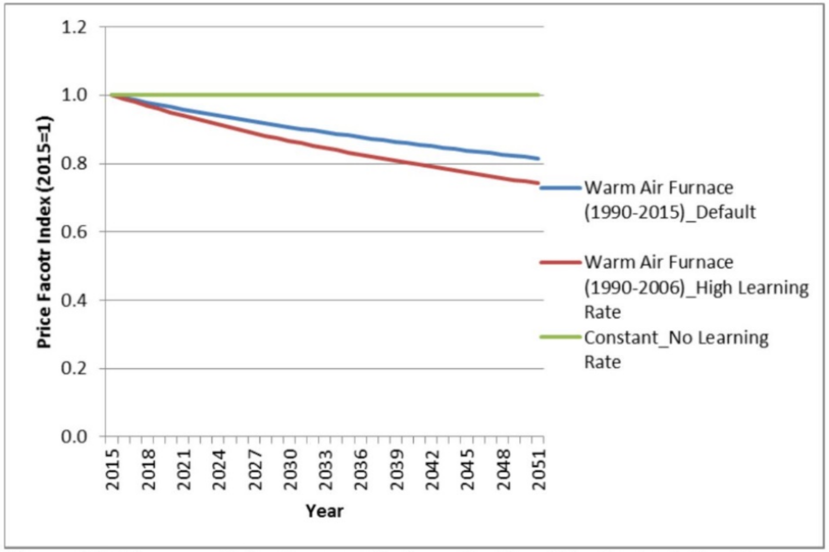
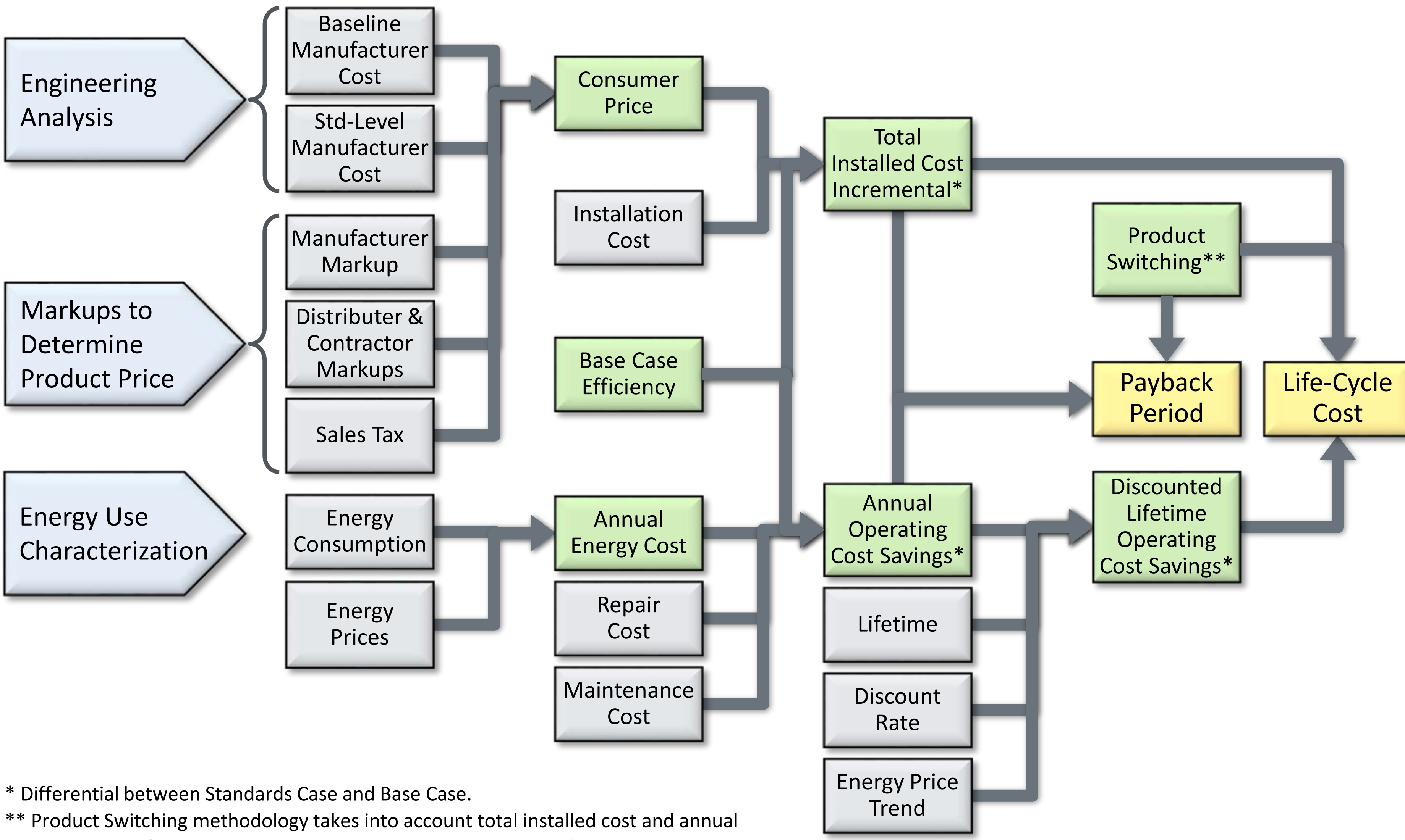


Figure 8C.5.2 **Price Forecast Indexes for Non-Weatherized Gas Furnaces and Mobile Home Gas Furnaces**

Desroches, L., et al., 2013. Incorporating Experience Curves in Appliance Standards Analysis. Energy Policy 52, 402-416.

Life Cycle Cost (LCC) and Payback Period (PBP) Analysis



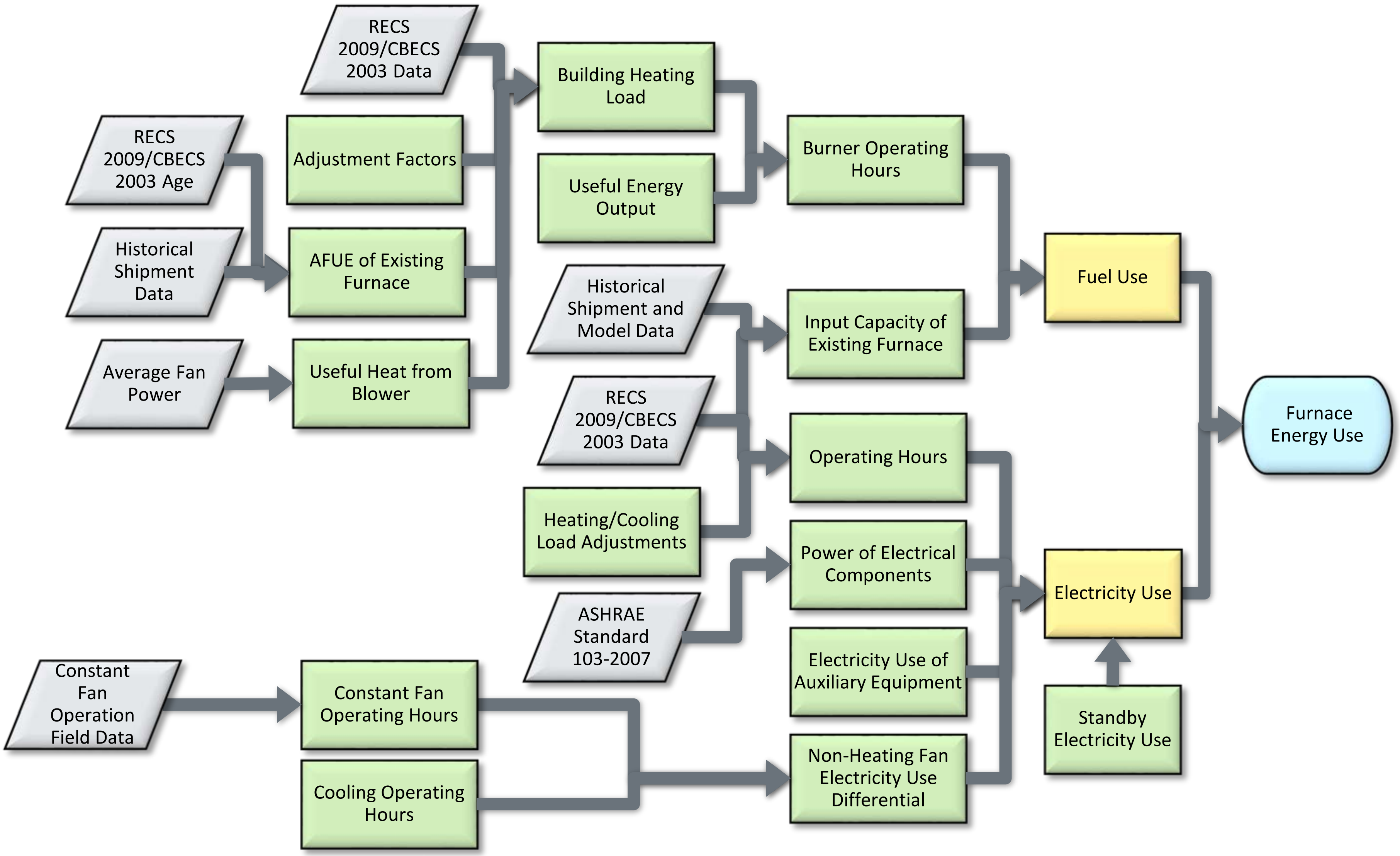
* Differential between Standards Case and Base Case.

** Product Switching methodology takes into account total installed cost and annual operating cost of proposed standard products in comparison to alternatives products.

LCC and PBP Analysis: Input Summary

Input	Purpose/Definition	Method
Consumer Product Price	Manufacturing cost multiplied by markups, sales tax, and price trend factor.	Manufacturing cost from engineering analysis. Markups and sales taxes: from markups analysis. Future price trend: historical PPI and shipment data.
Installation Costs	Labor and materials necessary to install appliance.	Higher costs for condensing furnace installations, which have additional venting requirements and condensate withdrawal.
Energy Use	Determine field energy use.	Based on RECS/CBECS energy use data and adjustment factors.
Energy Prices	Develop average marginal monthly prices projected into the future.	Multiplied most current average annual energy prices by monthly price factors and marginal price factors by geographical area. Then multiplied by the projected annual energy price trends.
Maintenance/ Repair Costs	Cost of replacing or repairing failed components in furnace and routine cost to maintain.	Based on maintenance frequency, failure year, warranty period, labor hours and cost, and material cost.
Discount Rates	Determine the present value of lifetime operating expenses.	Derived from various types of debt and equity using the Federal Reserve Board's Survey of Consumer Finances.
Lifetime	Age when the product is retired.	Based on national survey data and manufacturer shipment data.
Base Case Efficiency Distribution	Project market share of products at each efficiency level in the absence of standards.	Based on historical market share data, models information, and stakeholder input.
Product Switching	Project product switching due to standards.	Based on consumer choice model that takes into account both total installed costs and operating costs.

Energy Use Analysis: Flowchart



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LCC and PBP Analysis: Installation Costs

Purpose

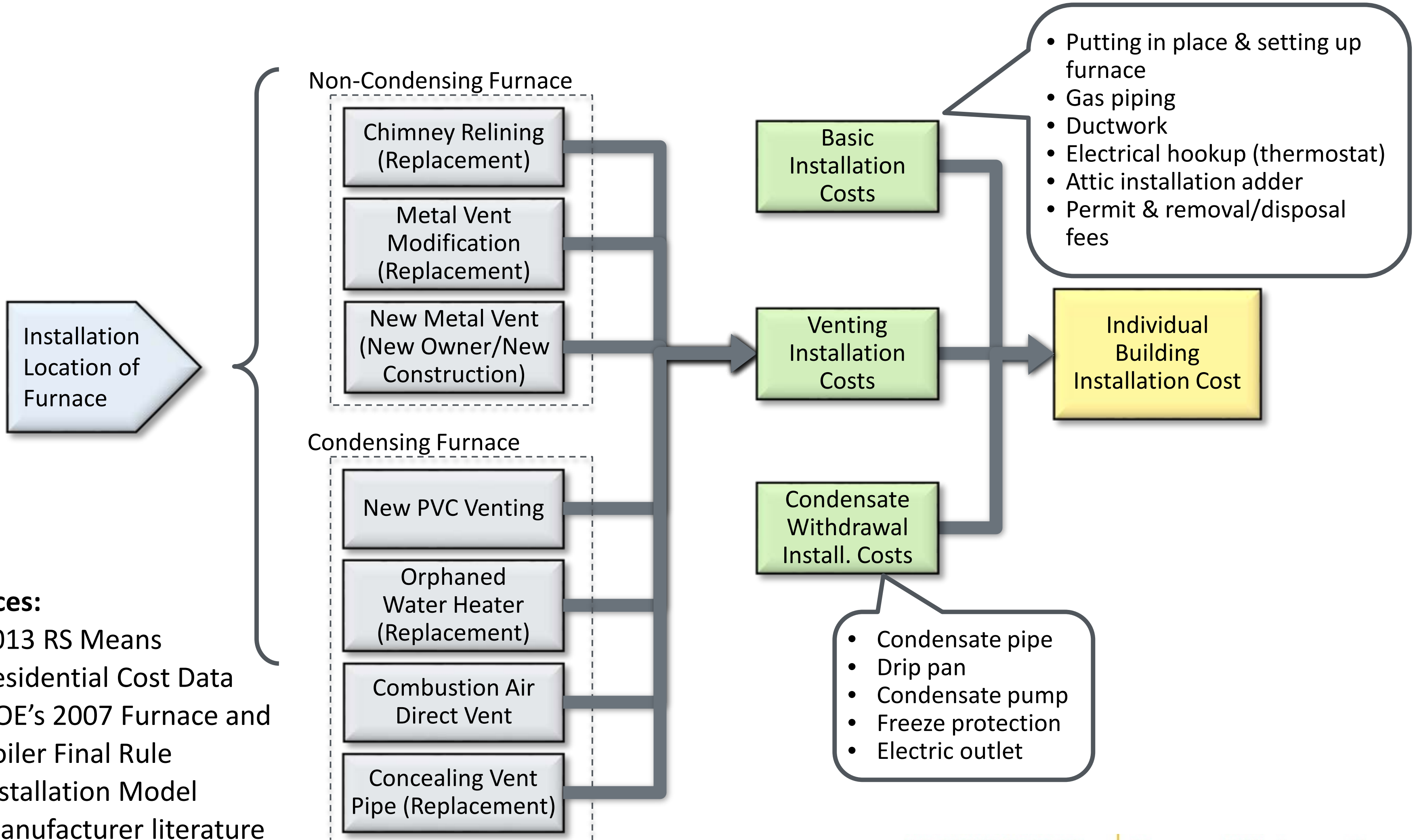
- Represent the labor and material costs necessary to install the product.

Methodology

- Based on 2015 RS Means Residential Cost Data, DOE's 2007 Furnace and Boiler Final Rule installation model, manufacturer literature.
- Higher costs for condensing furnace installations, which have additional venting requirements and condensate withdrawal. DOE's ***incremental*** installation cost for condensing NWGFs is similar to data provided by stakeholders.
  - Installation cost varies widely for different installation locations, contractors, and regions.
  - DOE did not include some installation costs that would be the same regardless of furnace efficiency, including asbestos abatement, emergency installation during the winter, ductwork costs, and premium comfort features.
- New venting technologies to address orphaned water heater installation costs may decrease over time, although DOE did not have enough data at this time to project such cost trends.

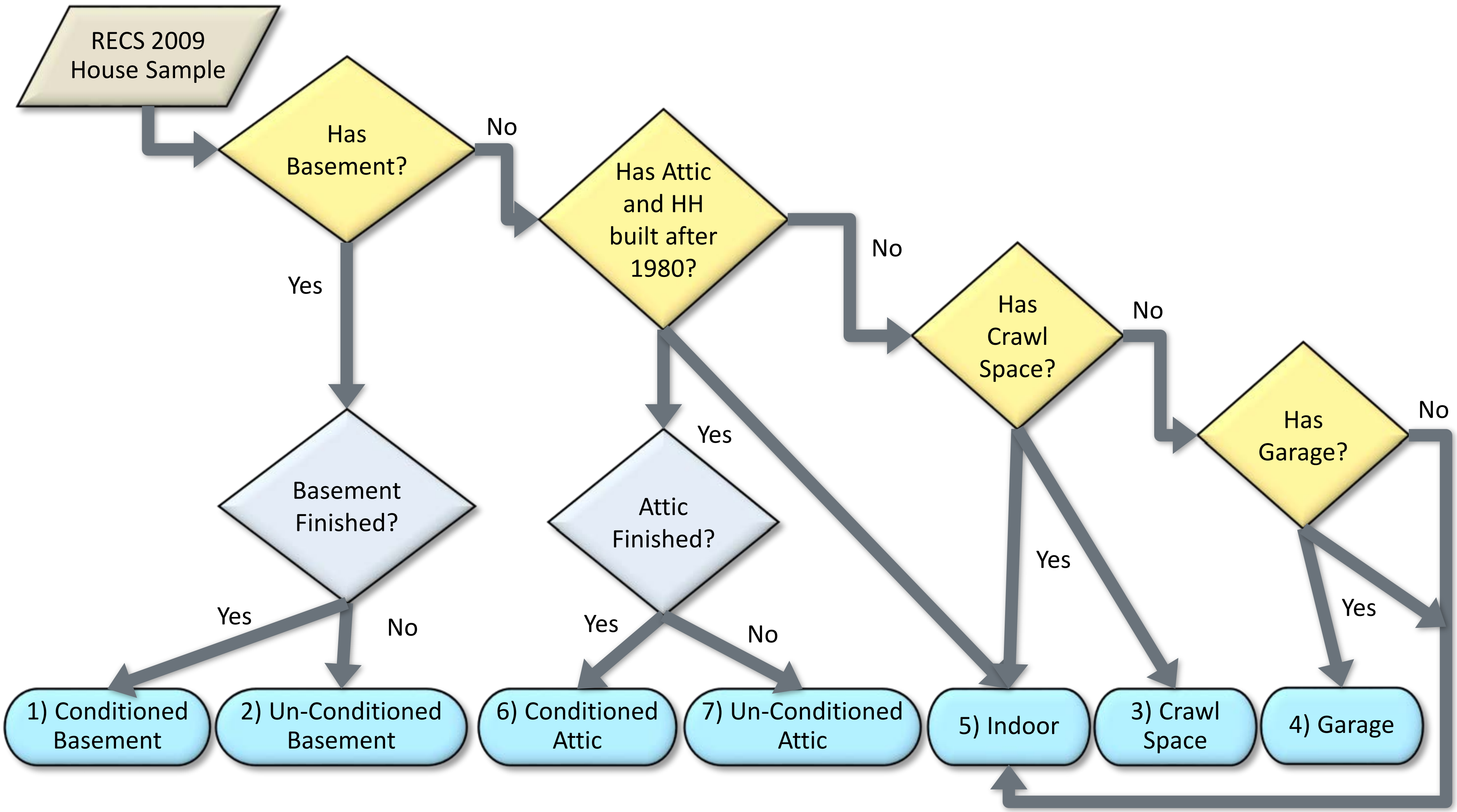
LCC and PBP Analysis: Installation Costs

Purpose: Represent the labor and material costs necessary to install the product.



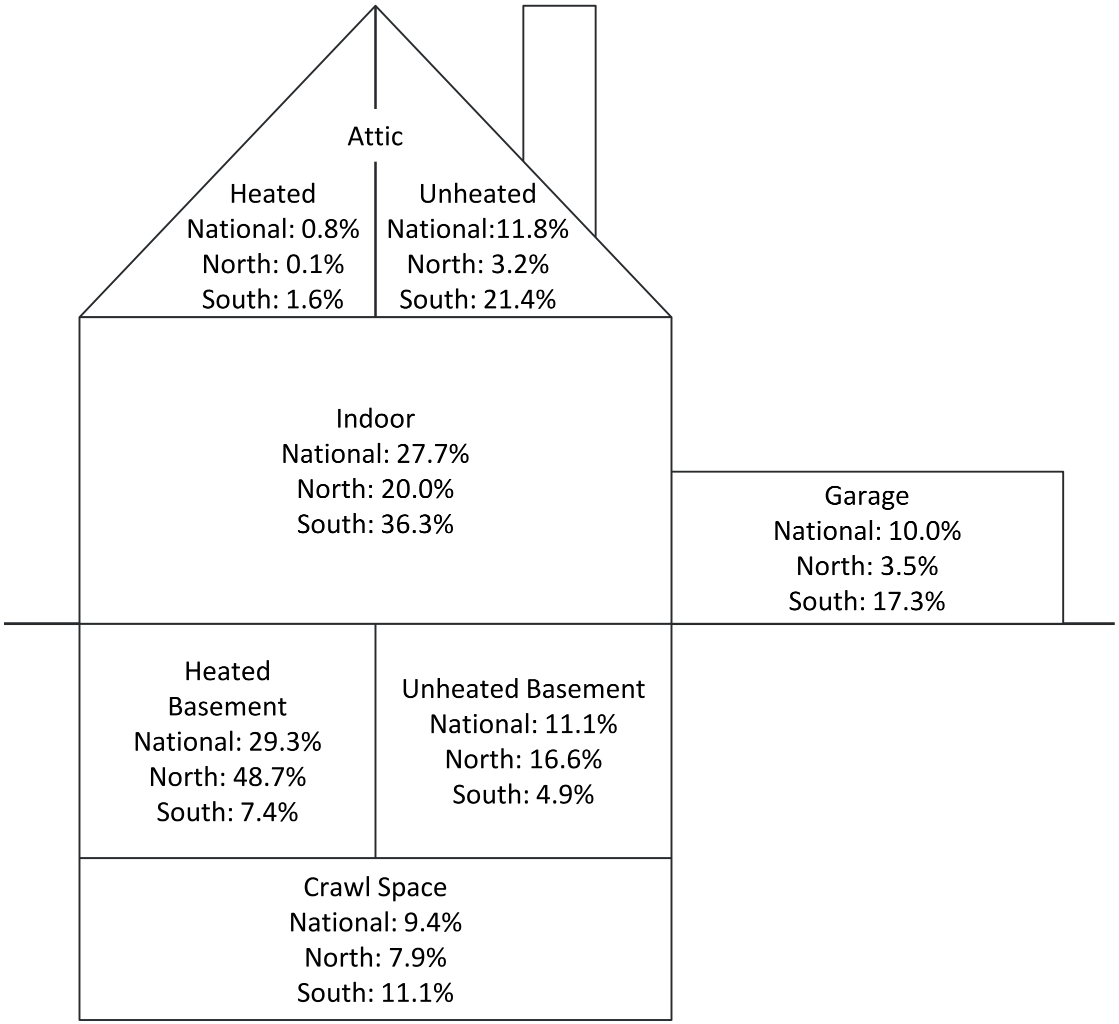
Sources:
- 2013 RS Means Residential Cost Data
- DOE's 2007 Furnace and Boiler Final Rule Installation Model
- Manufacturer literature

LCC and PBP Analysis: Installation Location Determination



Note: All NWGFs installed in commercial buildings and MHGFs were assumed to be in indoor locations.

LCC and PBP Analysis: NWGF Installation Location



LCC and PBP Analysis: Installation Costs

Difficult Installations

- DOE accounted for higher installation costs for a fraction of installations that might face potential problems with retrofitting to condensing furnaces.
- DOE investigated the implementation of the condensing furnace standards in Canada and found that the potential problems with retrofitting condensing furnaces were either overstated or the installing contractors found ways to resolve the issues.
- Regarding row house installations, DOE's current analysis includes costs comparable to the methods that were identified in the Philadelphia weatherization program to address venting difficulties in condensing NWGF installations.
- DOE's proposed separate standards for small and large NWGFs, which would significantly reduce the number of installations described as difficult. Under the proposed standards, more than half of multi-family NWGF installations would not be impacted because they are sized below the cutoff.

LCC and PBP Analysis: Installation Cost Results

Installation Cost Results Comparison (all installations)

Efficiency Level	AFUE	NPRM (2013$)		NODA (2014$)		SNPRM (2015$)	
		Average	Diff	Average	Diff	Average	Diff
NWGF							
0	80%	$1,069	--	$1,100	--	$1,122	--
1-4	90-98%	$1,370	$316	$1,402	$302	$1,375	$253
MHGF							
0	80%	$735	--	$746	--	$774	--
1-3	92-96%	$746	$11	$757	$11	$776	$2

Installation Cost Results Comparison (replacements only)

Efficiency Level	AFUE	NPRM (2013$)		NODA (2014$)		SNPRM (2015$)	
		Average	Diff	Average	Diff	Average	Diff
NWGF							
0	80%	$766	--	$776	--	$811	--
1-4	90-98%	$1,342	$575	$1,340	$564	$1,335	$524
MHGF							
0	80%	$597	--	$606	--	$631	--
1-3	92-96%	$816	$219	$828	$222	$851	$219

Note: DOE considered alternative venting technologies in sensitivity analysis (see appendix 8L of TSD).

LCC and PBP: Regional Installation Cost Results

Efficiency Level	AFUE	Average Installation Costs (2015$)				Total	Differential
		Baseline	Venting	Orphaned Water Heater	Condensate Withdrawal		
North							
0	80%	$746.7	$554.5	$0.0	$0.0	$1,301	--
1 to 4	90%-98%	$747	$495.4	$349.0	$58.6	$1,650	$349
North - Replacement							
0	80%	$745.8	$176.1	$0.0	$0.0	$922	--
1 to 4	90%-98%	$745.8	$533.0	$230.0	$65.8	$1,575	$653
North - New Construction/New Owner							
0	80%	$749.2	$1,621.8	$0.0	$0.0	$2,371	--
1 to 4	90%-98%	$749	$389.3	$684.6	$38.4	$1,862	($509)

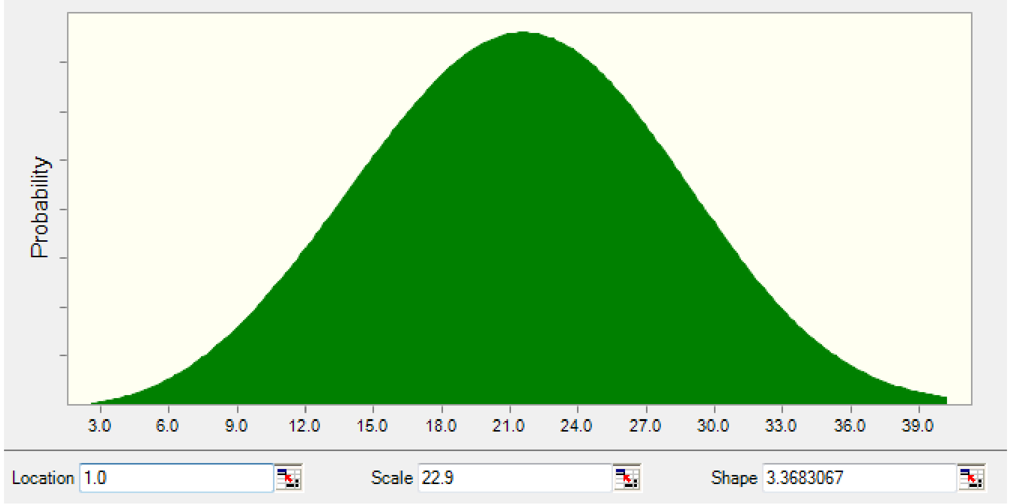
Efficiency Level	AFUE	Average Installation Costs (2015$)				Total	Differential
		Baseline	Venting	Orphaned Water Heater	Condensate Withdrawal		
South							
0	80%	$579.4	$340.9	$0.0	$0.0	$920	--
1 to 4	90%-98%	$579	$290.8	$122.9	$71.9	$1,065	$145
South - Replacement							
0	80%	$582.2	$106.8	$0.0	$0.0	$689	--
1 to 4	90%-98%	$582.2	$332.8	$89.0	$75.4	$1,079	$390
South - New Construction/New Owner							
0	80%	$570.7	$1,054.7	$0.0	$0.0	$1,625	--
1 to 4	90%-98%	$571	$162.7	$226.2	$61.4	$1,021	($604)

LCC and PBP Analysis: Lifetime (SNPRM)

Definition: Age when the furnace is retired from service.

Method: Used national survey data and manufacturer shipment data to calculate the distribution of lifetimes

- Sensitivity analysis considered higher and lower lifetime estimates as well as regional lifetime (see appendix 8G).



Product Class	Mean	Weibull Parameters		
		Alpha (scale)	Beta (shape)	Location (delay)
All Furnaces	21.5	22.9	3.37	1

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LCC and PBP Analysis: Lit Review of Lifetime Values

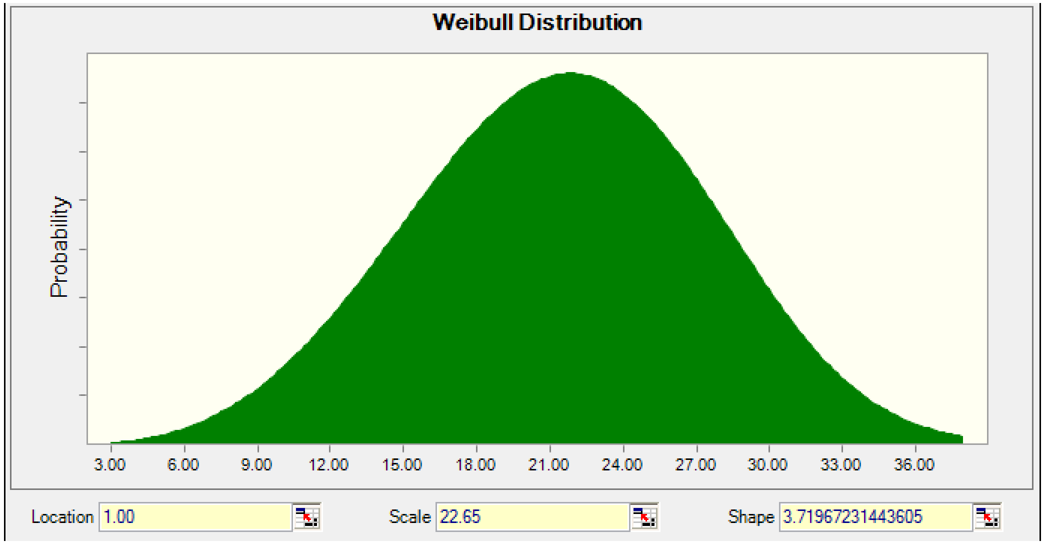
Lifetime Value

- DOE's literature review of average furnace lifetime values range between 15 and 30 years.
  - DOE found that the Canadian rulemaking analysis and survey data from the American Home Comfort Study (2004, 2006, 2008, 2010, 2013, 2016, and 2019) show that the average lifetime is at least 20 years.
- Sensitivity analysis average values:
  - Reference – 21.5 years
  - Low – 16.0 years (based on 2004 Appliance Magazine)
  - High – 27.0 years (symmetrical value to the low scenario, relative to reference lifetime value)
  - Regional – 19.7 years for the North and 23.3 years for the Rest of the Country for NWGF, and a median lifetime of 18.8 years for the North and 22.4 years

Lutz, James D. et al., 2011, Using national survey data to estimate lifetimes of residential appliances, HVAC&R Research, 17:5, 726-736,
DOI: 10.1080/10789669.2011.558166

LCC and PBP Analysis: Lifetime – Unpublished Changes

- Distribution based on most up-to-date shipments and survey data
  - 2013 and 2015 American Housing Survey, 2015 RECS, and 2012-2015 shipments data
- Regional data based on disaggregated American Home Comfort Survey results for North and Rest of Country:
  - 22.1 years in North
  - 19.7 years in Rest of Country



Product Class	Mean	Weibull Parameters		
		Alpha (scale)	Beta (shape)	Location (delay)
National Average	21.4	22.6	3.72	1

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LCC and PBP Analysis: No-New-Standards Case Efficiency Distribution

Purpose: Reflects projected market shares of products at different ELs for the no-new-standards case.

- Not all consumers purchase products at current minimum standard.
- LCC analysis recognizes that consumers already purchasing products at efficiencies greater than or equal to a prospective standard level are not impacted by the standard.

Method: Projected NWGF and MHGF efficiency market share in 2022 for each product class based on historical shipment data and the share of models in each product class from the AHRI certification directory.

Sources:

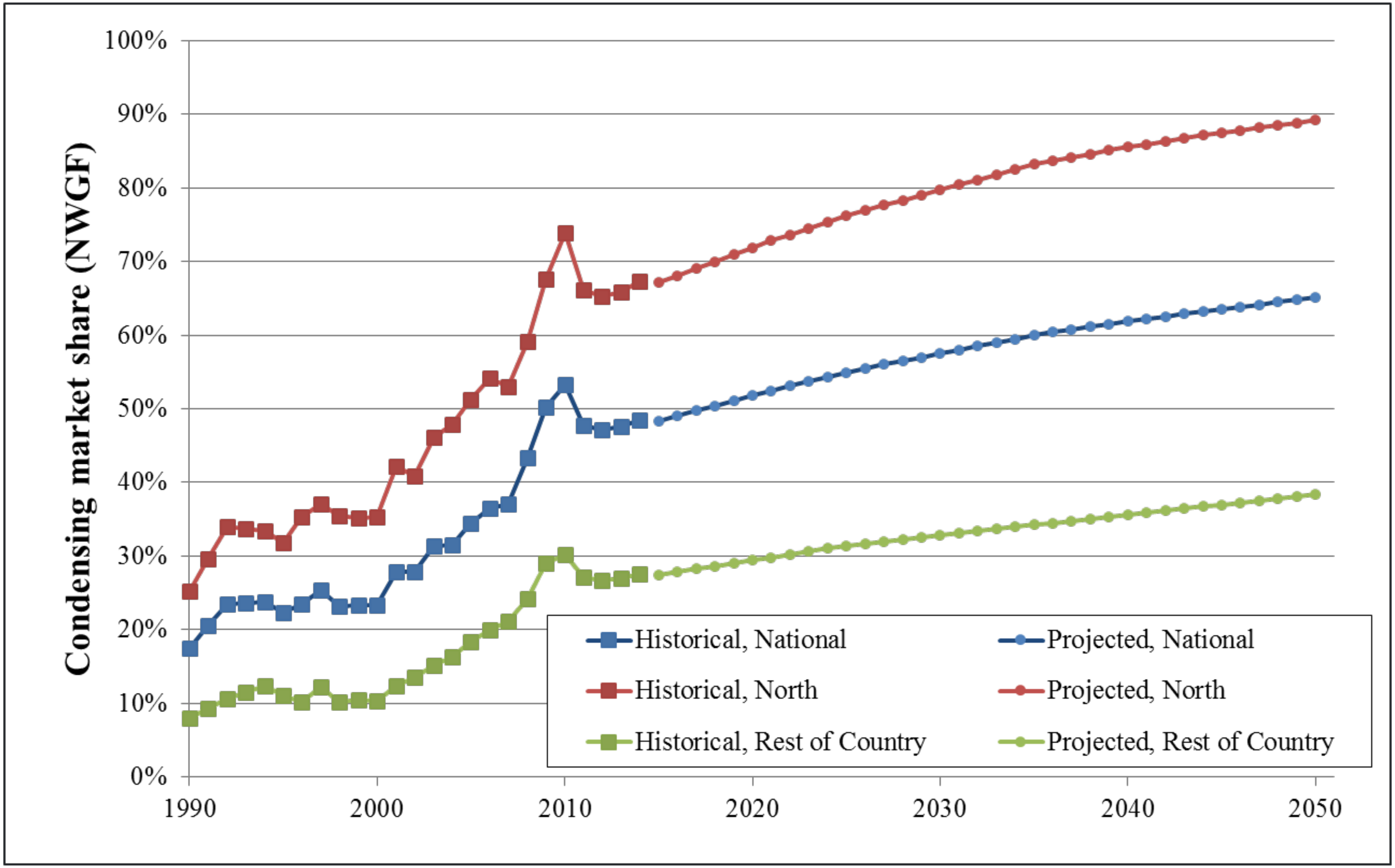
- Number of shipments disaggregated by non-condensing and condensing gas furnaces from AHRI (1978-1992, 1994-2014)
- Trend after 2015 based on 2011-2013 data, which excludes the federal tax incentive years
- 2013 AHRI Directory of Certified Product Performance

Efficiency, AFUE	2022 Market Share in Percentage, NWGFs				
	National	North, Repl	North, New	South, Repl	South, New
80%	46.5%	25.6%	30.2%	70.0%	64.5%
90%	5.9%	5.6%	10.0%	4.6%	6.5%
92%	21.2%	18.4%	33.5%	18.4%	24.4%
95%	25.4%	48.7%	25.7%	6.6%	4.4%
98%	0.9%	1.7%	0.7%	0.4%	0.2%

LCC and PBP Analysis: No-New-Standards Case Efficiency Distribution

- A consumer that uses more gas for heating does so primarily because the consumer has a higher heating load due to climate and home insulation conditions. This higher heating load is also reflected in the selection of a higher input furnace. The actual number of operating hours is primarily a function of heating degree days in a given climate region. This is captured in the analysis by using historical shipments data by efficiency level and by state. Therefore, the majority of variation in efficiency purchases, at least regionally, is captured.
- There are a number of additional factors influencing the furnace efficiency decision:
  - Systematic misperception of energy consumption of furnaces
  - Energy prices
  - Pre-existing circumstances (equipment purchased by a previous owner)
  - Environmentally conscious consumers may be willing to pay a premium
  - Efficiency is often correlated with other desirable features for which consumers may have a very high willingness to pay
  - Split incentive/principal-agent problem: e.g., landlord, builder, contractor.
  - Imperfect or asymmetric information

LCC and PBP Analysis: No-New-Standards Case Efficiency Distribution



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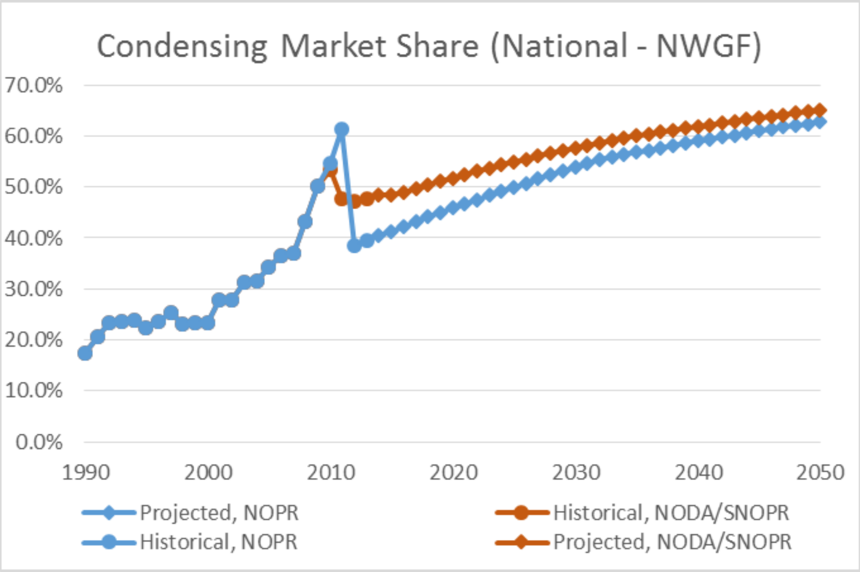
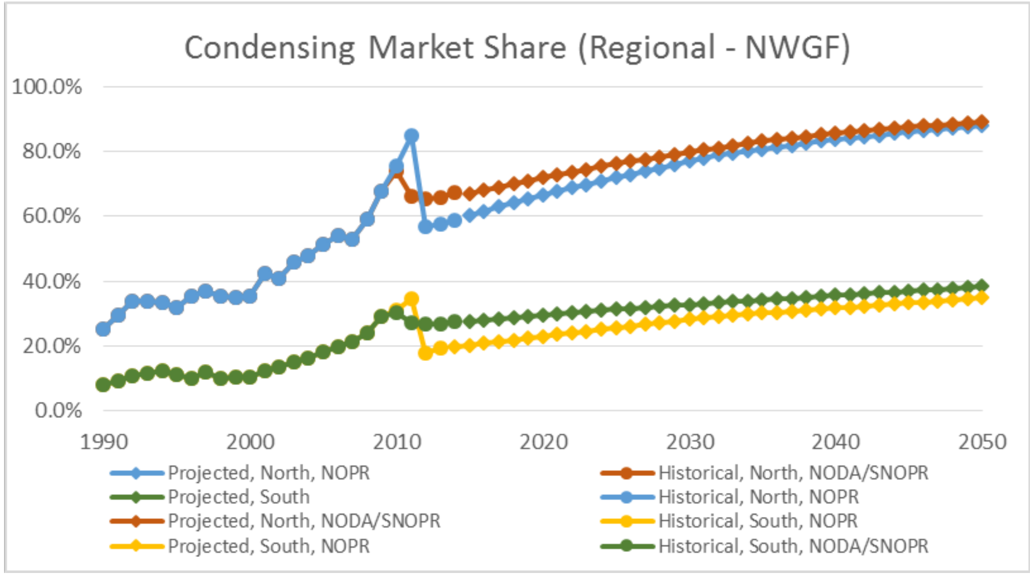
LCC and PBP Analysis: No-New-Standards Case Efficiency Distribution

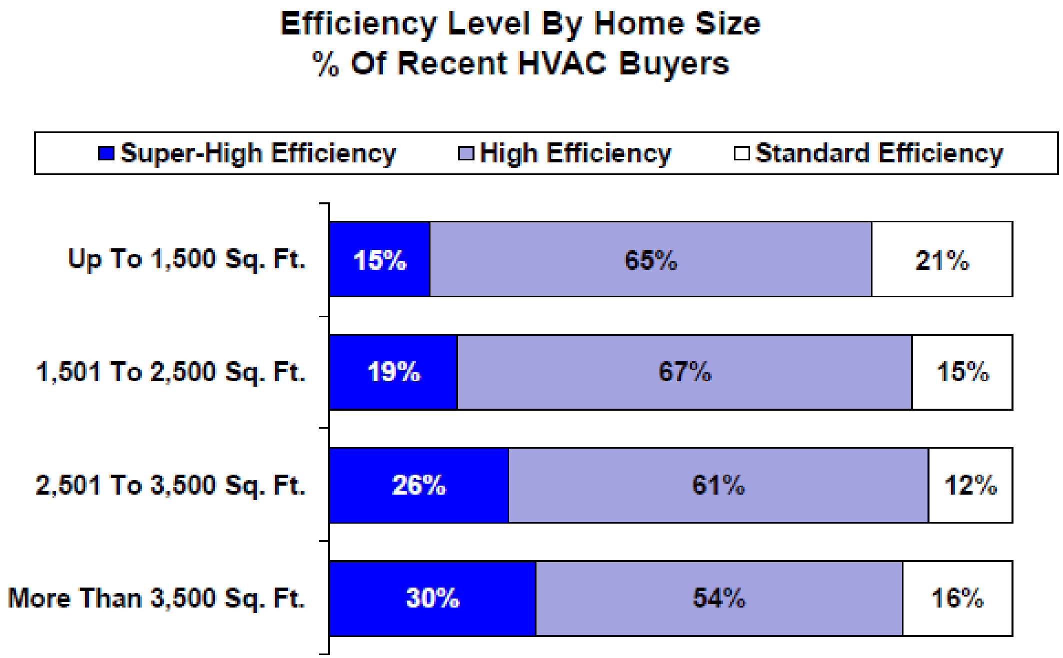




Efficiency, AFUE	SNPRM – 2022 Market Share, NWGFs				
	National	North, Repl	North, New	South, Repl	South, New
80%	46.5%	25.6%	30.2%	70.0%	64.5%
90%	5.9%	5.6%	10.0%	4.6%	6.5%
92%	21.2%	18.4%	33.5%	18.4%	24.4%
95%	25.4%	48.7%	25.7%	6.6%	4.4%
98%	0.9%	1.7%	0.7%	0.4%	0.2%

LCC and PBP Analysis: No-New-Standards Case Eff. Dist. – Unpublished

- Analysis updates based on latest data:
  - Updated using 2010-2015 AHRI and 2014 HARDI shipments data by efficiency and region
  - Updated new construction fraction using GTI fuel switching survey submitted by stakeholders
- DOE has found data from the American Home Comfort Survey to adjust the efficiency distribution by household characteristics such as square footage or income. The 2016 AHCS data show:



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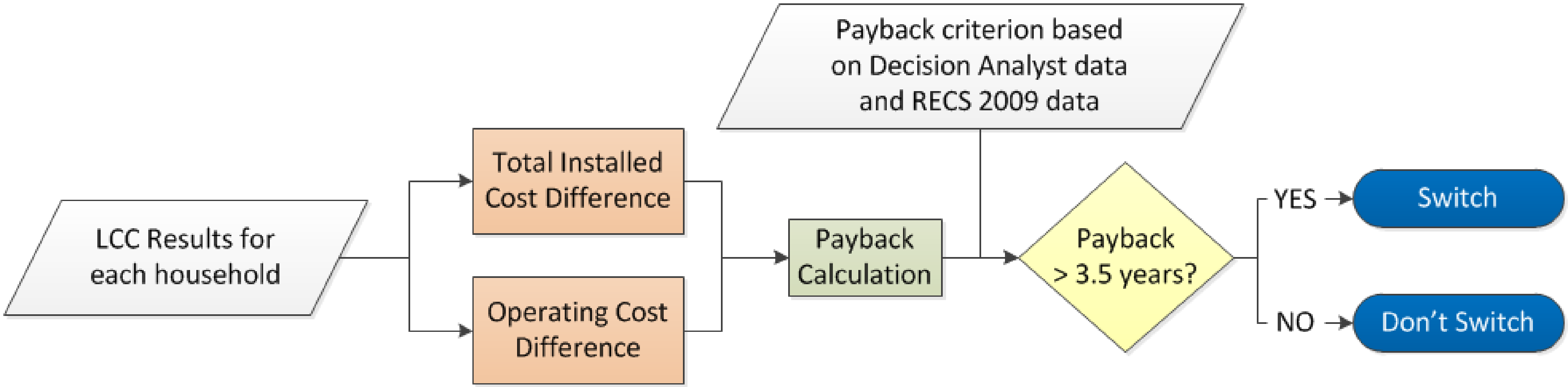
LCC and PBP Analysis: Product Switching Methodology

- In the face of high installation costs for a condensing NWGF, some consumers may choose to switch to electric space heating options in the standards case.
- **Switching options**
  - Space heating: non-condensing NWGF → condensing NWGF, EF, or HP
  - Space cooling: CAC→CAC or Air Handler + Heat Pump (AH + HP)
  - Water heating: GSWH→GSWH or ESWH
- **Inputs**: total installed cost differential, first year operating cost differential, lifetime, and energy prices of alternative space conditioning and water heating options.
- Switching decision based on PBP of condensing NWGF relative to alternative product(s)
- Switching PBP threshold based on:
  - 2006, 2008, 2010, and 2013 American Home Comfort Survey (AHCS)
  - average space conditioning energy cost determined from RECS 2001, 2005, and 2009
- Sensitivity analyses using high/low switching PBP criteria, as well as no switching scenario.

LCC and PBP Analysis: Product Switching Decision Criteria



Maximum Product Price Consumers would Pay to Purchase Higher-Efficiency Products Based on AHCS (2006-2013)

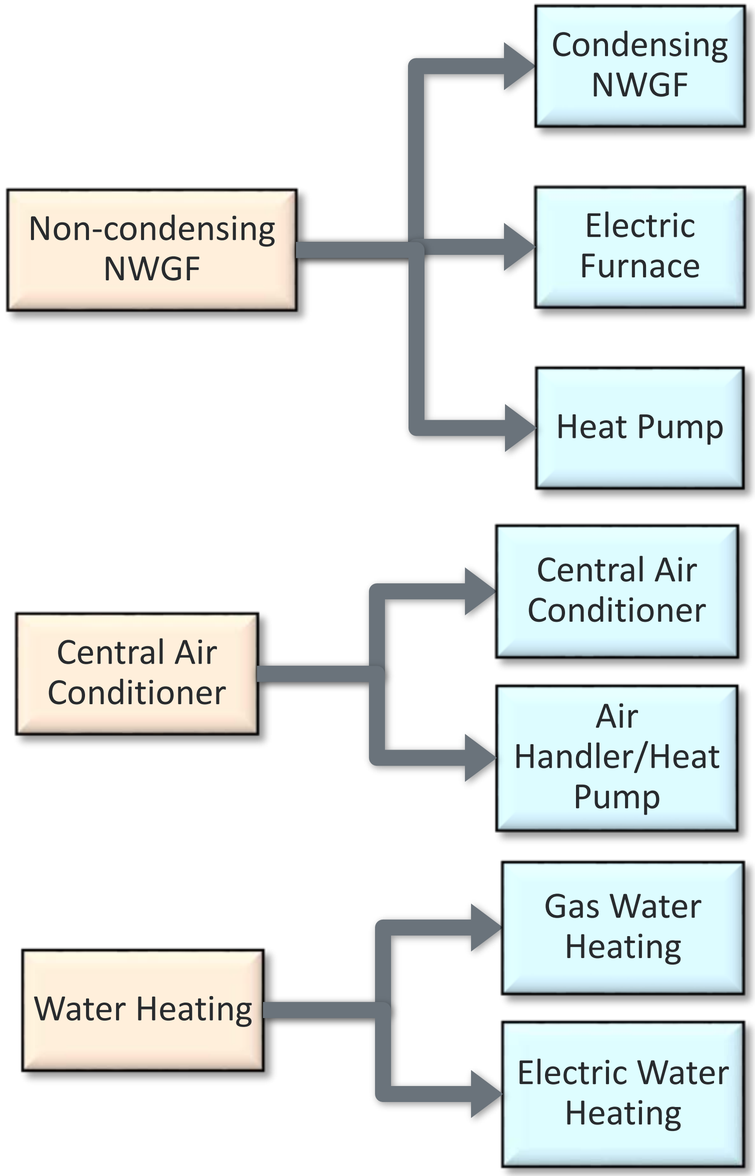
Year	Average Cost Consumers are Willing to Pay for 25% Higher Efficiency	
	Nominal $	2013$
2006	$720	$ 831.99
2008	$832	$ 900.74
2010	$817	$ 872.83
2013	$564	$ 564.00
Average		**$ 792.39**

Average Space Conditioning Energy Cost (Heating and Cooling) from RECS 2001, 2005, and 2009

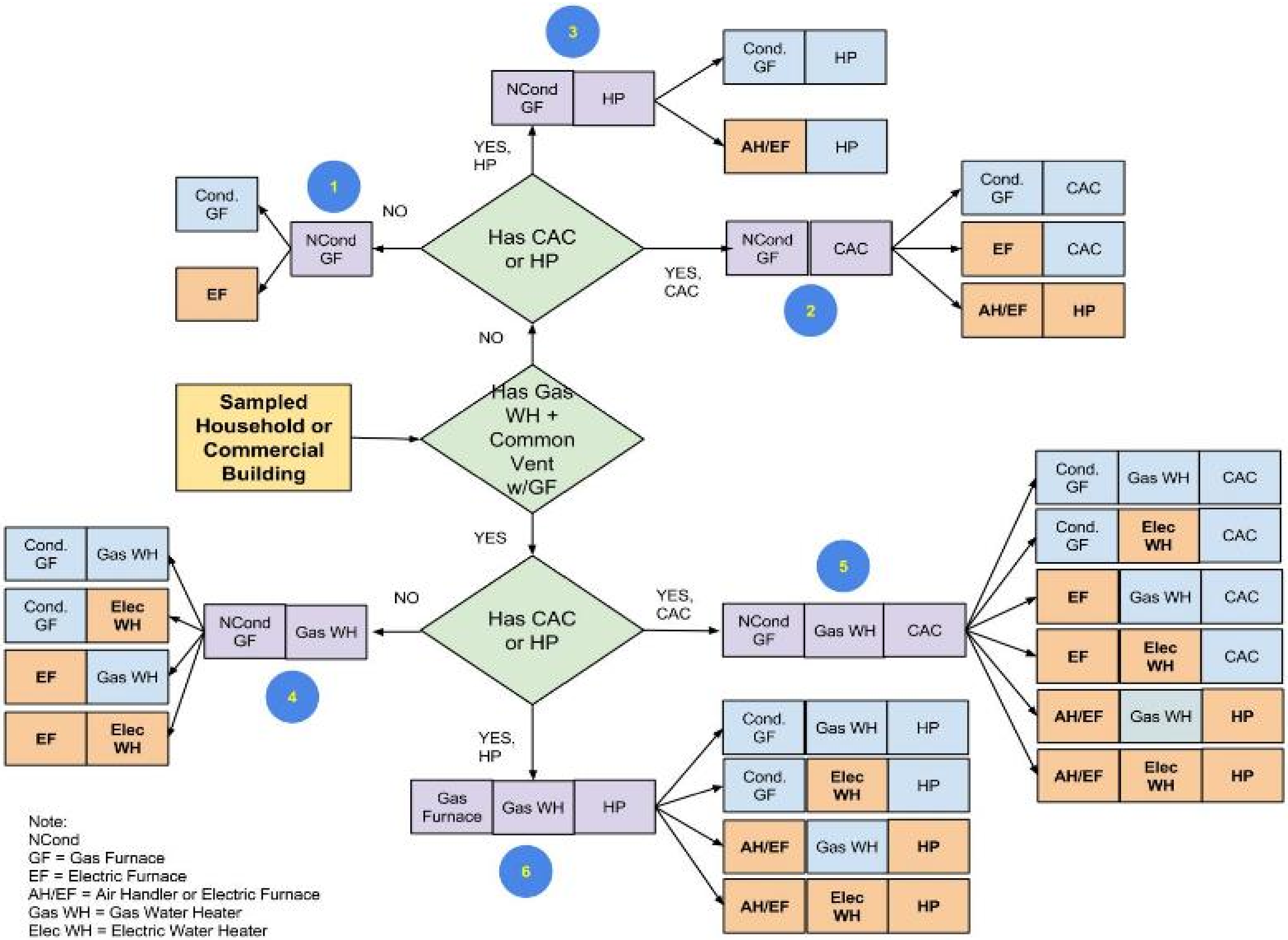
Year	Average Space Conditioning Energy Cost	
	Nominal $	2013$
2001	$667	$877.38
2005	$792	$944.93
2009	$825	$896.05
Average		**$906.12**

$$\frac{Price_{\ More-Efficient\ Product}}{25\%\ of\ Space\ Conditioning\ Energy\ Cost} = \frac{\$792}{25\% \times \$906/year} = 3.5\ years$$

LCC and PBP Analysis: Product Switching Options



LCC and PBP Analysis: Product Switching Options



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LCC and PBP Analysis: Product Switching Results

DOE implicitly assumes that all options provide the required space conditioning or water heating utility to consumers

Comparison of Product Switching for Households at Baseline (80% AFUE)

Rulemaking Phase	National Standard at:* 90% AFUE		92% AFUE		95% AFUE		98% AFUE	
	North	Rest of Country	North	Rest of Country	North	Rest of Country	North	Rest of Country
Switching to EF*								
NPRM	3.1%	5.8%	2.8%	5.7%	3.1%	5.8%	3.4%	7.2%
NODA	3.9%	6.2%	3.9%	6.2%	4.6%	6.9%	5.3%	8.2%
SNPRM	2.7%	4.1%	2.8%	4.3%	3.1%	4.7%	3.9%	5.6%
Switching to HP*								
NPRM	8.5%	14.3%	8.4%	14.3%	9.9%	19.1%	11.9%	27.4%
NODA	8.2%	14.3%	8.2%	14.7%	9.9%	18.1%	12.3%	26.6%
SNPRM	9.8%	23.5%	10.1%	25.6%	11.2%	30.9%	12.2%	36.8%
Switching GSWH to ESWH								
NPRM	2.7%	2.6%	2.3%	2.7%	2.8%	3.0%	3.3%	3.9%
NODA	3.7%	3.6%	3.8%	3.9%	4.9%	4.0%	6.4%	5.0%
SNPRM	3.5%	3.3%	3.7%	3.4%	4.1%	3.1%	4.8%	3.2%

* Components may not add to 100% due to rounding.

** Includes households that also switch from a gas water heater to an electric water heater.

LCC and PBP Analysis: Product Switching – Unpublished

- The survey data used by DOE to determine the product switching payback period criteria in the SNPRM did not provide sufficient information to derive a distribution of payback periods.
- DOE currently has sufficient survey data to be able to match the product switching payback period criteria to income based on AHCS and RECS data, as follows:

Income Group	Income Percentile	Average Payback Criteria (years)
1	0 to 20%	3.00
2	20 to 40%	3.25
3	40 to 60%	3.50
4	60 to 80%	3.75
5	80 to 90%	4.00
6	90 to 100%	4.00
Overall Average		**3.50**

- In addition, the actual payback criteria assigned to each sampled household is based on a triangular distribution around the average value shown above.

LCC and PBP Analysis: Extended Repair Option – Unpub.

- For the unpublished analysis, DOE has added an extended repair vs. replace decision criterion in its LCC analysis.
- The replace vs. repair criterion is based on the price elasticity values that vary by income as follows:

Income Group	Income Percentile	Price Elasticity (Product Price)
1	0 to 20%	0.500
2	20 to 40%	0.475
3	40 to 60%	0.450
4	60 to 80%	0.425
5	80 to 90%	0.400
6	90 to 100%	0.400
Overall Average		**0.450**

- Maximum repair cost is assumed to be half the total installed cost.
- Extended lifetime varies based on 2011 Decision Analyst report (6 years, on average).
- For NWGF at TSL 6, approximately 2% of affected households choose to delay replacement with an extended repair. At TSL 1, approximately 1% of affected households choose to delay replacement with an extended repair.

LCC and PBP Analysis: Product Switching Results – Unpub.

Fraction Product Switching or Repair vs. Replace by TSL for NWGF Installations

Consumer Option	Trial Standard Level								
	1	2	3	4	5	6	7	8	9
	% of Consumers*								
Purchase NWGF at Standard Level	97.1	96.5	97.5	94.9	86.5	94.0	85.3	93.5	83.2
Switch to Heat Pump**	0.6	0.8	1.0	2.0	7.9	2.7	8.6	2.9	9.8
Switch to Electric Furnace**	1.2	1.4	0.3	1.6	2.5	1.7	2.8	1.8	3.2
Repair vs. Replacing	1.08	1.3	1.2	1.6	3.2	1.7	3.4	1.8	3.9
Total	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**

* Components may not add to 100% due to rounding.
** Includes households that also switch from a gas water heater to an electric water heater.

LCC and PBP Analysis: SNPRM Sizing Methodology

Purpose: Determine the input capacity of the gas furnace.

Method: Assigned an input capacity for the existing furnace of each housing unit:

1. Calculate percentile rank of all RECS 2009 and CBECS 2003 housing units with a furnace in ascending order by heating square foot multiplied by a scaling factor to account for the outdoor design temperature (ODT) using building weights:

$$Adjusted\ SqFt_{heating} = \frac{SqFt_{heating} \text{ x } (65 - ODTdesign_{,\ heating})}{(65 - 42)}$$

2. Construct percentile tables by input capacity based on AHRI historical shipments data and AHRI product directory.

3. Using the adjusted heating square foot percentile from Step 1, match input capacity from the input capacity percentile table in step 2.

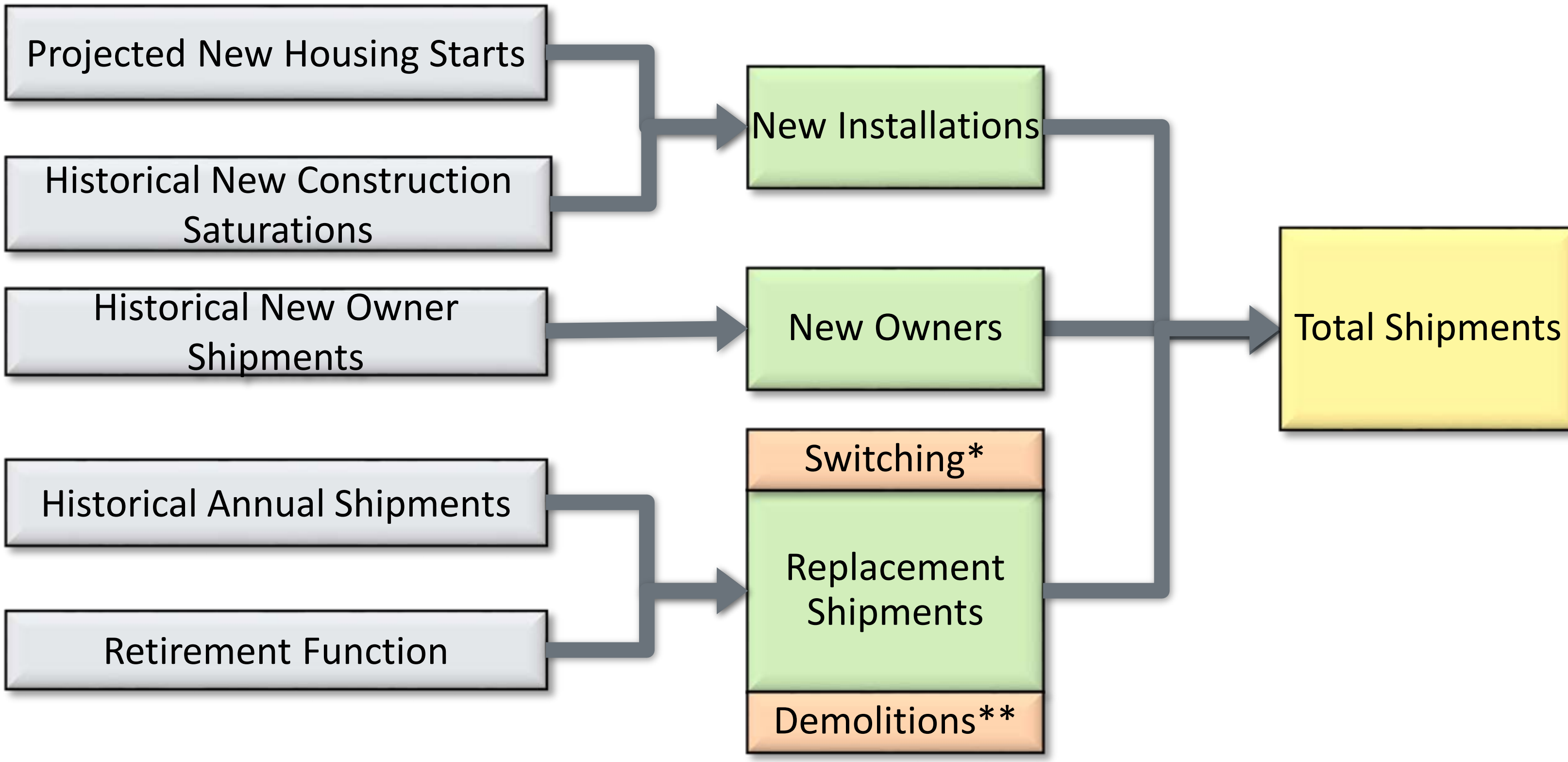
LCC and PBP Analysis: Sizing Methodology – Unpub

- For 2016 SNPRM, DOE revised its methodology to incorporate additional building criteria such as building vintage and insulation type to better reflect actual furnace sizing in the field, as well as updated shipment data.
- In addition, DOE now relies on Manual J calculations, an industry-developed standard for calculating space heating load commonly used for furnace sizing.
- This revised methodology allows for older, less insulated homes to be assigned larger NWGFs.
- Manual J calculations also take into account regional differences in the building shell and peak heating load. Calculated oversizing using Manual J. Downsizing occurs for a fraction of HHs based on payback criteria.

LCC and PBP Analysis: Results (SNPRM)

Efficiency, AFUE	LCCs (2015$)				Payback Period (years)		LCC Savings	
	Installed Cost	1st Year's Operating Cost	Lifetime Operating Cost	Average Life-Cycle Cost	Simple Payback	Average Lifetime	Average Savings* (2015$)	% of Customers Experiencing Net Cost
National								
80%	2,175	684	11,020	13,194	N/A	21.5	N/A	N/A
90%	2,597	623	10,026	12,623	6.8	21.5	582	18.3%
92%	2,635	612	9,859	12,493	6.4	21.5	617	17.1%
95%	2,742	597	9,608	12,350	6.5	21.5	561	22.2%
98%	2,858	586	9,403	12,261	6.9	21.5	506	34.2%
55 kBtu/h Cutoff								
80%	2,175	684	11,020	13,194	N/A	21.5	N/A	N/A
90%	2,542	628	10,127	12,668	6.5	21.5	667	12.1%
92%	2,576	618	9,971	12,547	6.1	21.5	692	11.1%
95%	2,672	604	9,737	12,410	6.2	21.5	609	15.2%
98%	2,775	593	9,540	12,315	6.6	21.5	543	26.0%
60 kBtu/h Cutoff								
80%	2,175	684	11,020	13,194	N/A	21.5	N/A	N/A
90%	2,483	636	10,261	12,744	6.4	21.5	745	7.2%
92%	2,512	628	10,126	12,638	5.9	21.5	741	6.6%
95%	2,592	615	9,927	12,519	6.0	21.5	602	10.0%
98%	2,679	605	9,751	12,430	6.3	21.5	530	19.3%

Shipments Analysis: Flowchart

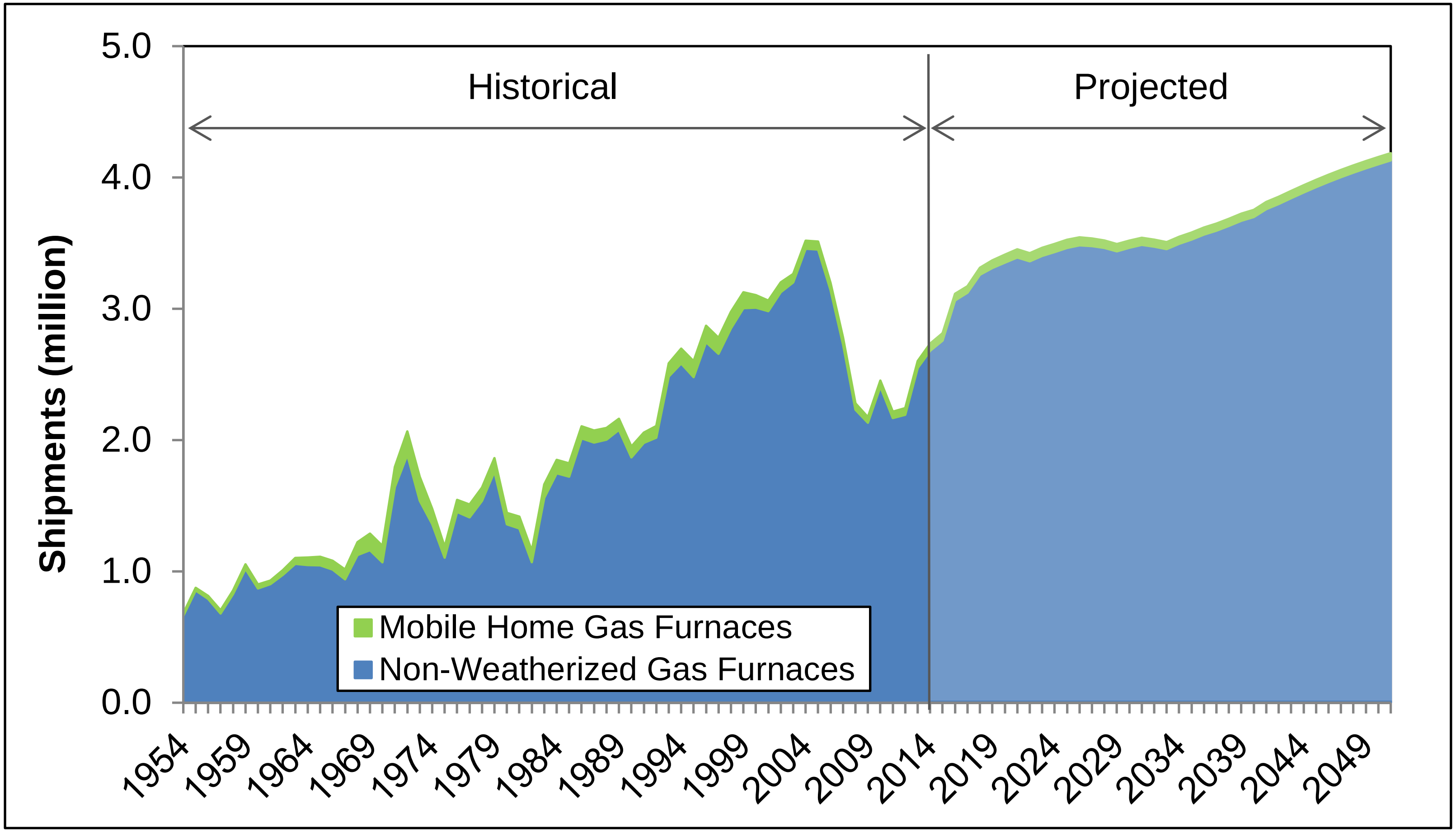


* Switching to electric space conditioning and/or water heating products based on product switching methodology.

** Based on year-to-year changes to projected housing stock.

Shipments Analysis: Historical and Projected Shipments

Historical and Projected No-New-Standards Case Shipments for NWGFs and MHGF



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National Impact Analyses (SNPRM)

Trial Standard Levels (TSLs) – AFUE Standards

TSL	Product Class			
	Non-Weatherized Gas Furnace		Mobile Home Gas Furnace	
	Efficiency Level	AFUE (Cutoff Criteria)	Efficiency Level	AFUE
1	2	92% (>80 kBtu/h)	1	92%
	0	80% (≤80 kBtu/h)		
2	2	92% (>70 kBtu/h)	1	92%
	0	80% (≤70 kBtu/h)		
3	3	95% (North)	2	95% (North)
	0	80% (Rest of Country)	0	80% (Rest of Country)
4	2	92% (>60 kBtu/h)	1	92%
	0	80% (≤60 kBtu/h)		
5	2	92%	1	92%
6	2	92% (>55kBtu/h)	1	92%
	0	80% (≤55 kBtu/h)		
7	3	95%	2	95%
8	3	95% (>55 kBtu/h)	2	95%
	0	80% (≤55 kBtu/h)		
9	4	98%	3	96%

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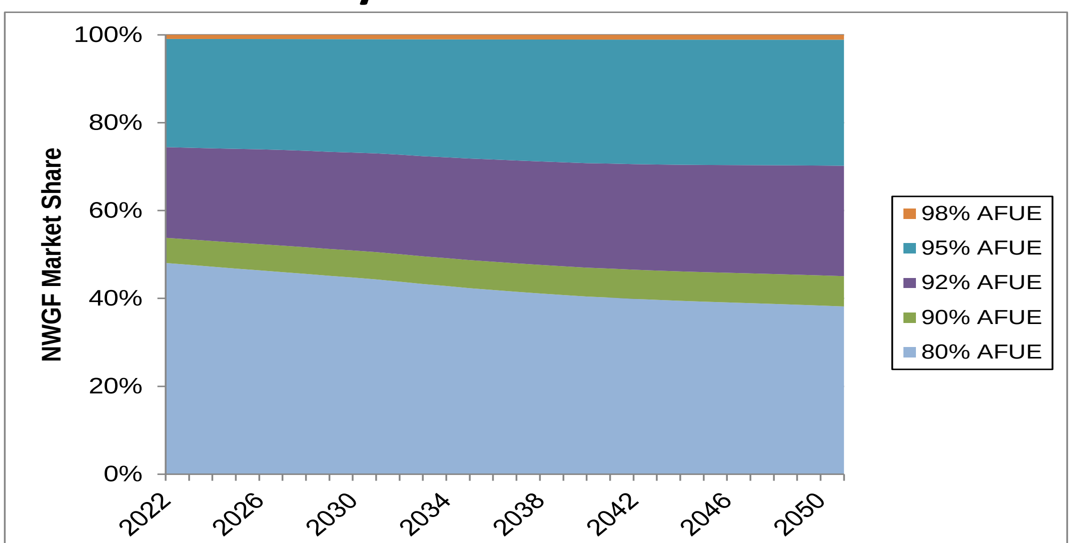
National Impact Analyses (SNPRM)

NWGF Efficiency Distributions in 2022 for AFUE Standards, %

EL	No-New-Standards Case	Trial Standard Level (TSL)								
		1*	2*	3**	4*	5†	6*	7†	8*	9†
0	48.1	42.5	33.6	35.6	26.9		13.8		14.0	
1	5.7	2.9	1.5	2.6	0.9		0.5		0.5	
2	20.6	29.0	38.8	10.3	45.8	70.4	58.3		2.0	
3	24.6	24.7	25.1	50.5	25.4	28.5	26.5	98.9	82.5	
4	0.9	0.9	0.9	0.9	1.0	1.1	1.0	1.1	1.0	100.0

Projection of No-New-Standards Case Efficiency Distribution for NWGFs



* The input capacity threshold definitions for small NWGFs are as follows for these TSLs:
TSL 1: 80 kBtu/h
TSL 2: 70 kBtu/h
TSL 4: 60 kBtu/h
TSL 6: 55 kBtu/h
TSL 8: 55 kBtu/h.
** Refers to a regional standard (North).
† Refers to national standards.

National Impact Analysis – AFUE (SNPRM)

Category	NPRM* (TSL 3)	TSL 1	TSL 2	TSL 3	TSL 4	TSL 5	TSL 6	TSL 7	TSL 8	TSL 9
National Full-Fuel Cycle Energy Savings (quads, 30 years of shipments)										
	2.78	0.88	1.75	1.81	2.27	2.78	2.86	4.17	4.15	5.72
National Full-Fuel Cycle Energy Savings (quads, 9 years of shipments)										
	0.82	0.27	0.52	0.56	0.68	0.77	0.83	1.18	1.22	1.69
NPV of Consumer benefits (2015$ billion, 30 years of shipments)										
3% Discount Rate	16.09	6.35	12.95	15.68	17.04	23.79	21.65	31.80	28.98	39.47
7% Discount Rate	3.09	1.84	3.66	4.51	4.76	5.64	5.64	7.51	7.42	8.97
NPV of Consumer benefits (2015$ billion, 9 years of shipments)										
3% Discount Rate	4.70	2.10	4.21	5.25	5.49	6.94	6.71	9.29	8.89	11.44
7% Discount Rate	1.08	0.83	1.63	2.04	2.10	2.20	2.38	2.92	3.07	3.36

* NPRM results in 2013$ and based on AEO 2013 compared to SNPRM in 2015$ and based on AEO 2015.

Furnaces: GRIM Results

	Units	No Standards Case	Trial Standard Level*								
			1	2	3	4	5	6	7	8	9
INPV	2015$M	1104.3	1031.6 - 1097.0	1005.8 - 1101.7	846.8 - 1104.6	1007.0 - 1119.2	985.2 - 1118.0	1016.4 - 1142.8	729.2 - 1126.8	771.6 - 1147.1	526.5 - 1100.0
Change in INPV	2015$M	-	(72.8) - (7.3)	(98.5) - (2.7)	(257.6) - 0.3	(97.4) - 14.8	(119.2) - 13.7	(88.0) - 38.5	(375.2) - 22.5	(332.8) - 42.8	(577.9) - (4.3)
	%	-	(6.6) - (0.7)	(8.9) - (0.2)	(23.3) - 0.0	(8.8) - 1.3	(10.8) - 1.2	(8.0) - 3.5	(34.0) - 2.0	(30.1) - 3.9	(52.3) - (0.4)
Total Conversion Costs	2015$M	-	34.1	43.0	67.0	47.8	61.9	54.7	107.6	94.2	327.9
Free Cash Flow (2021)	2015$M	69.3	56.8	52.8	43.4	50.7	44.3	47.6	25.1	31.2	(66.0)
	% Change	-	(18.0)	(23.8)	(37.4)	(26.9)	(36.0)	(31.4)	(63.7)	(55.0)	(195.2)

Upper Bound

- The upper bound to industry profitability is the preservation of gross margin markup scenario.

Lower Bound

- The lower bound to industry profitability is the 3-tier scenario.

Furnaces: Cumulative Regulatory Burden Results

Compliance Dates and Expected Conversion Costs of Federal Energy Conservation Standards Affecting Non-Weatherized Gas Furnace and Mobile Home Gas Furnace Manufacturers

Federal Energy Conservation Standards	Number of Manu.	Manu. in Today's Rule	Approx. Year std.	Conversion Costs	Conversion Costs / Revenue
Commercial Packaged Boilers† (March 24, 2016)	45	2	2019	$27.5M (2014$)	2.3%
Commercial Water Heater (May 31, 2016)	25	2	2019	$29.8M (2014$)	3.0%
Furnace Fans (July 3, 2014)	38	13	2019	$40.6M (2013$)	1.6%
Residential Boilers (January 15, 2016)	27	2	2021	$2.5M (2014$)	<1 %
Central Air Conditioners and Heat Pumps† 80 FR 52206 (August 25, 2015)	30	10	2023	342.6M (2015$)	<1%
Commercial Warm Air Furnaces (January 15, 2016)	16	8	2023	$7.5M to $22.2M (2014$)	1.7% to 5.1%††
Small, Large, and Very Large Commercial Package Air Conditioning and Heating Equipment (January 15, 2016)	29	9	2018 and 2023	$520.8M (2014$)	4.9%

† indicates a proposed rule.

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Furnaces: Key Issues from Stakeholder Comments

Key issues raised related to the focus areas:

- Cumulative regulatory burden (CRB)
  - Accounting for concurrent appliance standards and test procedures
  - Issues specific to the furnace fans standard
- Regulatory Flexibility Analysis (small businesses)
  - Stakeholder disagreement with general methodology
  - Stakeholder concerns about small MHGF manufacturer

Furnaces: Key Issue – CRB

CRB: Concurrent Appliance Standards

- Manufacturers submitted comments about appliance standards rulemakings that were not included in CRB tables:
  - For CRB, DOE reviews other appliance standards that have a compliance date within 3 years of the expected compliance date of the proposed rule. The residential furnaces SNPRM had an anticipated compliance date in 2022. Thus, DOE reviewed all appliance standards with compliance dates in the time frame of 2019 to 2025. The rationale is that manufacturer would be making concurrent investments in multiple rulemakings if the compliance dates are in analyzed timeframes.
  - DOE reviewed the standards identified by stakeholders in comments. Two rules were finalized but had compliance dates outside of the 6-year window for CRB. Two other rules were in the preliminary stages of rulemaking. DOE only incorporates Appliance Standard final rules in its CRB evaluation. At industry's request, DOE has added Appliance Standard proposed rules to its CRB tables. However, rules in stages before a proposed rule do not yet have proposed levels, estimated compliance costs, or compliance dates for evaluation.
  - From the NPRM to the SNPRM, the anticipated compliance year shifted by 1 year. This resulted in additional changes in what DOE considered in its evaluation of CRB.

Furnaces: Key Issue – CRB

CRB: Concurrent Appliance Standards

- Manufacturers noted that test procedure (TP) final rules were not included in the list of cumulative regulatory rulemakings.
  - Where TP rulemakings require re-rating of products, DOE incorporates that cost as component of product conversion costs in the ECS rulemaking. The cost of TPs is reflected in the ECS conversion costs shown in CRB tables.

- Manufacturers commented that DOE did not quantify the cumulative negative INPV impacts of the rulemakings included in the cumulative regulatory burden analysis.
  - INPV is the industry value calculated from the revenues of the covered product. Typically, there is zero overlapping revenue between Appliance Standards. Incorporating INPV impacts of other regulations would require a redefinition of the industry – summing both the total costs and total revenues.

  - Where cumulative impacts affect the same revenue stream, DOE takes steps to analyze the combined impacts. This is seen in DOE's analysis of furnace fans and residential furnaces.

Furnaces: Key Issue – CRB

CRB: Furnace Fans

- Stakeholders from industry commented that the GRIM may not be fully recognizing the impacts of the overlap between the furnace fan and NWGF and MHGF rules.
  - DOE recognizes that there is unique overlap between furnace fans and NWGFs/MHGFs because they share a common revenue stream and design changes from the residential furnace SNPRM are additive to the changes that results from the furnace fan Final Rule. Additionally, the compliance dates of the two rules occur within a short period of time, 2019 for furnace fans and 2022 for NWGFs and MHGFs.
  - To account for this in the GRIM, DOE incorporated increases in manufacturer production costs and increases in working capital due to the furnace fan standard beginning in 2019. Additionally, DOE added the relevant conversion costs from the furnace fan rule that occur between 2015 and 2019.
  - DOE explicitly took the conversion cost and cash flow impacts from the furnace fan rulemaking into account when walking down to TSL 6 in the residential furnace SNPRM.

Furnace: Key Issue – RegFlex

DOE analyzed the impacts on small businesses based on SBA's Regulatory Flexibility Analysis guidance in the NPRM and SNPRM.

- The Small Business Administration (SBA) set a size threshold of 1,250 employees or fewer for the industry category "Air-Conditioning and Warm Air Heating Equipment and Commercial and Industrial Refrigeration Equipment Manufacturing."
- Based on public information, DOE identified 13 manufacturers of NWGF or MHGF
  - 12 companies produce NWGFs
  - 6 companies produce MHGFs
- DOE identified three small domestic companies that manufacture NWGFs and/or MHGFs in the United States.
  - Thermo Products, Texas Furnace, and Mortex are all privately-held companies with no publicly available financials.
  - DOE was unable to find reliable market share data from either public or paid sources.
  - DOE relied on headcount and revenue estimates from subscription market research tools (i.e., Hoovers).
  - DOE contractors attempted to contact all three small manufacturers. None of the small businesses consented to formal MIA interviews.

Furnace: Key Issue – RegFlex

DOE attempted to qualify potential impacts on small domestic manufacturers based on limited available information.

- DOE analyzed the small manufacturers' share of listings in the DOE Certification Compliance Database.

Percent of Models in DOE Certification Database		
	NWGF	MHGF
Small Manuf. #1	less than 1%	4%
Small Manuf. #2	5%	n/a
Small Manuf. #3	n/a	17%

- DOE analyzed the percentage of small manufacturer models that would meet the proposed standard.

Percent of Models Meeting or Exceeding TSL 6		
	NWGF	MHGF
Small Manuf. #1	93%	71%
Small Manuf. #2	22%	n/a
Small Manuf. #3	n/a	0%

Furnace: Key Issue – RegFlex

DOE estimated manufacturer conversion costs and compared them to company revenue.

Small Business Conversion Costs Estimates				
	Est. company revenue in 2015 ($MM)	Est. 5-year revenue ($MM)	Conversion costs ($MM)	(Conversion costs) / (5-year revenue)
Small Manuf. #1	190	950	0.57	0.1%
Small Manuf. #2	34.7	173.5	4.9	2.8%
Small Manuf. #3	30.0	150	0.8	0.5%

- DOE contractors were not afforded to opportunity to visit small manufacture production facilities.
- DOE used models counts, in lieu of market share data, to apportion capital conversion costs across companies.
- DOE used percentage of industry models failing to apportion product conversion costs across companies.
- DOE compares compliance costs to revenue per SBA guidance. Conversion costs are invested over the 5-year compliance period. Thus DOE presents conversion costs relative to 5-year revenues in its regulatory flexibility analysis.

Furnace: Key Issue – RegFlex

DOE recognizes impact on small manufacturers.

DOE does not certify that the standard "would not have a significant economic impact on a substantial number of small entities."

- SNPRM RegFlex highlights that small manufacturer #2 "accounts for approximately 17 percent of [MHGF] listings in the DOE Certification Compliance Database. This domestic small manufacturer does not offer condensing MHGFs, and none of their products will meet the proposed standard."
- NPRM RegFlex highlights that small manufacturer #2 "will need to develop a condensing product line from scratch" and will "face substantially higher conversion costs for R&D and, perhaps, for tooling-up production of secondary heat exchangers." DOE recognizes that the business many "re-evaluate the cost-benefit of staying in the MHGF market."

DOE evaluates the possibility of selecting a different standard level at the expense of national energy savings and reduced consumer benefits. The Department declines walking down to a level that would set the standard to baseline for MHGF.

DOE presents options for compliance flexibility:

- "EPCA provides that a manufacturer whose annual gross revenue from all of its operations does not exceed $8 million may apply for an exemption from all or part of an energy conservation standard for a period not longer than 24 months after the effective date of a final rule establishing the standards. (42 U.S.C. 6295(t)) Additionally, Section 504 of the Department of Energy Organization Act, 42 U.S.C. 7194, provides authority for the Secretary to adjust a rule issued under EPCA in order to prevent "special hardship, inequity, or unfair distribution of burdens" that may be imposed on that manufacturer as a result of such rule." To date, this exemption has not been granted.

Emissions Analysis

FFC Emission Results: AFUE and Standby and Off-Mode Standards

Rulemaking Stage	CO_2 (million metric tons)	NO_X (tons)	SO_2 (tons)	Hg (tons)
NPRM	153	840	-189.6*	-0.59*
SNPRM	159	717	-67.6*	-0.26*

* Negative values indicate an increase in emissions.

Results: FFC Emission Reductions Benefits, *million 2015$*

Proposed Standard (SNPRM)	CO_2	Low NO_X value at 3% discount rate	Low NO_X value at 7% discount rate
AFUE Standard (TSL 6)	839 to 12,551	495	165
Standby Standard (TSL 3)	98.4 to 1,454	46.8	15.8

Indirect Employment Impacts

- Direct employment impacts are analyzed in MIA.
- Indirect employment impacts are estimated using ImSET, an input/output econometric model of the U.S. economy.
- Indirect employment impacts are estimated to be short-term effects primarily in the following sectors:
  - Production sector
  - Energy generation sector
  - General consumer good sector
- SNPRM assumed that all products are produced domestically.
- Indirect employment impacts are likely to be transitory.

Proprietary Data

- Data from manufacturer interviews
- Historical shipment data submitted by trade associations or purchased from trade associations
- Purchased various market research reports/data and trade literature
- Purchased reference materials (e.g., RS Means, Manual J, etc.)

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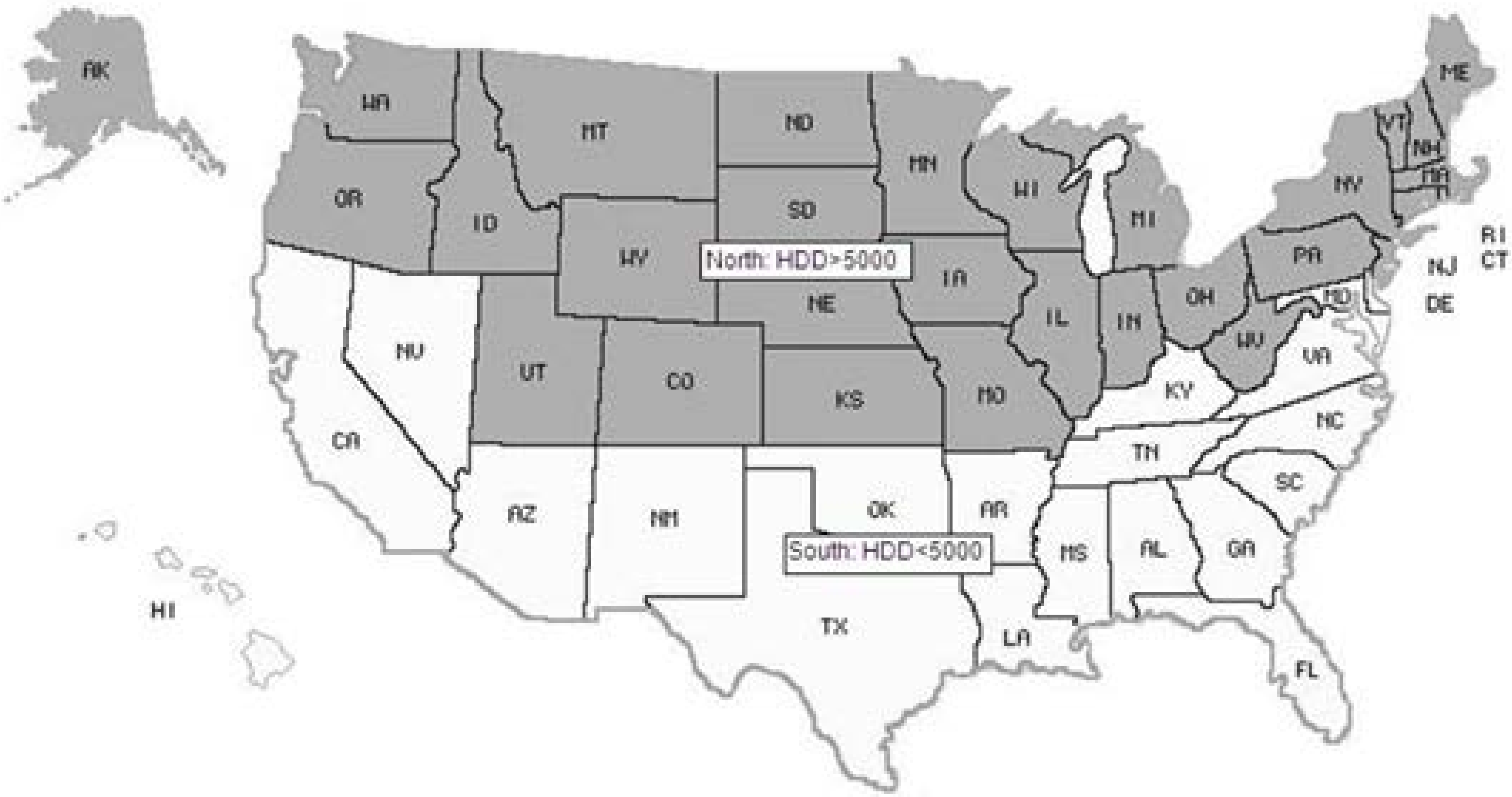
Backup

Map of the Regions for the Furnace SNOPR Analysis



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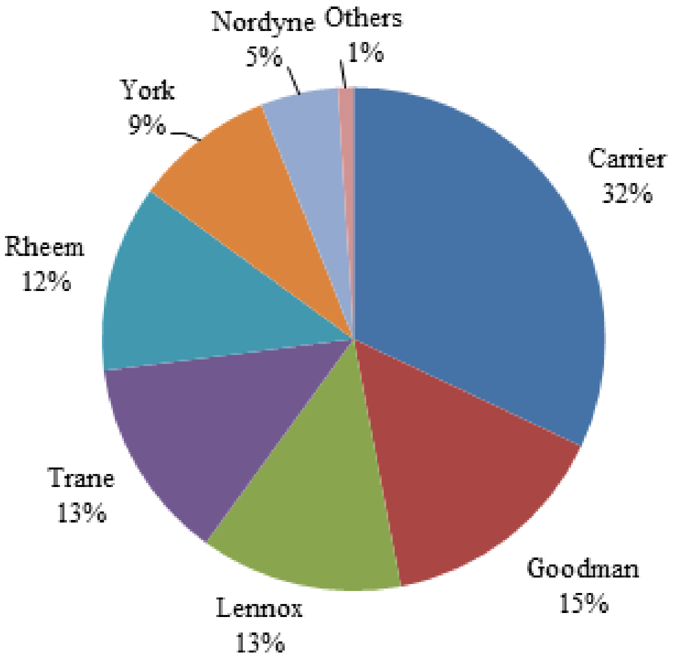
Furnaces: Furnace Manufacturers and Market Share

- Seven US Furnace OEMs account for about 99% of unit shipments
- Three Small Businesses: Mortex, Texas Furnace, and Thermo Products

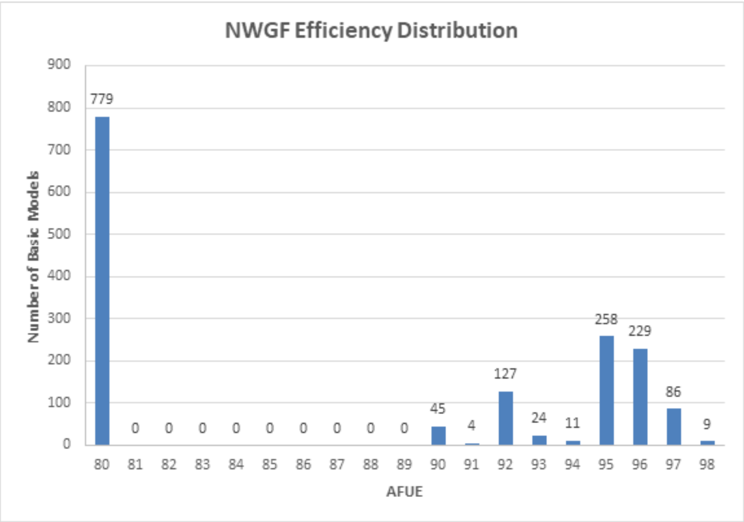
NWGF and MHGF Manufacturer	Parent Company	NWGF	MHGF
Carrier Corporation	United Technologies Corporation	X	X
Dettson Industries, Inc.	N/A	X	X
GD Midea Heating & Ventilating Equipment Co., Ltd	Midea Group	X	
Goodman Manufacturing Co., LP.	Daikin Industries, Ltd.	X	
Lennox Industries, Inc.	Lennox International, Inc.	X	
Mortex	Mortex Products, Inc.		X
Nordyne, LLC	Nortek, Inc.	X	X
Rheem Manufactuing Company	Paloma Group	X	
Texas Furnace, LLC	AllStyle Coil Company, L.P.	X	
Thermo Products, LLC	Burnham Holdings, Inc.	X	X
Trane	Ingersoll Rand	X	
Wolf Steele, Ltd.	Napoleon Systems and Development, Ltd.	X	
York International Corporation	Johnson Controls, Inc.	X	X

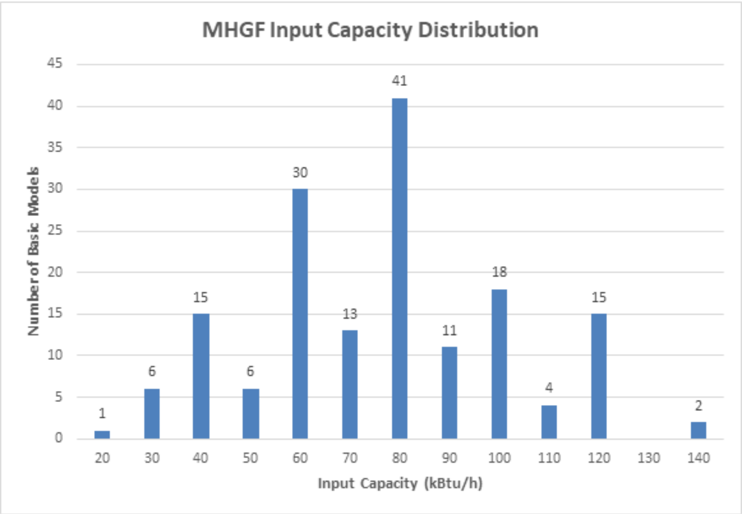


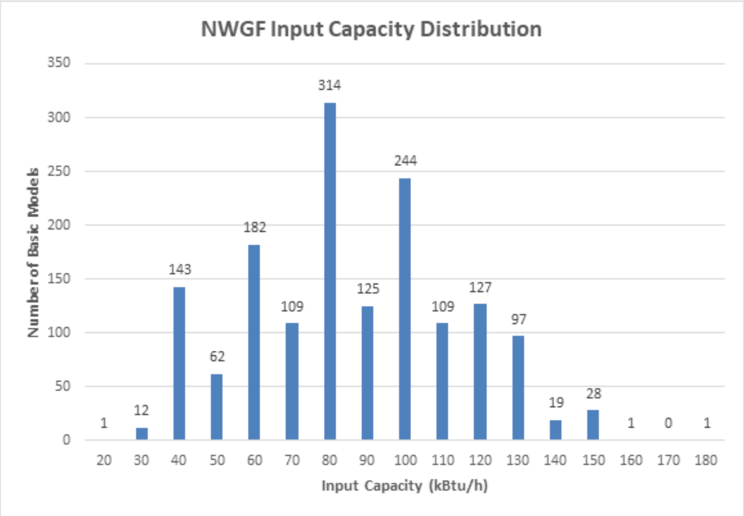
Sources for:

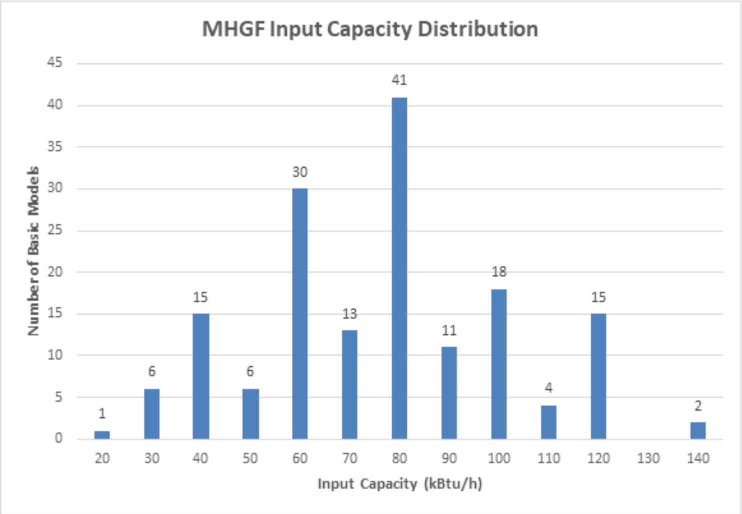
- Manufacturer List: AHRI *Directory of Certified Product Performance*
- Market Shares: September 2009 issue of *Appliance Magazine* (last time such data was published)

Furnace Efficiency Distribution and Model quantities by Capacity

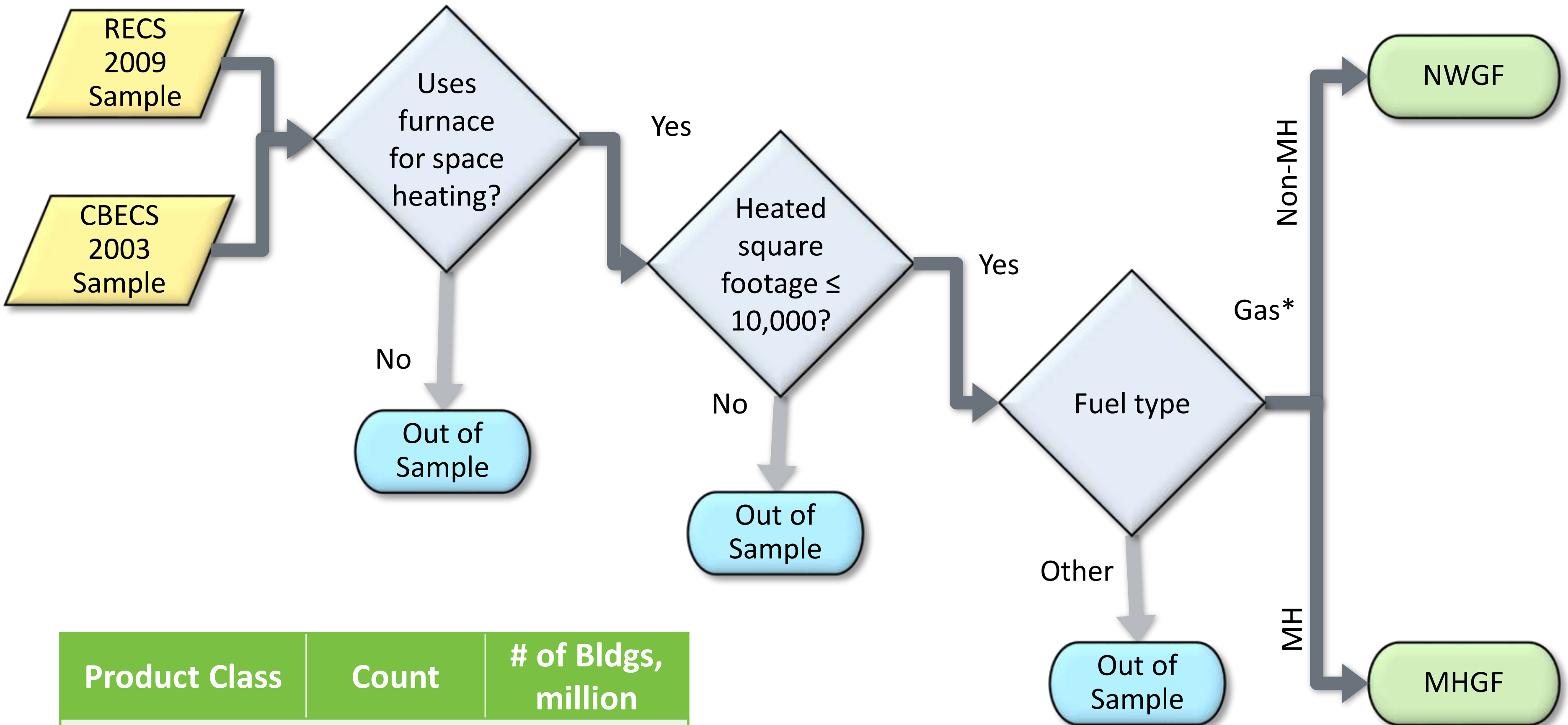








Energy Use Analysis: Building Sample Determination



Product Class	Count	# of Bldgs, million
RECS 2009		
NWGF	5,700	53.7
MHGF	195	2.5
CBECS 2003		
NWGF	685	1.162
MHGF	0	0

* Includes natural gas and LPG

Energy Use Analysis: Building Sample Adjustments

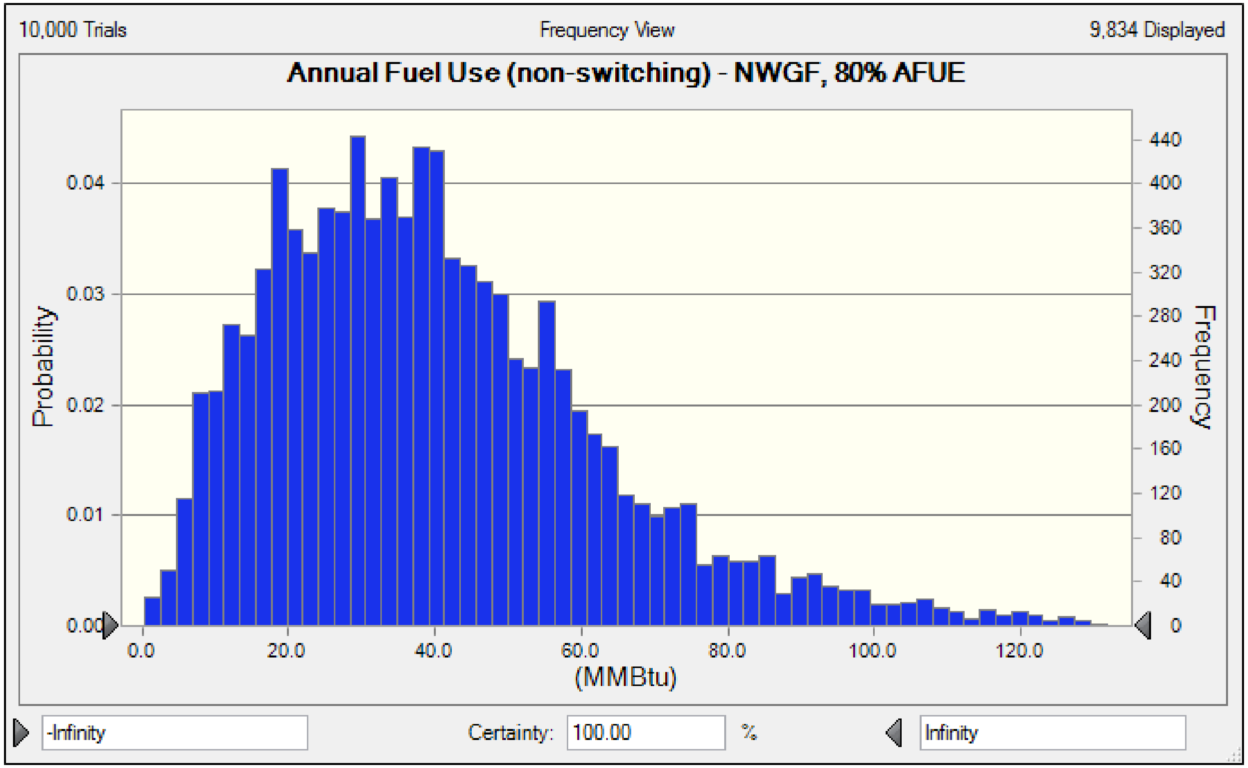
- **Households sharing a furnace**: RECS 2009-reported weight is decreased by the number of units sharing the furnace as follows:

Single-family home:	share furnace with 1 other unit
Multi-family home(2-4 units):	share furnace with 3 other units
Multi-family home (5+ units):	share furnace with # of units reported in building

- **Buildings with multiple furnaces**: RECS 2009-reported weight is increased by the number of furnaces in a building
  - Assumed that residential buildings over 5,000 square feet assumed to have two NWGFs .
- Projected growth of the number of furnaces by 2022 based on shipments analysis.
- **Historical Shipments**: matched NWGF sample weights to AHRI furnace shipments.
- **Disaggregating NWGFs from WGFs RECS 2009**: used AHRI shipments data to account for weatherized gas furnaces in RECS 2009 sample.
  - About 10 percent of total furnace shipments are weatherized furnaces
  - DOE multiplied the RECS 2009 weight for households with both a gas furnace and central air conditioning (CAC) by 0.97 for the North region, 0.79 for the hot-dry Rest of Country region, and 0.82 for hot-humid Rest of Country region.

LCC and PBP Analysis: Energy Use Analysis Results

Distribution of Fuel Use for Baseline (80% AFUE) NWGF in 2022



Product Class	Average (Median) Heating Energy Use from RECS 2009/CBECS 2003, MMBtu/yr	Average (Median) Estimated Heating Energy Use at Baseline, MMBtu/yr		
		NPRM, 2021	NODA, 2021	SNPRM, 2022
NWGF	50.5 (43.7)	42.7 (37.4)	43.3 (37.7)	43.3 (37.7)
MHGF	39.7 (36.2)	33.3 (31.3)	33.9 (31.3)	33.9 (31.2)

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LCC and PBP Analysis: Energy Prices

Purpose: Develop average marginal monthly prices by geographical area.

Method: Multiply most current average annual energy prices by monthly price factors and marginal price factors.

- 2014 average annual energy prices by geographical area based on:
  - *Electricity*: EIA's 2014 Form 826 data
  - *Natural Gas*: EIA's 2014 Natural Gas Navigator monthly
  - *LPG*: EIA's 2014 State Energy Consumption, Price, and Expenditures Estimates (SEDS)
- Monthly energy price factors by geographical area based on:
  - *Electricity*: EIA's 1995-2014 Form 826 monthly data
  - *Natural Gas*: EIA's 1995-2014 Natural Gas Navigator monthly data
  - *LPG*: EIA's 2009 Short Term Energy Outlook 1995-2009 historical data
- Marginal energy price factors for electricity and natural gas by 30 geographical areas and 10 Census regions based on EIA monthly data from 2005-2014.

LCC and PBP Analysis: Marginal Natural Gas Prices

- DOE developed seasonal marginal price factors (which relate marginal to average prices) for 23 gas tariffs provided by GTI and compared them to marginal price factors developed from the EIA data. The winter and summer price factors used by DOE are generally comparable to those computed from the tariff data.
  - DOE's use of EIA State-level data effectively averages overall consumer sales in each State, and so incorporates information about all utilities. DOE's approach is, therefore, representative of a large group of consumers with diverse baseline gas usage levels.
  - A full tariff-based analysis would require data that are generally not available in the public domain.
  - RECS 2009 billing data was also used to validate marginal energy price factors for each RECS 2009 geographical area.

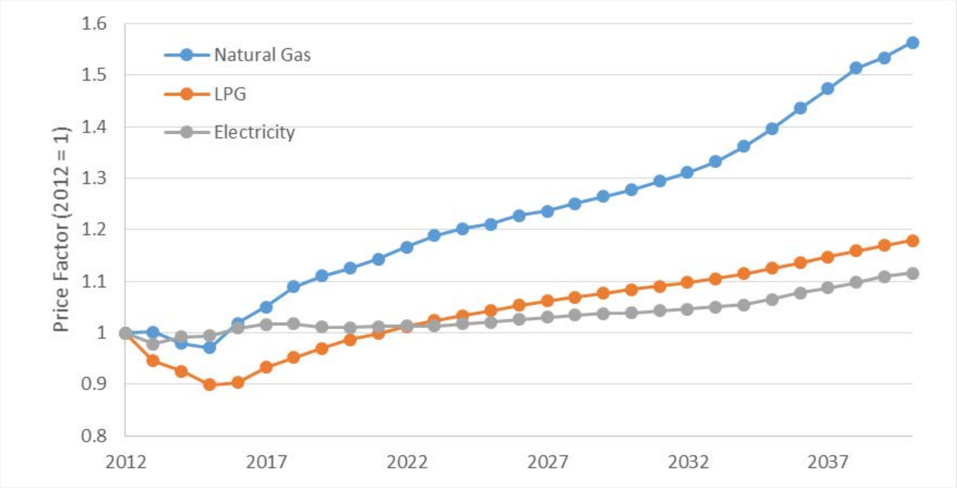
LCC and PBP Analysis: Energy Price Results

Summary of Non-Weatherized Gas Furnaces Average and Marginal Prices

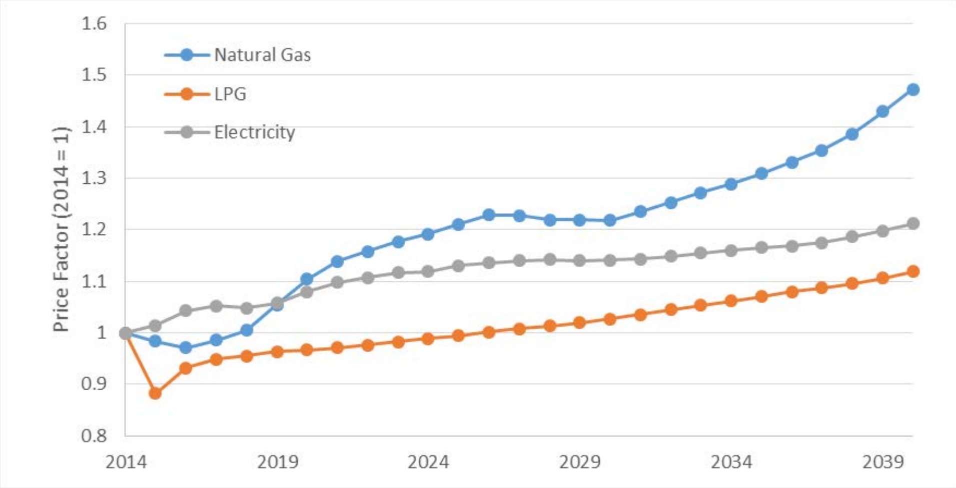
Rulemaking Phase	Natural Gas, $/MMBtu		Electricity, $/kWh		LPG, $/MMBtu
	Average	Marginal	Average	Marginal	Average
NPRM (in 2021, 2013$)	12.78	11.35	0.1281	0.1202	25.94
NODA (in 2021, 2014$)	13.46	11.92	0.1299	0.1223	25.81
SNPRM (in 2022, 2015$)	13.22	11.71	0.1372	0.1292	31.30

National Residential Energy Price Forecasts

NPRM (AEO 2013)



SNPRM (AEO 2015)



Note: Appendix 8K describes sensitivity analysis that considered alternative energy price trends (high and low economic growth scenarios).

LCC and PBP Analysis: Repair and Maintenance

Repair Cost: Cost of replacing or repairing components in the furnace that have failed.

- *Sources: 2015 RS Means Facilities Repair and Maintenance Data,* manufacturer literature, Decision Analysts 2008 American Home Comfort Study.

Maintenance Cost: Labor and materials required to maintain furnace.

- *Sources*: Decision Analysts 2008 American Home Comfort Study, *2015 RS Means Facilities Repair and Maintenance Data*.
- Accounts for additional maintenance costs associated with condensate withdrawal system and condensate neutralizer.

Product Class	Efficiency Level	Repair Cost (2015$)		Maintenance Cost (2015$)	
		Annualized	Incremental	Annualized	Incremental
Non-Weatherized Gas Furnace	80%	20.32	-	40.78	-
	90%	23.26	2.94	42.77	1.99
	92%	23.26	2.94	42.77	1.99
	95%	23.26	2.94	42.77	1.99
	98%	23.26	2.94	42.77	1.99
Mobile Home Gas Furnace	80%	9.07	-	40.28	-
	92%	10.21	1.14	42.24	1.96
	95%	10.21	1.14	42.24	1.96
	97%	10.21	1.14	42.24	1.96

LCC and PBP Analysis: Residential Discount Rates

Purpose: Used to determine the present value of lifetime operating expenses.

Method: Derived from various types of debt and equity using the Federal Reserve Board's *Survey of Consumer Finances*.

- Primary data sources: Federal Reserve Board's *Survey of Consumer Finances* for the years 1995, 1998, 2001, 2004, 2007, 2010, and 2013.

Average real effective discount

Income Group	Discount Rate (%)
1	4.82
2	5.01
3	4.59
4	3.87
5	3.57
6	3.31
Overall Average	**4.34**

LCC and PBP Analysis: Res. Discount Rates – Unpublished

Residential Discount Rate values updates using the most up-to-date data:

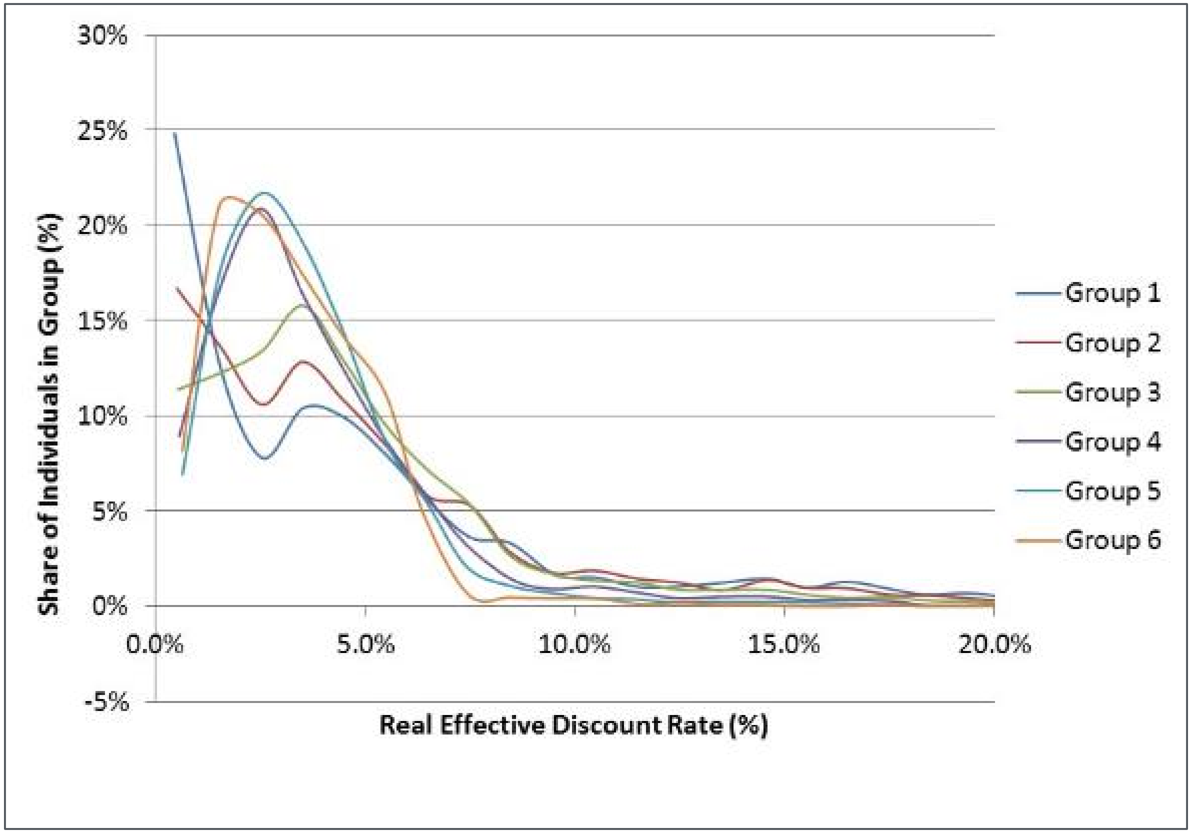
- Updated using Federal Reserve Board's *Survey of Consumer Finances* for 2016.
- Updated interest rate data up to 2018.

Average real effective discount

Income Group	SNPRM Discount Rate (%)	Unpublished Discount Rate (%)
1	4.82	4.74
2	5.01	5.01
3	4.59	4.52
4	3.87	3.87
5	3.57	3.51
6	3.31	3.18
Overall Average	**4.34**	**4.30**

LCC and PBP Analysis: Residential Discount Rates

Distribution of Real Discount Rates by Income Group



LCC and PBP Analysis: Downsizing Methodology

Purpose: Under a separate standard for small NWGFs that does not require condensing technology, DOE expects that some consumers who would otherwise install a typically-oversized furnace would choose to downsize in order to be able to purchase a non-condensing furnace.

Method: Identified households from the NWGF sample that might downsize:

1. Determine if a household would install a non-condensing NWGF with an input capacity greater than the small furnace size limit without amended standards.
2. Determine input capacity of the NWGF using a 35% oversize factor* rather than the standard 70% oversize factor.**
3. If the input capacity of the furnace determined using 35% oversize factor is less than or equal to the input capacity limit for small furnaces, assumed that the consumer would downsize to the small furnace size limit.

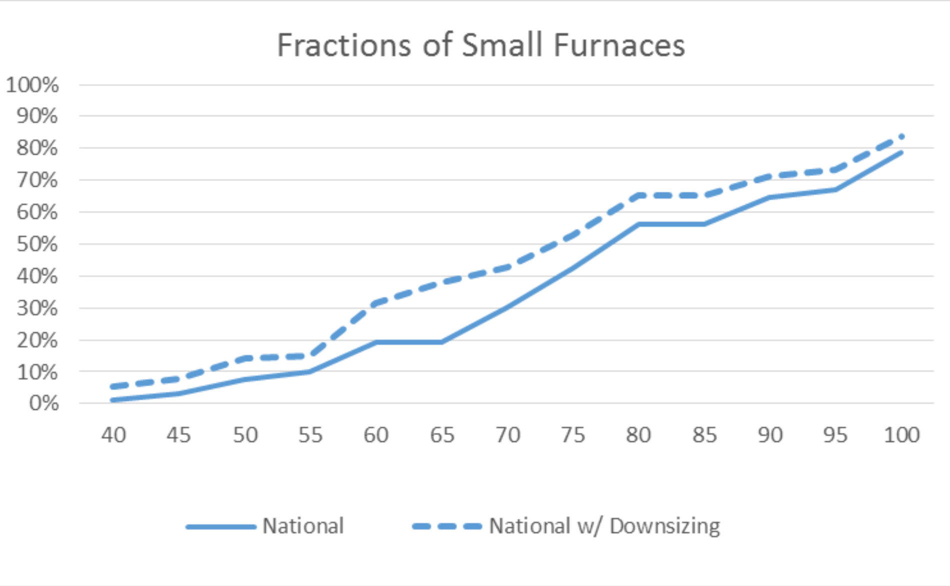
* ACCA recommends a maximum oversize factor of 40 percent.

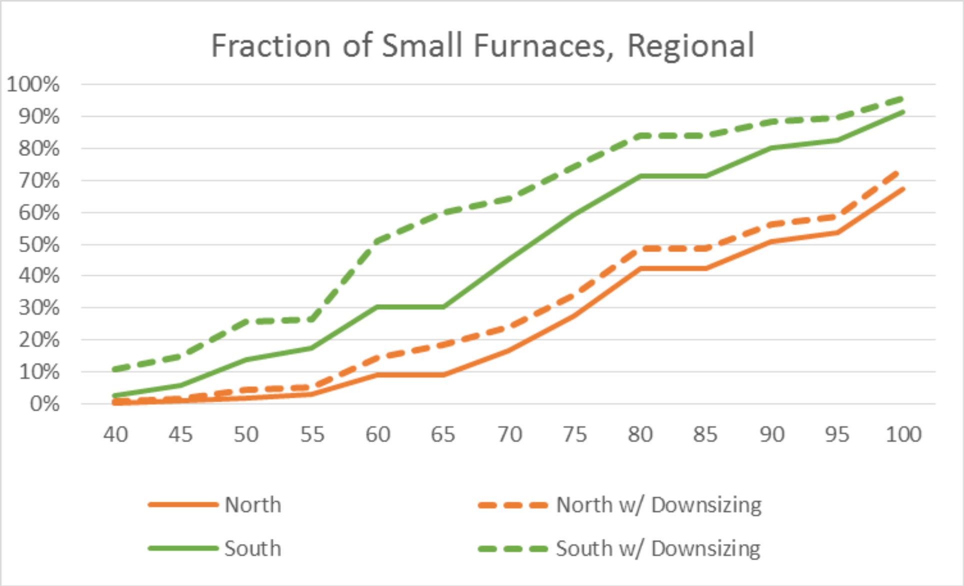
** Oversize factor from furnace and boiler test procedure.

Note: Appendix 8M describes sensitivity analysis that considered alternative downsizing scenarios.

LCC and PBP Analysis: Sizing Methodology Results

Cumulative Shipments by Input Capacity Cutoff (with and without downsizing)





Summary of Major Analytical Changes – Unpublished

Input	Description of Change
Markups	Revised methodology, lowering mechanical contractor markup. Updated sales tax data.
Building Sample	Commercial sample updated from CBECS 2003 to CBECS 2012.
Product Sizing	Revised methodology, which now utilizes Manual J calculations and updated shipments by capacity.
Energy Use	Updated energy use adjustments with AEO 2018 data and electricity use estimates for condensing GFs.
Product Price Trends	Updated PPI data to 2017.
Installation Costs	Updated labor and material costs to RS Means 2018. Added additional installation costs to address emergency installations and issues raised by stakeholders for multi-family and mobile homes.
Maint./Repair Costs	Updated labor and material costs to RS Means 2018.
Energy Prices	Updated with 2016 EIA data. Revised marginal price methodology with RECS 2009 billing data.
Energy Price Trends	Updated with AEO 2018.
Efficiency Distributions	Updated using 2010-2015 AHRI and 2014 HARDI shipments data. Added adjustment factor by square footage based on AHCS data. Updated new construction fraction using GTI fuel switching survey submitted by stakeholders.
Product Lifetime	Updated regional lifetime distributions using updated RECS, AHS, shipments, and AHCS data.
Shipments	Updated to 2017 AHRI shipments data. Updated regional fractions using 2010-2015 AHRI data. Updated commercial fraction of shipments using CBECS 2012. Updated housing starts using AEO 2018.
Consumer Choice	Added extended repair option. Converted fuel switching option criteria to a distribution by income.
Downsizing	Calculated oversizing using Manual J. Downsizing occurs for a fraction of HHs based on payback criteria.
Emissions	Updated to latest emissions monetization values.
MHGF	Revised entire analysis to align with NWGF TSLs.
Manufacturer Impacts	Revised analysis to take into account one small manufacturer of MHGF not currently producing condensing models.
Other Minor Updates	Dollar year now $2017, present year 2018, start year of analysis 2024, updated data for discount rates.

General Analysis Topics: Peer Review

Interactions with Stakeholders in Residential Furnaces Rulemaking

Document Name	Date	Notes
Ex Parte Meeting Record	09/12/14	Meeting between AGA and DOE to discuss fuel switching impact model
Preliminary Analysis Spreadsheets	09/22/14	Various preliminary spreadsheets DOE put out for stakeholders prior to issuance of the NPRM
AGA Workshop on Condensing v. Noncondensing Appliances	10/9/14	AGA workshop held for stakeholders to discuss DOE's furnace rule
AGA Marginal Cost & Fuel Switching Analysis	10/21/14	Posted after AGA workshop; independent AGA analysis
GTI Fuel Switching Analysis	10/21/14	Independent GTI analysis
Ex Parte Meeting Record	10/23/14	Meeting between AGA, APGA, GTI, and DOE to discuss fuel switching
Notice of Public Meeting	10/30/14	Notice for meeting to discuss DOE's analytical tools
Public Meeting	11/07/14	Public meeting where DOE discussed analytical tools
Correspondence between APGA and DOE Counsel	11/14/14	DOE answers to APGA follow-up questions from the Nov. 7, 2014 public meeting
NPRM Spreadsheets	02/05/15, 02/11/15	DOE spreadsheets revised for NPRM; put out ahead of NPRM issuance
Summary of Changes to Analytical Tools	02/12/15 & 02/24/15	Summarizes changes DOE made to analytical tools in light of meetings
NPRM Public Meeting	03/27/15 & 4/13/2015	Public meeting to discuss March 2015 NPRM
Correspondence between DOE and APGA/AGA	04/23/15	DOE answers to questions from APGA/AGA on shipments data presented at the NPRM public meeting
SNPRM Public Meeting	9/23/2016	Public meeting to discuss September 2016 SNPRM

Furnaces: Direct Employment Results

DOE's direct employment analysis is based on changes in labor content between efficiency levels calculated in the engineering analysis and changes in shipment volumes/distribution calculated in the shipments analysis.

Total Number of Non-Weatherized Gas Furnace and Mobile Home Gas Furnace Production Workers in 2022

	No-New-Standards Case	Trial Standard Level								
		1	2	3	4	5	6	7	8	9
Domestic Production Workers in 2022	1,709	1,709 to 1,770	1,709 to 1,799	1,709 to 1,825	1,709 to 1,867	1,709 to 1,936	1,709 to 1,952	1,709 to 1,918	1,709 to 1,942	1,709 to 2,654
Change in Domestic Production Workers in 2022	-	(1,709) to 61	(1,709) to 90	(1,709) to 116	(1,709) to 158	(1,709) to 227	(1,709) to 243	(1,709) to 209	(1,709) to 233	(1,709) to 945

Lower bound reflects the worst case scenario of all production moving out of the country.

Upper bound reflects the increase in labor intensity of producing more efficient units and shows a net increase in domestic direct employment.

Cumulative regulatory burden

Typically, multiple appliance standards affect the same companies without affecting the same products or revenue streams.

Federal Energy Conservation Standards	Number of Manu.	Manu. in Today's Rule	Approx. Year std.	Conversion Costs	Conversion Costs / Revenue
Residential Microwave Ovens (June 17, 2013)	14	9	2016	$43.1 million (2010$)	0.6%
Commercial Refrigeration Equipment (March 28, 2014)	54	1	2017	$184.0 million (2012$)	2.0%
Packaged Terminal AC (July 21, 2015)	12	2	2017	N/A	N/A
Automatic Commercial Ice Makers (Jan. 28, 2015)	16	4	2018	$25.1 million (2013$)	2.5%

Name of the appliance standard contributing to CRB.

Total number of manufacturers in the named appliance standard.

Number of overlapping manufacturers between the named appliance standard and today's rulemaking.

Conversion costs from the named appliance standard.

Conversion costs divided by conversion period revenue from the named appliance standard.

Cumulative regulatory burden (CRB)

Where CRB regulations impact the same manufacturers, products, and revenue streams in the timeframe of the standard, DOE attempts to integrate the joint effects into its engineering and MIA analyses.

- Residential Furnaces
  - Incorporation of furnace fans conversion costs into cash flow analysis
  - Low NOx cost adders included in MPCs for LCC and MIA

- Beverage Vending Machines
  - DOE estimated and accounted for conversion costs related to EPA SNAP compliance
  - DOE aligned compliance year of the standard with compliance year of the EPA regulation

- Commercial Unitary Air Conditioners
  - Through a negotiated rulemaking, DOE aligned the compliance year of the CUAC standard with the expected timeframe of the Montreal Protocol phaseout of HFCs for air-conditioning applications

Cumulative regulatory burden (CRB)

DOE recognizes that multiple regulations that affect the same company without affecting the same product or revenue streams can still lead to constraints.

Through manufacturer interviews, DOE attempts to understand potential bottlenecks from shared company resources (such as engineering time and test lab availability) when multiple product redesigns need to occur within a short period.

Also through interviews, DOE attempts to identify potential bottlenecks arising from constraints on shared external resources. In some industries, most or all manufacturers rely on a small ecosystem of vendors (such as 3rd party test labs with unique capabilities or specialized tooling suppliers) that are unable to service an entire industry in the limited conversion period between when a standard is published and when compliance is required.

Cumulative regulatory burden (CRB) - issues/challenges

DOE faces continued stakeholder concern about CRB.

Stakeholders cited concerns about CRB in the residential furnaces, CRE, and dishwashers rulemakings.

Common issues are:

- Scope of Regulations (e.g. Federal vs. state vs. municipal regulations)
- Timeframe considered in the CRB analysis
- DOE's policy towards voluntary programs and towards regulations that are not finalized (i.e. Energy Star and DOE Rulemakings in Early Phases)
- Incorporation of CRB in the GRIM Model

Further discussion later in the presentation, in the context of specific rulemakings.

Cumulative regulatory burden (CRB)

CRB: Non-Federal Regulations

Process Rule appears to be intentionally focused on federal regulations.

Non-federal regulations often do not have clear costs and scope of coverage may not align with DOE's scope of covered product.

In certain cases, DOE has been able to develop its own compliance costs for non-federal rulemakings. However, this is not always feasible.

- In the residential furnaces rulemaking, DOE accounted for the increase in MPCs of low NOx compliance in the form of a cost adder, estimated from the tear-down of low NOx products.
- DOE was would not have been able to determine the cost of proposed ultra-low NOx requirements (in certain districts of California) as there were no ultra-low NOx products available at the time of the SNPRM analysis.

DOE's ability to align dates or standard levels are limited by regulatory requirements.